ELECTRIC POWER RESEARCH INSTITUTE

Best Practices Guidebook for Integration of Distributed Energy Resources Into Utility System Planning

Technical Report

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Best Practices Guidebook for Integration of Distributed Energy Resources Into Utility System Planning

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Cosponsor
DTE Energy
2000 Second Avenue
Detroit, MI 48226-1279

EPRI Project Manager
W. Steeley

ELECTRIC POWER RESEARCH INSTITUTE
3420 Hillview Avenue, Palo Alto, California 94304-1395 • PO Box 10412, Palo Alto, California 94303-0813 • USA
800.313.3774 • 650.855.2121 • askepri@epri.com • www.epri.com

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CITATIONS

This report was prepared by

DTE Energy
2000 Second Avenue
Detroit, MI 48226-1279

Principal Investigators
H. Asgeirsson
N. Carlson
J. Connors
D. Costyk
A. Jacob
R. Seguin

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PRODUCT DESCRIPTION

A distributed energy resources (DER) installation offers a potential solution to distribution system capacity shortfalls. This report provides, for the first time, a practical guidebook of industry best practices for integrating a DER installation into the energy company planning and operating process. The information presented in the report is based on DTE Energy's real-world experience in DER planning and implementation, with a focus on distribution solutions and customer services.

Results & Findings

This guidebook will help distribution companies evaluate DER capacity advantages and implement cost-effective DER installations that improve system reliability and customer service. The guidebook includes practical DER experience-based information, including key lessons learned, capital budget planning, financial calculations for engineers, planning and protection, system design, siting and approval, construction and commissioning, and methods of control and operation. Finally, the guidebook presents a series of case studies of DTE Energy's DER-based distribution solutions.

Challenges & Objectives

Energy company distribution systems require extensive investment for upkeep. In addition, load growth over time increases the possibility of overload conditions, or loss of load, which may require upgrades to guard against these contingency events. In some situations, a DER installation may solve a capacity shortfall and defer the need for an upgrade, improving system reliability and customer service while reducing the economic impact on both the energy company and ratepayers. DTE Energy's hands-on experience in applying DER can help guide other organizations engaged in or contemplating a DER installation.

Applications, Values & Use

Information in this report can help distribution organizations evaluate DER for their systems and implement DER installations that provide cost-effective, safe, and reliable solutions to distribution system problems.

EPRI Perspective

The continuing need for energy company system investments is occurring during a period where capital budgets have been flat to declining. Across the country, energy companies are trying to maintain their quality of service with less investment. For some applications, DER may offer a cost-effective way to defer such investments. As an industry leader in applying DER, DTE Energy has acquired an extensive body of real-world experience in putting DER to work to solve distribution problems. This report, the first of its kind, distills DTE Energy's DER experience into a practical guidebook to help distribution organizations make informed decisions when evaluating and implementing DER projects.

Approach

In 2002, DTE Energy created a new group, Distributed Resource Planning, with the intent to explore the possibilities of using DER on the distribution system to manage overloads and improve reliability. In that year, the Distributed Resource Planning group completed three DER projects. At this early stage, all the projects were constructed on DTE Energy-owned property. Each involved an emergency-type situation that staved off the specter of rolling blackouts due to overloaded or damaged circuits. With the knowledge gained from completing these first three installations, DTE Energy bought generators to be used in the future and standardized DER design and installation. In the second year, DTE Energy bought four more generators and installed them out in the distribution circuit, partnering with a school and a church. In the third year, DTE Energy developed a continuing budget strategy, involved previous customers to act on its behalf, relocated generation from one circuit to another, and continued to decrease the time and cost of installations.

DTE Energy's experience in applying DER has yielded a number of valuable lessons that have been incorporated into this guidebook of best practices for integrating DER into the utility planning and operations process.

Keywords

Distributed Energy Resources
Distributed Generation
Distribution Planning
Distribution Capacity Shortfalls

ABSTRACT

DTE Energy's real-world experience in applying Distributed Energy Resources (DER) has yielded a number of important lessons, explained in greater detail in this guidebook. The guidebook is designed to help distribution organizations 1) evaluate DER as a potential solution to distribution system capacity shortfalls and 2) implement cost-effective DER installations that enhance system reliability and improve customer service. Following are key points of the lessons learned:

- Real management support is essential for DER to be successful.
- A champion should shepherd the integration.
- The evaluation measure should be changed so that the cost of the DER alternative is not based on the cost of capacity added, but rather is compared to the cost to resolve the capacity shortfall problem.
- A DER capital budget is essential.
- A DER installation is comparable to a portable substation whose purchase is justified based on repeated use over time.
- Utilization of DER is not always the answer; thus, other alternatives should be considered.
- DER implementation can make more effective use of existing manpower resources.
- Automatic operation and innovative protection can make DER integration into the planning and operating processes as seamless as possible.
- Community alliances are critical to a successful DER installation experience.
- DER installation should be considered another important tool in the planning and operations process to resolve distribution problems.
- DER should be considered as distribution capacity, not generation.

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INTRODUCTION AND BACKGROUND

Objective

The objective of this report is to provide a useful guidebook of industry best practices for integrating distributed energy resources (DER) into the utility planning and operating process. The information presented in this report is based on DTE Energy's real-world experience in DER planning and implementation for distribution solutions and customer services.

Definition and Terminology

The DER concept encompasses small generators, energy storage devices and energy management systems installed at customer sites or in the distribution system.

This report uses the term *distributed energy resources* rather than *distributed generation*. The latter term is less accurate and may be counterproductive because it can limit our thinking about how to utilize this technology's full potential. It is more appropriate to view DER as a substitute for new distribution capacity—a practical and cost-effective alternative to sticks and wires for delivering reliable, high-quality power to customers—rather than generation for generation's sake. This can be an important distinction for transmission and distribution utilities that are precluded from owning generation.

Report Organization

This report provides a detailed look at all aspects of the DER planning and operating processes organized into chapters.

Chapter 1 describes DTE Energy's vision of DER, provides a company overview and highlights DTE Energy's accomplishments and ***lessons learned*** in the DER arena.

Chapter 2 addresses the integration of DER into utility planning and operations process, including capital budget planning, financial calculations for engineers and project prioritization under constrained budgets. The chapter also describes methods of developing a DER capital budget plan.

Chapter 3 covers planning and protection, including distribution modeling, protective equipment and protection issues such as selectivity, sensitivity and islanding.

Chapter 4 covers design, including design of generators, connectors, monitoring and control equipment and physical design.

Chapter 5 describes the siting and approval process, including customer education, securing approvals and environmental permitting.

Chapter 6 covers construction and in-commissioning, including site preparation, installation, decommissioning and storage.

Chapter 7 describes methods of control and operation, including communications and monitoring.

Chapter 8 presents a series of case studies of distribution solutions that provide illustrative examples of project justification.

DTE Energy's DER Vision

DTE Energy is committed to a broad vision for DER that includes both near-term and long-term perspectives. In the near term, DTE Energy sees DER as another tool for providing system and customer solutions. Right now, DTE Energy is installing DER in the distribution system as a practical and economical solution to local reliability and power quality problems. Like a portable substation, DER can be used as an emergency, temporary, maintenance or permanent system. These installations can help:

- Eliminate or defer expensive distribution system expansions
- Improve distribution system reliability
- Generate environmentally clean power and most importantly,
- Provide high quality service to customers.

In the longer term, DTE Energy sees DER as a disruptive technology comparable to personal computers or cell phones. Just as these technologies fundamentally altered the computer and telecommunications industries, DER can help transform the traditional paradigm of the electric power system. This view was expressed by Anthony F. Earley, chairman and chief executive officer of DTE Energy:

> "Several years ago, the leadership at DTE Energy tried to envision what the electric utility business would look like in a decade. One of our conclusions was that this industry would go through the same transformation that the computer business experienced. There, mainframe computers gave way to desktops, which gave way to laptops. In the electric industry, the day of large central-station power plants has already given way to modular, combined-cycle gas-powered plants. We envisioned a day when the next step, distributed (or personal) generation would play a major role. In fact, utilities may be among the first real-world, large-scale users of distributed generation. Distributed generation will increasingly become a cost-effective alternative to the expansion and reinforcement of T&D infrastructure."

This is especially significant given the electricity sector's recent history. The combination of environmental policies and the move to deregulate the power industry have stalled infrastructure investment. Uncertainty about future rate relief has caused utilities to defer capital investments in infrastructure and to control operating costs aggressively. Meanwhile the aging power system is working harder than ever to serve increasing demand, including an explosion in digital electronic loads that are acutely sensitive to power quality and reliability.

The August 2003 blackout was a stark reminder of society's dependence on an aging power infrastructure. It also demonstrated that a reliable, economical supply of electricity is more than just a convenience. Today, it's a necessity—our economy and way of life depend on it.

Utilities can use DER to supplement the aging grid in areas where growth is straining the system, to address localized reliability problems or power quality concerns, or to provide temporary power during maintenance and repair activities. The use of DER can provide an effective strategy in areas of rapid growth as well as areas of slow growth. In areas of rapid growth, DER can be an effective solution that gains sufficient time to complete traditional transmission and distribution (T&D) project solutions. In slow growth areas, it can also be an effective strategy to "DER and defer" larger T&D projects.

DTE Energy believes that DER will increasingly be a part of the utility landscape and play an expanding role in providing reliable, economical and high quality power.

Looking a bit further ahead, DTE Energy envisions DER microgrids, or virtual utilities, providing continuous, economical, on-site power to multiple users and facilities in developments, complexes and premium power parks. The microgrid's appeal is:

- Fast siting
- Comparatively low initial costs and high efficiency
- Improved power quality, reliability and security
- The capability of selling surplus energy.

DTE Energy is committed to make its vision a reality. In 2004, DTE Energy signed a $5.4 million contract with NextEnergy to develop, construct, operate and maintain a state-of-the-art microgrid in the Power Pavilion on the NextEnergy site in Detroit. This microgrid demonstration project will be fueled by hydrogen, natural gas and sunlight. It will include the use of several emerging on-site energy technologies, including fuel cells, internal and external combustion engines, miniturbine technology and solar cells.

The microgrid will also include underground electrical and thermal distribution systems to provide electricity, heating and air conditioning to the NextEnergy facility. In addition, it will have the capability to serve the broader energy needs of the prospective buildings located within "Tech Town," a research and business technology park under development on the campus of Wayne State University in Detroit.

The NextEnergy facility will include a 5,600-square-foot Power Pavilion, which will house the microgrid, a hydrogen fueling infrastructure, office space, as well as a laboratory and product demonstration and exhibition facilities. This exciting project will be a test bed to study, document and prove the energy efficiency, cost and environmental impact of alternative technologies compared to existing central-station generation systems. It provides a tremendous learning opportunity.

Bridge to the Future

In time, the broad deployment of DER technology will help provide a bridge to a future power system design. This electronically controlled system of the future will move large blocks of power with unprecedented precision and flexibility, with embedded DER technologies to increase reliability, power quality, system security and reduce costs. As society transitions to cleaner energy sources and, ultimately, a hydrogen economy, DER technologies such as fuel cells will help provide a market for hydrogen fuels and the foundation for a hydrogen delivery infrastructure.

DER also has enormous potential in developing nations. Just as cell phones allow these countries to bypass the expensive infrastructure of landlines, DER will allow them to leapfrog electric infrastructure development.

Jump In and Steer

DTE Energy staff members use a simple analogy to describe the company's perspective on DER: Imagine a semi-truck loaded with DER technology starting up and heading toward the utility. There are three ways to deal with the approaching DER technology truck:

1. Throw yourself in front of the truck and hope it stops
2. Grab onto the back bumper and drag your feet
3. Jump into the truck's cab and help steer it.

DTE Energy chooses the third option to deal with this new technology.

DTE Energy Organization and Company Overview

DTE Energy is a full-spectrum regional energy provider that is an electric and natural gas utility and also operates non-regulated energy-related businesses. The latter businesses include Plug Power, which was formed in 1997 as a joint venture with Mechanical Technologies Inc. Plug Power originally focused on residential PEM (proton electrolyte membrane) fuel cells. It became a publicly traded company in 1999 with its initial public offering and has two strategic owners—DTE Energy and General Electric Company. Plug Power's expanded product focus is on PEM development up to 100 kW in both standby and continuous-duty applications.

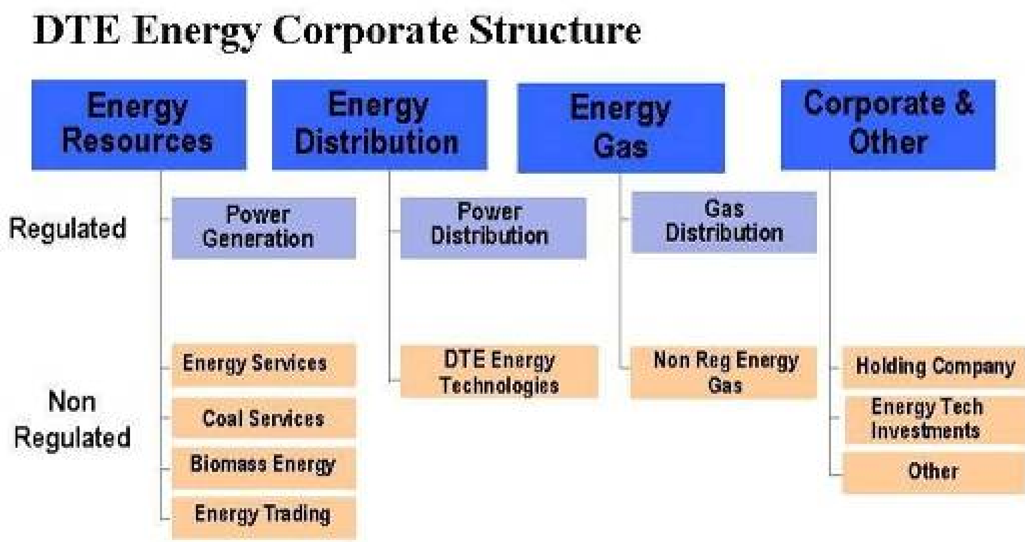


Figure 1-1
DTE Energy Corporate Structure

DTE Energy Technologies is a non-utility business that was originally formed to focus on energy efficiency and energy monitoring. It was subsequently transformed into an integrated DER business encompassing sales, installation, monitoring and control and services including maintenance. Distributed generation products include fuel cells, lean-burn high-efficiency internal combustion (IC) engines, low-emissions IC engines and Stirling engines.

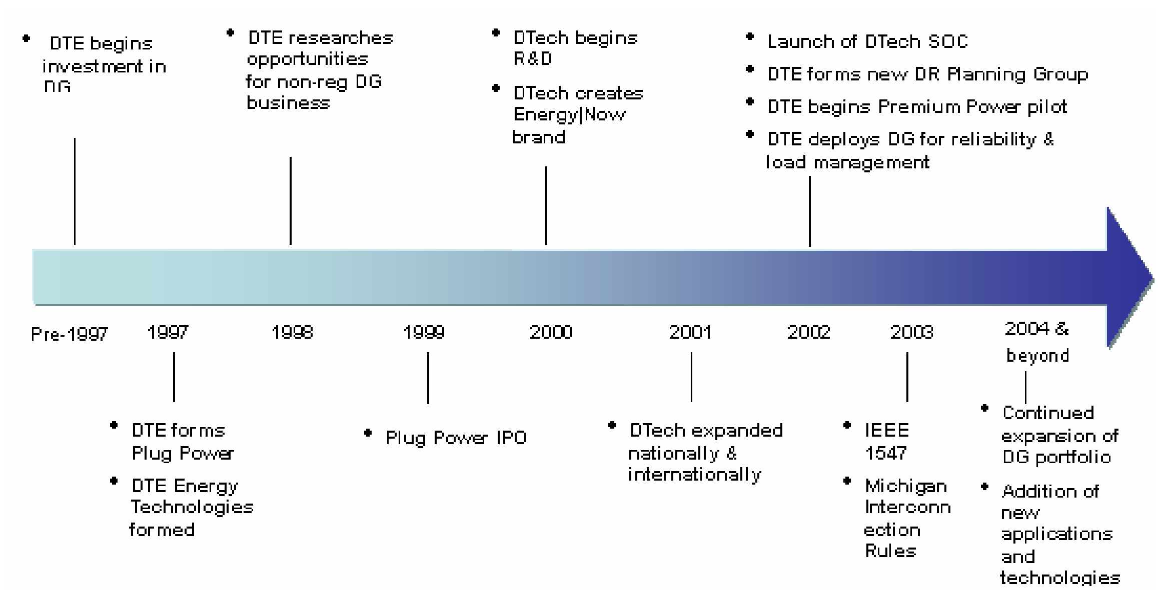


Figure 1-2
DTE Energy's History With Distributed Energy Resources

Figure 1-3
The DTE Energy Technologies System Operations Center

The DTE Energy Technologies System Operations Center (SOC) provides centralized, end-to-end monitoring of all of the vital functions required to serve electric loads continuously and efficiently with various distributed generation technologies. The SOC was developed to complement the DTE Energy Technologies portfolio of distributed generation products to enable customers to manage their systems for optimum reliability, quality and convenience. The SOC system has the capability to provide a wide range of services, such as:

- Preventive monitoring and predictive maintenance
- Unit scheduling and dispatching
- Interconnections and energy trading

SOC services are provided 24 hours a day, seven days a week, regardless of customer location. The SOC is unique both in its ability to handle numerous generation units across many customers with various rate structures and in the scope of the services it is capable of offering.

At the end of 2005, DTE Energy decided to shut down DTech operations for continuous duty generation in light of high gas prices. DTE Energy is still committed to the use of DER and the system operation center.

Real-World DER Accomplishments

Detroit Edison, the principal subsidiary of DTE Energy, is the nation's seventh largest electric utility. As the energy supplier to America's industrial heartland, Detroit Edison serves more than 2.1 million customers in Southeastern Michigan. Detroit Edison is a leader in implementing DER technology on its distribution system.

Guided by DTE Energy's vision for DER, Detroit Edison is actively implementing DER in the distribution system to resolve both utility and customer problems. DTE Energy has conducted DER technology demonstrations and installed DER as distribution solutions internal to the distribution circuit, at the substation and in an island mode to perform maintenance. Examples of these applications are presented in Chapter 8.

Throughout these implementations, DTE Energy is:

- Partnering with customers on overloaded circuits, sharing the costs and benefits of DER through a premium power rate.
- Formally including DER analysis into the capital budget process as an alternative to traditional T&D solutions.
- Listing all known customer-owned DER and/or interruptible equipment
- Developing tools, such as the Distribution Engineering Workstation (DEW), to quantify the impacts of DER on the distribution system, particularly with regard to protection concerns.

DER Planning Group

In 2002, DTE Energy created a new group, Distributed Resource Planning, with the intent to explore the possibilities of using DER on the distribution system to manage overloads and improve reliability. In that year, the Distributed Resource Planning group completed three DER projects. At this early stage, all the projects were constructed on DTE Energy-owned property. These projects were all emergency-type situations that staved off the specter of rolling blackouts due to overloaded or damaged circuits.

With the knowledge gained from completing these first three experiences, DTE Energy bought generators to be used in the future and standardized DER design and installation. In the second year, DTE Energy bought four more generators and installed them out in the distribution circuit partnering with a school and a church. In the third year, DTE Energy developed a continuing budget strategy, involved previous customers to act on its behalf, relocated generation from one circuit to another and continued to decrease the time and cost of installations.

Lessons Learned

DTE Energy's experience in applying DER yielded a number of valuable lessons that have become rules that guide the company's DER team. These rules can help guide other utilities engaged in or contemplating DER.

Real Management Support is Essential. In order for DER to be successful, it takes real management support. At DTE Energy, this support came from the highest levels, specifically the CEO and President.

Name a Champion to Shepherd the Integration. This management support came in the form of naming a champion to shepherd the integration. In DTE Energy's case, a small DER planning group was established and given director-level reporting. This level of reporting demonstrated how serious management was to the success of DER integration. The group was in charge of more than just interconnections, it was also responsible for integrating DER into the planning and operating processes. To evaluate the level of success, management set specific expectations for performance on this group.

Change the Evaluation Measure. One of the expectations of management was to make sure that DER projects made sense economically. Therefore, an important part of the DER economic evaluation, which compares traditional T&D solutions to DER solutions, is to *change the measure*. The cost of the DER alternative should not be based on the cost per kW of capacity added, but rather compared to the cost to resolve the capacity shortfall problem. For example, consider the cost to build a new substation for an area experiencing loading problems. A new 30 MW substation will cost around $6M and this translates to a cost per kW of $200. This will usually be cheaper than a DER alternative, when one factors in the cost of buying DER. However, this assumes that one will be using the whole 30 MW of capacity right away. Generally, most overloads are not 30 MW, they are more on the magnitude of 1 or 2 MW. The cost to resolve a 1 MW capacity shortfall problem with the same $6M substation is $6,000 per kW. Now comparing this cost of a 1-MW DER alternative, approximately $450 per kW, it begins to look very favorable for the *DER and Defer* strategy.

Develop a DER Capital Budget. After DTE Energy integrated this new measure on all new capital projects, the next step was to develop a DER capital project budget. While the DER and defer strategy permits better economic utilization of resources, it is not the only reason to use DER. After probability analysis is performed, it becomes apparent that load will arrive before some T&D projects will be completed. DER can be a tool to help make sure these projects are addressed even if the final T&D solution is years away. DER can become a planned budget line item to rescue the project when and if it cannot be done (storms, right-of-way, community approvals, load growth faster than anticipated, etc.). DER can also be used as a "Do Nothing" alternative in the capital project budget process. This becomes not only part of a project alternative analysis but can be used as preplanned recovery plan.

It's Just Like a Portable Substation. There is another way to look at the economics of using DER. The purchase of a portable substation is not based on the need to facilitate maintenance or change out a transformer for one particular instance. It would not be possible to justify its purchase on that basis alone. The portable substation is justified on repeated use over time. This is the same rationale used to demonstrate the cost effectiveness for the purchase of DER. The DTE Energy DER team arrived at this truism after a review of the economics of its first DER installation. This project involved the use of a leased portable generator in an emergency. Over the course of a subsequent economic evaluation, it was demonstrated that purchasing the DER was more economically sound than leasing one. Once a DER is purchased, the comparison is between the DER installation cost and the cost of traditional T&D cost.

Consider Your Alternatives. While utility-owned DER is sometimes a cost-effective solution to a summer peak loading situation, it is not the only answer. Sometimes just considering utilizing utility-owned DER equipment prevents seeing other possible alternatives. There may be customer-owned generation on the circuit that can be used under a joint use arrangement with the customer. DTE Energy has also started a program offering premium service with back-up generation to customers with the caveat that the utility can use this generation during high demand situations. The optimal solution is to have a customer on a circuit with potential summer overload situations and who depend on premium power for their operations, whether that be manufacturing processes or commercial uses.

Effective Use of Manpower Resources. Another issue to consider when undertaking a DER project is the manpower resources available. Remember, part of the reason for seeking the DER alternative is because the work cannot get done on time. Much of the utility work force may be unfamiliar with DER equipment. To make things easier, DTE Energy chose to standardize its design and, whenever possible, to use a construction contractor with generation experience. In addition, the DER group does most of the project management itself. The group did not want to use an already taxed distribution work force to design, project manage and construct this additional new and unfamiliar work.

Automatic Operation & Innovative Protection. In order to make the integration of DER into the planning and operating processes as seamless as possible, DTE Energy automated the operation of the DER. This is done with help from communication and operation groups. In essence, the DER should act like fans on a transformer that come on and off automatically when needed. When the load on a circuit reaches its day-to-day level, the DER senses this and turns on to maintain this level of load on the circuit. Furthermore, DTE Energy developed a load-following strategy to provide freedom from transfer trip scheme and at the same time minimizing fuel expenses. The automatic load following strategy without transfer trip required protection engineers to think differently about DER. In the past, protection engineers were hesitant about DER because they had no input into the operation and design of customer-owned DER on distribution circuits. Now that the utility owns and operates the DER, the protection engineers are more accepting of DER equipment since they are assured of input into the design and operation. It's important to involve the protection group in the planning and site selection of the DER installation.

Build Community Partnerships. A key aspect of the DER process is for the utility to build good relationships with various community members such as municipalities, environmental agencies and customers. DTE Energy has partnered with schools and churches in the site selection process. Typically, schools and churches can be found in densely populated areas that may have temperature-sensitive short duration load problems. These organizations typically have enough available land to enable the DER to be *out of sight and sound* of neighbors. In addition, making a monetary land lease payment to these community-based entities is what a good corporate citizen might do anyway. DTE Energy found after siting its first DER at a school that the school officials became allies and helped in other DER sitings. Convincing a community's planning board that the project is only a temporary fix, that steps are being taken to minimize the impact to the neighbors and that all other alternatives are exhausted goes a long way to securing their approval. Similarly, the state Department of Environmental Quality (DEQ) and other environmental agencies have specific requirements that need to be met. Making the DEQ a partner instead of an enemy goes along way to making the next DER project easier.

Get the Word Out: the DER Road Show. DTE Energy emphasized communication to seal DER integration. DER Group created what became known as a “DER Road Show” to get the message out at all levels throughout the company. DTE Energy typically conducts “After Action Reviews” to engage internal participants affected by the DER. This helps to gain their input and buy in on the next DER project. Making engineering and operations personnel more comfortable with this new way to solve distribution problems will get them thinking of other uses.

It’s Just Another Tool. It is important to note that DTE Energy views the DER alternative to the traditional T&D approach as exactly that and only that—an alternative. DER is not a replacement of the traditional method, but a tool in the planning and operations process to resolve distribution problems. DTE Energy considers DER as primarily distribution capacity, not as generation in the utility sense.

2

INTEGRATING DER INTO THE UTILITY PLANNING AND OPERATION PROCESS

Chapter Organization

This chapter describes DTE Energy's integration of DER into the utility planning and operations process. It describes the challenges of implementing organizational change, capital budget planning, possible DER solutions, financial calculations for engineers, planning under constrained budgets, project prioritization and developing a DER capital budget plan.

Introduction

One of the expectations of DTE Energy management was to make sure that DER projects made sense economically. Therefore, an important part of the DER economic evaluation, which compares traditional T&D solutions to DER solutions, is to *change the measure*. The cost of the DER alternative should not be based on the cost per kW of capacity added, but rather compared to the cost to resolve the capacity shortfall problem. For example, consider the cost to build a new substation for an area experiencing loading problems. A new 30 MW substation will cost around $6M and this translates to a cost per kW of $200. This will usually be cheaper than a DER alternative, when one factors in the cost of buying DER. However, this assumes that one will be using the whole 30 MW of capacity right away. Generally, most overloads are not 30 MW, they are more on the magnitude of 1 or 2 MW. The cost to resolve a 1 MW capacity shortfall problem with the same $6M substation is $6,000 per kW. Now comparing this cost of a 1-MW DER alternative, approximately $450 per kW, it begins to look very favorable for the *DER and Defer* strategy.

After DTE Energy integrated this new measure on all new capital projects, the next step was to develop a DER capital project budget. While the DER and Defer strategy permits better economic utilization of resources, it is not the only reason to use DER. After probability analysis is performed, it becomes apparent that load will arrive before some T&D projects will be completed. DER can be a tool to help make sure these projects are addressed even if the final T&D solution is years away. DER can become a planned budget line item to rescue the project when and if it cannot be done (storms, R/W, community approvals, load growth faster than anticipated, etc.). DER can also be used as a Do Nothing alternative in the capital project budget process. This becomes not only part of a project alternative analysis but can be used as preplanned recovery plan.

There is another way to look at the economics of using DER—that *it's just like a portable substation*. The purchase of a portable substation is not based on the need to facilitate maintenance or change out a transformer for one particular instance. It would not be possible to justify its purchase on that basis alone. The portable substation is justified on repeated use over time. This is the same rationale used to demonstrate the cost effectiveness for the purchase of DER. The DTE Energy DER team arrived at this truism after a review of the economics of its first DER installation. This project involved the use of a leased portable generator in an emergency. Over the course of a subsequent economic evaluation, it was demonstrated that purchasing the DER was more economically sound than leasing one. Once a DER is purchased, the comparison is between the DER installation cost and the cost of traditional T&D cost.

Sealing the DER integration requires a great deal of effective communication—10 times more than one might expect, at all levels throughout the company. The DER planning group typically conducts After Action Reviews to engage internal participants affected by the DER to gain their input and buy in. The goal is for engineering and operations staff to become more comfortable with this new way to solve distribution problems and get them thinking of other uses.

Implementing Organizational Change

Integrating DER into utility planning and operations represents a major change for company cultures. In his book, *Leading Change*, John Kotter, a Harvard Business School professor, describes a comprehensive eight-step approach to implementing organizational change. Kotter's approach is based on establishing a sense of urgency coupled with vision and communication. He also identifies pitfalls to be avoided.

Table 2-1
The Eight-Stage Process of Creating Major Change: Winning Approaches and Pitfalls

The Eight Things to Do	The Eight Mistakes
• Establishing a Sense of Urgency • Creating the Guiding Coalition • Developing a Vision and Strategy • Communicating the Change in Vision • Empowering Broad-based Action • Generating Short-term Wins • Consolidating Gains and Producing More Change • Anchoring New Approaches in the Culture	• Allowing Too Much Complacency • Failing to Create a Sufficiently Powerful Guiding Coalition • Underestimating the Power of Vision • Under Communicating the Vision • Permitting Obstacles to Block the New Vision • Failing to Create Short-term Wins • Declaring Victory too Soon • Neglecting to Anchor Changes Firmly in the Corporate Culture

The professor's eight-stage process reflects DTE Energy's real-world experience in guiding the integration of DER into utility operations. As outlined in the preceding chapter, DTE Energy has taken a series of concrete steps that correspond with the action items in the left-hand column of the preceding table. The company has created a guiding coalition in its Distributed Resources Planning Group, developed a DER vision and strategy and implemented DER solutions for its customers. These "short term wins" provide a foundation and momentum for future successful projects.

An important early step in implementing change is to replace misconceptions with facts. Mark Osbourne of Portland General Electric identified and demolished the top five misconceptions about DER in his presentation, "Dispatchable Standby Generation."

Misconception 1: It's too Expensive. ***Not compared to peakers or in free fuel niches.***

Misconception 2: Paralleling is Unsafe. ***You just need the right protection.***

Misconception 3: Customers Won't Let You Control. ***If it's worth their while they will.***

Misconception 4: Utilities Hate DER. ***If it's worth their while they won't.***

Misconception 5: It's New and Scary. ***Actually, it's really old and you already know how to do it—you just don't know you do.***

Capital Budget Planning

The utility business has become much more complex today. Managing distribution is no longer just about solving overloads and low voltage, it’s about making business decisions. It’s about quantifying distribution problems and communicating them in investment terms.

To further complicate the situation, capital budgets are declining at the same time that customer’s expectations are increasing. Companies must also balance the need to build new distribution with the need to care for the existing system—serving new load versus addressing the reliability concerns of the existing load.

We cannot afford to solve every 1-MVA criteria shortfall problems with a traditional 30-MVA solution, especially in the case of problems that may only exist for a few hours per year and capacity that will not be fully utilized for several years.

DER is one approach to delivering just in time "right-sized" capacity to resolve smaller shortfalls while minimizing the initial capital outlay and freeing dollars for reliability and maintenance. The challenge is to demonstrate how DER can fit into the distribution engineer’s tool kit as a means of solving distribution problems. The best way to do this is to lead by example and teach others how we ourselves are using it.

DTE Energy is not selling DER; the company is trying to present it as an alternative solution. In fact, most of the time sticks and wires are cheaper. However, in a small number of instances the cost of traditional T&D alternatives can be greater than the cost of DER. These alternatives should be examined for a DER opportunity. The following figures offer a basis for performing such evaluations.

Figure 2-1 depicts the slow but steady growth of system peak load. Also shown is the T&D capital budget, which includes both new capital projects and capital maintenance. Perhaps the best that can be hoped for is a flat capital budget. In preparing the capital budget we must balance the amounts for capital maintenance and new system additions.

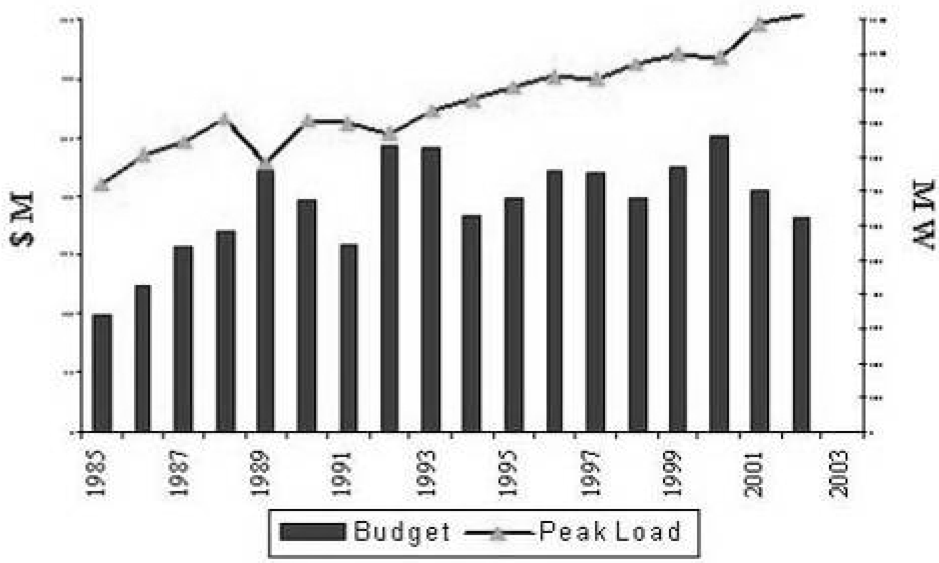


Figure 2-1
T&D Capital Budget vs. Peak Load

Figure 2-2 presents a load duration curve for a typical DTE Energy circuit. It shows that loads above 80% of the circuit peak occur only about 1% of the year—approximately 100 hours depending primarily on temperature.

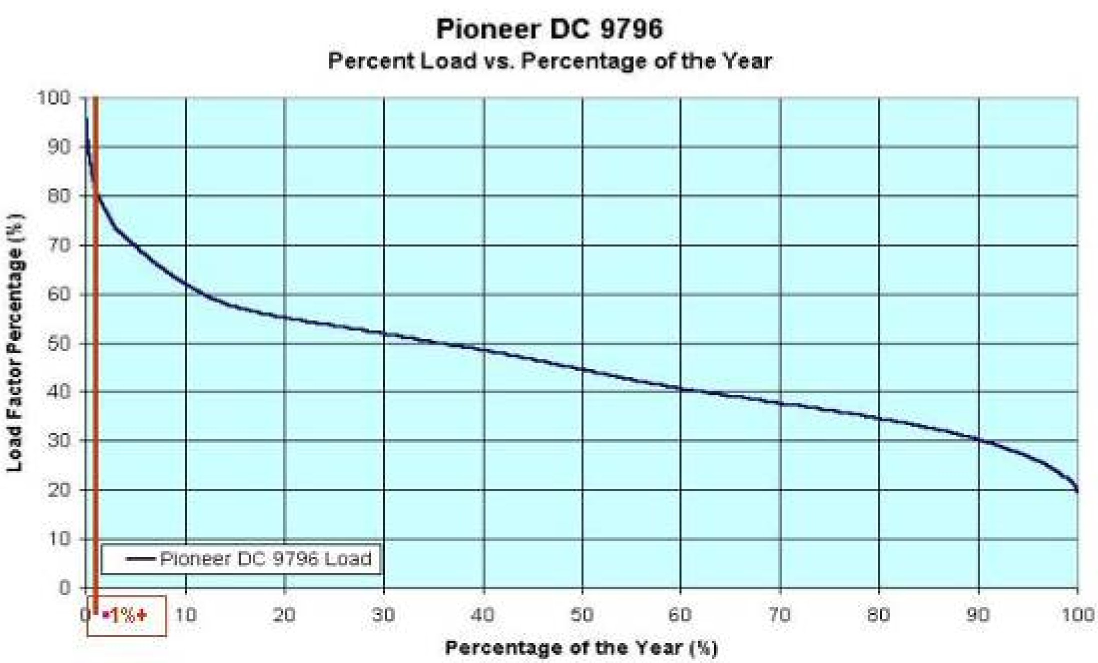


Figure 2-2
Asset Utilization Opportunity

Figure 2-3 shows capital project cost for new business and overload projects divided by the energized capacity added.

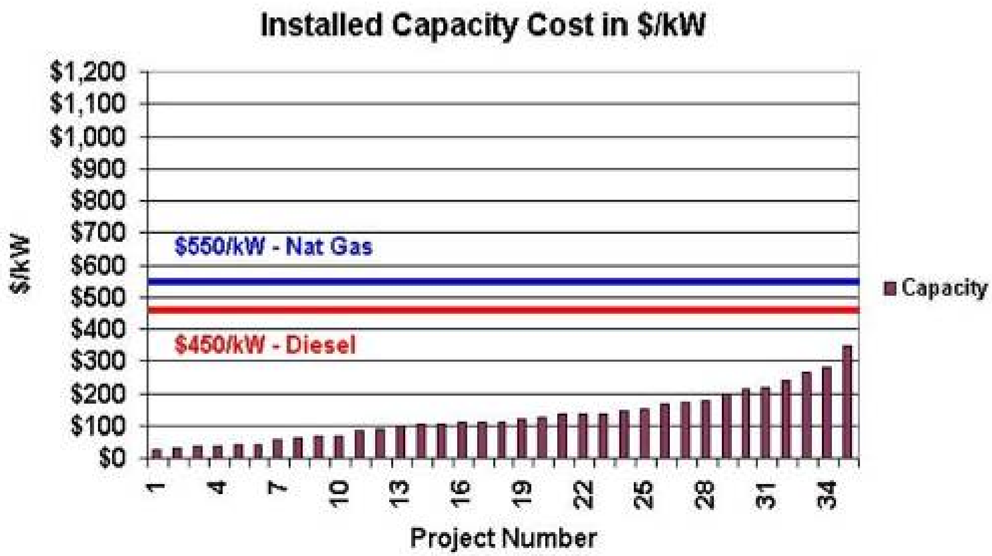


Figure 2-3
Installed Capacity Cost in Dollars per kW

But if we divide that same cost by the project planning criteria short fall, we can see the cost to serve the new load can be higher than the DER. The shortfall cost in $/kW is shown in Figure 2-4. Note that now we see projects that are potential candidates for a "DER and defer" strategy. That does not mean that DER can be used in each of those projects, only that a few have the possibility. Also note that the majority are still cheaper than DER. DER is a specialty tool, like a directional bore machine. You don't dig every hole with it but you're really glad to have it when it comes time to get under the road. DTE Energy's DER team sees a parallel with distribution and DER. DER is a specialty tool and like a directional bore machine it has its place.

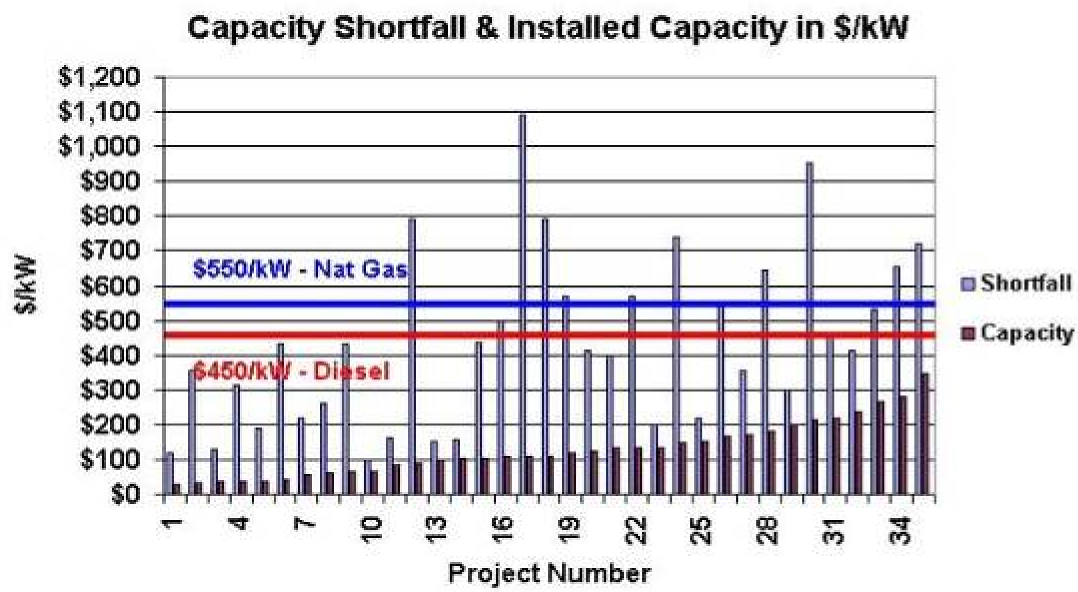


Figure 2-4
Capacity Shortfall and Installed Capacity in Dollars per kW

The following example calculation helps demonstrate the point:

What is the cost of capacity addition vs. the cost of meeting the incremental capacity needed by the system? Assume that we are adding 10 MVA of capacity for $1.5 M while the incremental capacity addition needed is 2 MVA for 100 hours.

- For the 10 MVA capacity addition the cost is $\$1.5 \times 10^{6}/10{,}000$ kW = $150/kW
- The cost to resolve the 2 MVA shortfall is $\$1.5 \times 10^{6}/2{,}000$ kW = $750/kW

This is a potential candidate for DER because of the cost of meeting the shortfall is greater than the cost of a typical generator installation. We believe that you should compare DER to the cost to resolve the problem.

Cost per kW: What's Included, Not Included

Listed below are what DTE Energy included in the cost of distribution and did not include. Many DER advocates tend to use numbers in the hundreds of dollars per kW, even claims of $500 and more. For DTE Energy the figures are substantially lower. However, there is still a place for the economic deployment of DER in lieu of sticks and wires.

Items that *are* included:

- All new business projects and their installed capacities
- All overload projects and their installed capacities
- All increase load blanket cost at no capacity addition

- All system improvement blanket cost at no capacity addition
- All blanket land purchases at no capacity addition
- All project cost (includes prior, current and future year expenditures) plus land, transformers and all project-specific overheads
- Utilized capacity (capacity available for use) only, not total installed capacity.

Items *not* included in distribution cost per kW (although these are sometimes included by broad-brush DER advocates):

- Street lights
- Relocations (required removal of facilities located in public rights-of-way (R/W)
- Transmission (not our company; not all cost is associated with distribution load)
- Subtransmission (not all cost is associated with increased distribution load). Impacts of including evaluated.
- Reliability projects (cost does not result in significant capacity increase). Impacts of including evaluated.
- Distribution transformers
- Service standards (small reliability projects—Michigan Public Service Commission-mandated reliability projects requiring capital budget to resolve frequent outages)
- Tree trimming (capital tree trim)
- Maintenance (primary pole top maintenance)
- Downed wire replacement program
- Underground residential distribution (URD) replacement (end-of-life replacement of failing URD cable)
- Normal unit retirement changeout (NURC)
- Emergency unit retirement changeout (EURC)
- Secondary improvement (replacing and rebuilding of old secondary system)
- Contribution in aid of construction (CIAC)

Possible DER Solutions

There are several categories of possible DER solutions:

- **Maintenance use**, e.g., facilitating shutdowns of substations for maintenance
- **Emergency use**, such as saving or minimizing an emergency outage or equipment damage, or relieving overload or low-voltage conditions. This involves immediate relief of an emergency problem using a portable generator or a leased unit. It should also include circuit-

specific interruptible load to manage loading under emergency. *Explore known customer generation for emergency help.*

- **Temporary use**, when the utility cannot get a permanent fix done in time. This provides relief of a problem using leased or purchased DG to return levels to within planning criteria and should last one to four years. The generator as well as circuit-specific interruptible load should be used to manage that level. *Temporary solutions involve partnering with customers for siting of DER. Explore known customer generation for help.*
- **Permanent use**, to provide redundant service or a long-term solution such as an alternative to new T&D capacity or replacement of old generation with DER. By definition, this is relief of a problem that returns loading to acceptable levels for an estimated five years or longer.

Ownership of Potential DER Solutions

Potential DER solutions may be owned by utilities, customers, or both. Some examples follow.

Utility Owned: Distribution solutions for load relief.

Utility and Customer Joint Ownership: Premium DER power systems owned by the utility and leased by the customer in a mutually beneficial arrangement. Utilities benefit from non-sellback negawatts or load offset, as well as sellback megawatts or total available DER. Customers benefit from availability of standby power and lower rates if an interruptible power agreement is in place.

Customer Owned. At the present time, there is no formal customer-utility relationship, although some customers may be amenable to informal utility requests for DG use and/or load reduction. Customer interruptible rates may enable use of customer-owned DER to be used to prevent generation shortfalls.

Financial Calculations

The goal for today's distribution engineer is to address as many opportunities or solve as many problems as possible within the constraints of a limited budget. Traditional distribution solutions were based on adding additional capacity—more sticks and wires. Today, DER has emerged as a new tool to

- Defer capital investment and/or reduce budget expenditures
- Free money for other projects or to solve more problems
- Optimize manpower and/or conserve limited resources

Putting the new tool to work may require forcing some nontraditional thinking about the potential roles of DER in distribution projects. Examining the opportunities for applying DER and the consequences of not applying it, may help persuade reluctant colleagues to consider DER.

In the case of a proposed distribution project, the following exercise may help in evaluating the potential role of DER versus traditional distribution solutions based on adding more sticks and wires.

1. What would happen if the project is not funded? *Run to failure.*
2. How will service be provided and/or restored? Can DER play a role?
3. If so, can DER be used as an intermediate solution between full implementation of the project and doing nothing?

Options:

- Do the project
- Actively use DER to defer the project and avoid disaster
- Do nothing—perhaps DER can be used in disaster recovery.

Evaluate the Alternatives Consistently

Assemble alternative solutions and consider all costs, revenues and credits:

$Hard:	Direct costs	Insurance
	Corporate overheads	Depreciation
	Property taxes	Salvage value
	Business taxes	New revenue
		Income taxes on revenue
$Soft:	Negative publicity	Regulatory backlash
	Customer satisfaction (may be $Hard if customers can choose alternative supplier)	
	Avoided costs	

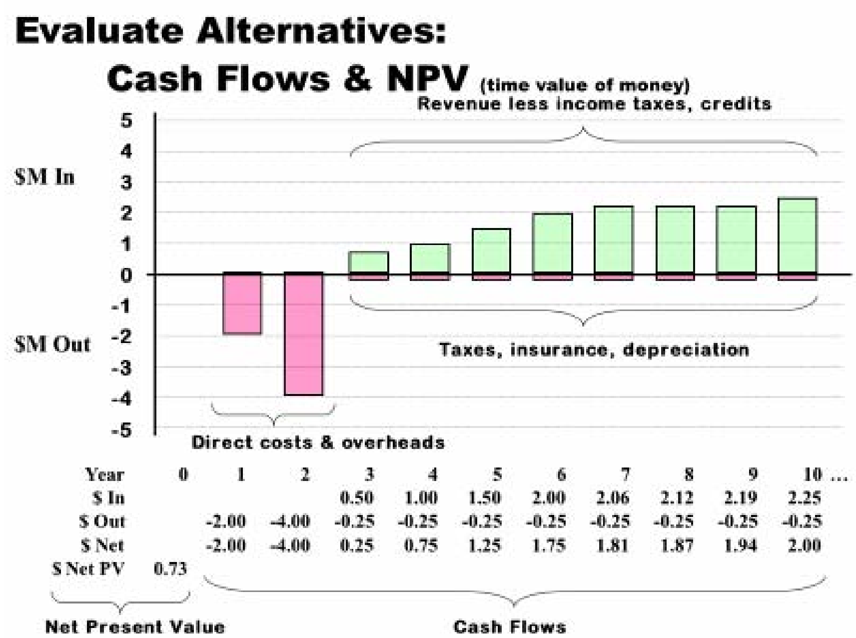


Figure 2-5
Evaluating Alternatives

Consider Value and Cash Flow

One cannot always afford the best, since one cannot spend what one doesn't have and budget limitations may dictate the selection of a less-than-optimum alternative.

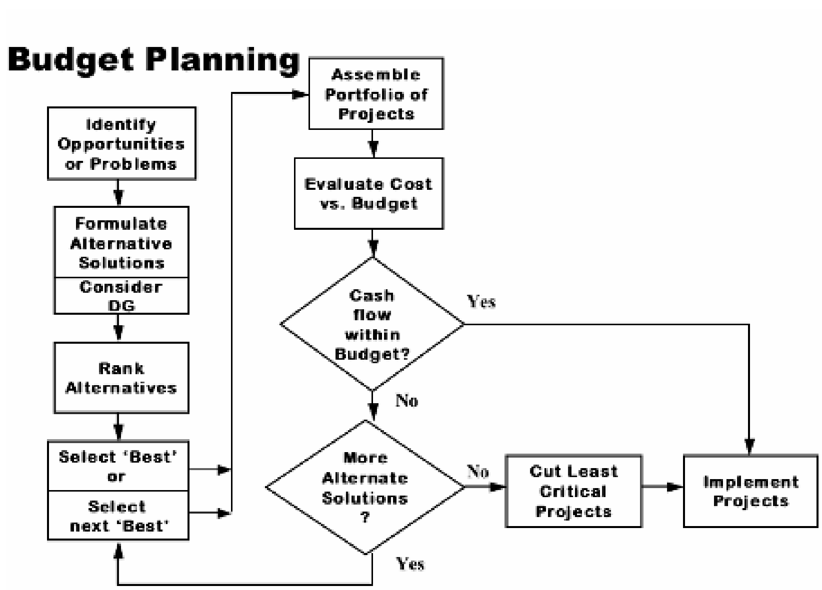


Figure 2-6
Budget Planning

Simplified Examples for Analyses

This subsection presents a simplified example for analyses. In this example, the situation facing the company is how to meet new load expected in three years with no current distribution capacity to serve it.

The utility faces three alternatives:

A. **Traditional:** Build new substation

B. **Proactive:** Defer new substation with DER

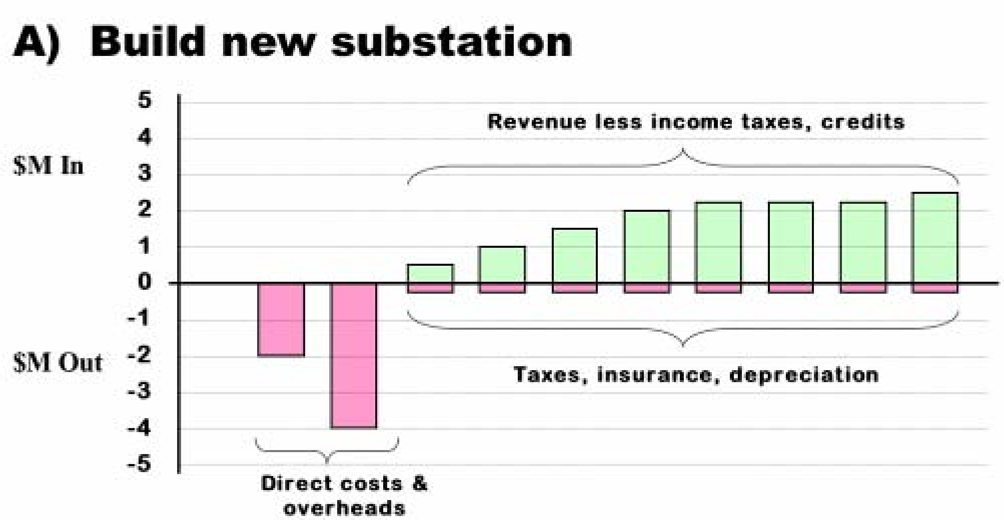
C. **Reactive:** Substation delayed; use DER

In this example, we assume the following:

- Substation cost of $6 million over three years.
- Distributed generation cost of $280,000 to install, $20,000/year to operate.
- Cost of money = 10%
- Expected load/revenue = +$500,000 per year for years one through four; 3% growth thereafter.

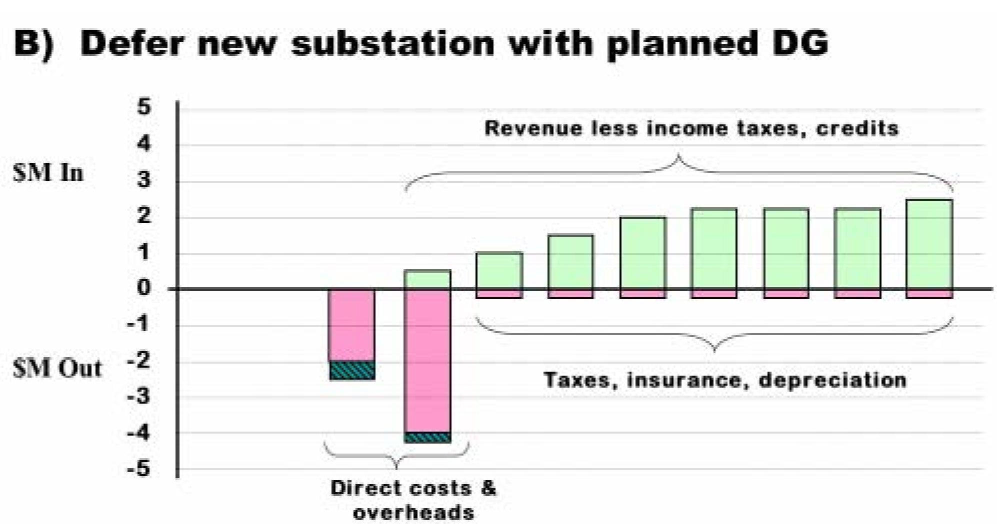
(Note: These numbers are for illustration purposes only and may not be reflective of actual costs.)

The following figures graphically illustrate the cash flows associated with each of the three alternatives.



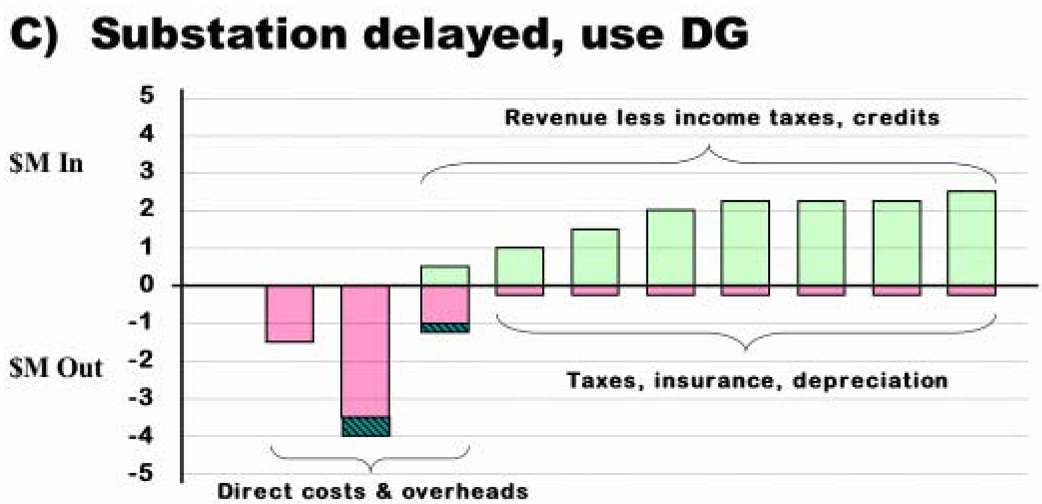
Year	0	1	2	3	4	5	6	7	8	9	10 …
$ In				0.50	1.00	1.50	2.00	2.06	2.12	2.19	2.25
$ Out		-2.00	-4.00	-0.25	-0.25	-0.25	-0.25	-0.25	-0.25	-0.25	-0.25
$ DG											
$ Net		-2.00	-4.00	0.25	0.75	1.25	1.75	1.81	1.87	1.94	2.00
$ Net PV	0.73										

Figure 2-7
Alternative A: Build New Substation



Year	0	1	2	3	4	5	6	7	8	9	10 …
$ In				0.50	1.00	1.50	2.00	2.06	2.12	2.19	2.25
$ Out			-2.00	-4.00	-0.25	-0.25	-0.25	-0.25	-0.25	-0.25	-0.25
$ DG			-0.28	-0.02							
$ Net		0.00	-2.28	-3.52	0.75	1.25	1.75	1.81	1.87	1.94	2.00
$ Net PV	1.14										

Figure 2-8
Alternative B: Defer New Substation With Planned Distributed Generation



Year	0	1	2	3	4	5	6	7	8	9	10 …
$ In				0.50	1.00	1.50	2.00	2.06	2.12	2.19	2.25
$ Out		-1.50	-3.50	-1.00	-0.25	-0.25	-0.25	-0.25	-0.25	-0.25	-0.25
$ DG			-0.28	-0.02							
$ Net		-1.50	-3.78	-0.52	0.75	1.25	1.75	1.81	1.87	1.94	2.00
$ Net PV	0.79										

Figure 2-9
Alternative C: Substation Delayed, Use Distributed Generation

The information in the preceding three figures breaks down to the following results:

Alternative		**$M Net Cash Flow**		
	NPV	**Year 1**	**Year 2**	**Year 3**
A. Build New Substation	0.73	-2.00	-4.00	0.25
B. Defer New Substation with DER 1 year deferral	1.14	0	-2.28	-3.52
C. Substation Delayed, Use DER 1 year deferral	0.79	-1.50	-3.78	-0.52

Alternative B with Respect to Alternative A:

- Alternative B has greater NPV and better cash flow in years 1 and 2. (Savings through deferred investment exceeds DER cost.)
- If new load is speculative, Alternative B gives a one-year hedge; allows an additional year to re-evaluate project need and scope.

<u>Alternative C with Respect to Alternative A:</u>

- Alternative C has greater NPV and better cash flow in years 1 and 2. (The unintentional delay produces savings—if DER solves the problem.)

Recap: DER Financial Considerations

1. As an alternative to each project, consider the recovery plan if the project is not funded:
   - Is DER feasible and useful in the recovery plan?
   - Can DER be used proactively to avoid the crisis and defer the project?
   - Is the recovery plan a better alternative than the project? If so, re-evaluate project need/timing.
2. Evaluate alternatives consistently.
3. Consider the cash flow of a project as well as its value.
4. If loads are speculative, perform sensitivity analysis on revenue. How does it impact NPV and cash flow? Does DER buy time to hedge investment?
5. It's impossible to defer everything. Be cognizant of impact on future year's budgets.
6. Check methodology with Finance Department.

Planning Under a Constrained Budget

Limited budgets necessitate the cutting of least-critical projects, which is easy to say but hard to do. However, "least critical" does not necessarily mean smallest NPV.

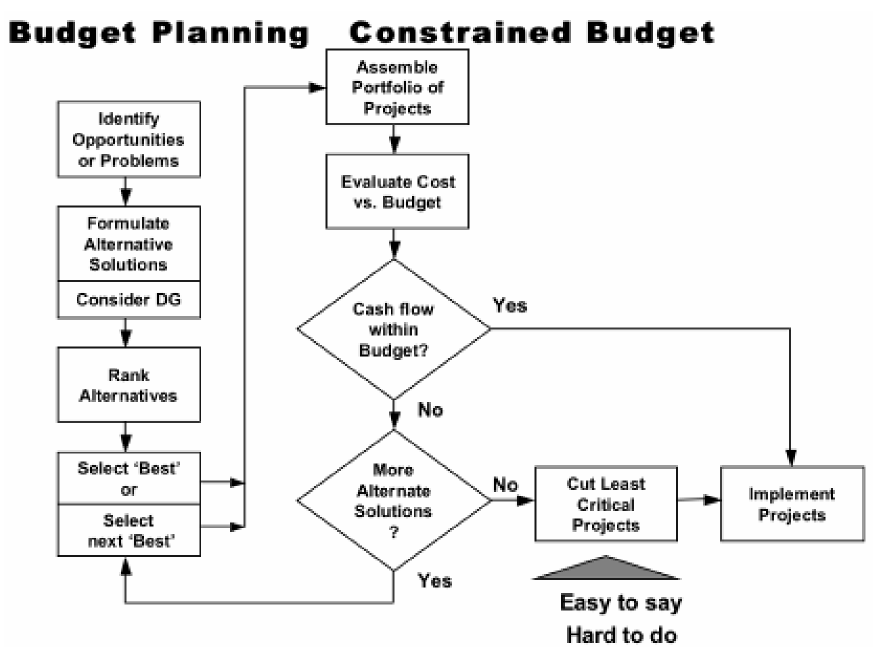


Figure 2-10
Budget Planning Under Constrained Budget

Projects must be divided into "Must Do" and "Discretionary" categories (note that assigning these categories is sure to invite criticism and argument).

Must Do projects involve

- Safety
- Regulatory requirements, e.g., relocations or serving new business (obligation to serve)

Discretionary projects involve

- Reliability
- Overloads

Illustrative example: You only have $200. You need two new tires. The cost is $75/tire, but there is a sale—four tires for $200, or $50/tire. However, little Billie MUST go to the orthodontist at a cost of $50. So you take Billie and buy two tires. *You can't always afford the best deal.*

It is important to maintain a sense of perspective when evaluating the criticality of projects and realize that the sky is not falling. Every year, *every* project seems absolutely critical to *somebody* and yet every year some projects get cut or miss their completion date. Occasionally, however, the wrong projects get cut. To minimize the consequences of cutting the wrong project, analyze the "Run to Failure and Recovery" alternative; estimate the probability of failure and prioritize according to dollars at risk.

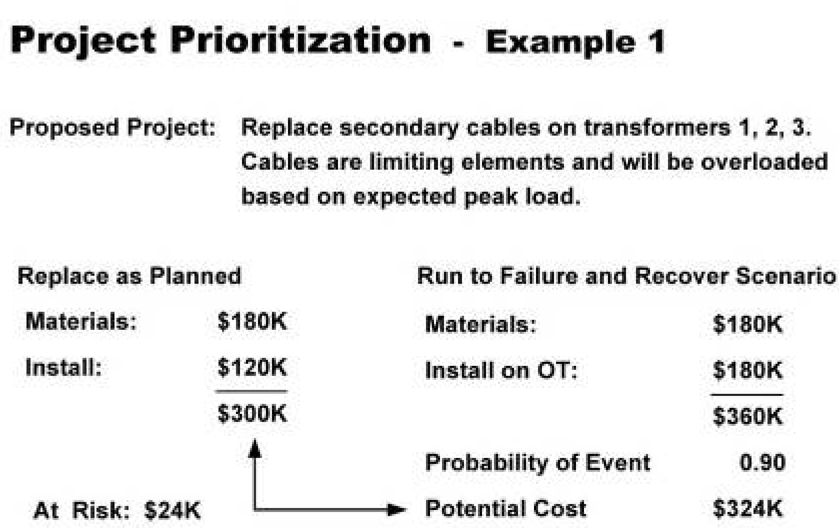


Figure 2-11
Project Prioritization: Example 1

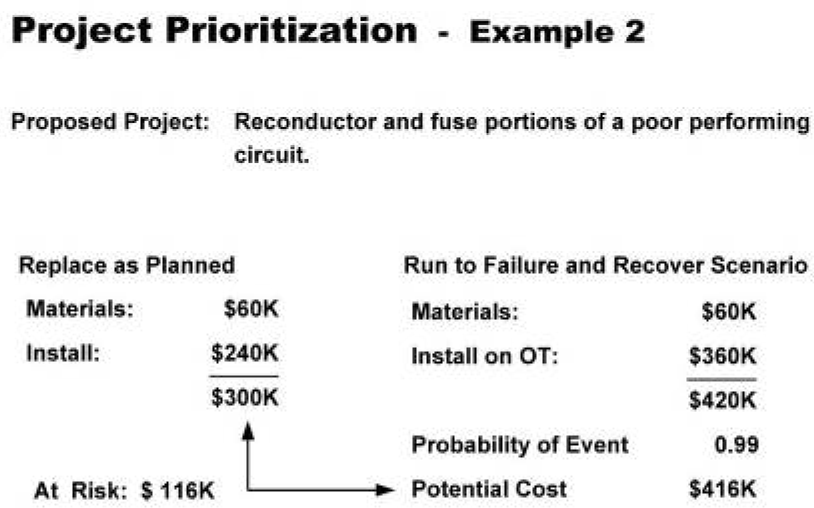


Figure 2-12
Project Prioritization: Example 2

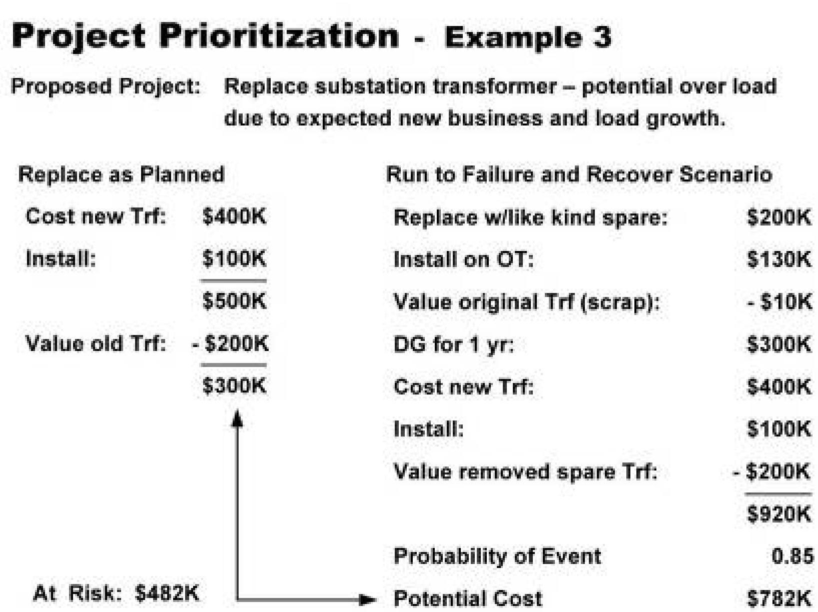


Figure 2-13
Project Prioritization: Example 3

Recap: Project Prioritization

There is no single correct way to prioritize projects and NPV does not tell the whole story. Use the "Run to Failure and Recovery" scenario to quantify risk and prioritize projects under constrained budgets.

Apply a consistent failure philosophy to all projects, i.e., Murphy's Law. If numbers and probabilities are unknown, estimate and analyze the relative results rather than the absolute values. If you cut the wrong project you will have prepared a portfolio of basic recovery plans and costs.

Developing a DER Capital Budget

After DTE Energy integrated this new measure on all new capital projects, the next step was to develop a DER capital project budget. While the DER and Defer strategy permits better economic utilization of resources, it is not the only reason to use DER. After probability analysis is performed, it becomes apparent that load will arrive before some T&D projects will be completed. DER can be a tool to help make sure these projects are addressed even if the final T&D solution is years away. DER can become a planned budget line item to rescue the project when and if it cannot be done (storms, R/W, community approvals, load growth faster than anticipated, etc.). DER can also be used as a Do Nothing alternative in the capital project budget process. This becomes not only part of a project alternative analysis but can be used as preplanned recovery plan.

The DER Planning Group has budget development responsibility. The group gets its project ideas in three basic ways:

1. A Project Value Analysis (PVA) review outcome
2. Projects that cannot be completed on time.
    - Load is coming faster that anticipated.
    - We can’t get the work done on time. (Probability analysis of not getting future project completed on time).
3. Capital Budget projects that are not funded.

Project Value Analysis outcomes. Each year before the annual capital budget presentations, all projects over $1M are reviewed by a cross functional team to determine if a project has merit and that the alternative solution proposed is the best. The DER group is part of that process and the DER alternative is proposed to DER and Defer as well as possibly as a part of the pole and wire alternative. This is one way we get DER projects. At this point, projects may not be funded and become potential DER projects.

Projects not completed on time. The DER group examines the previous year's capital budget plan, which identifies all capital projects for increased loads and new business. The group makes sure to identify those projects requiring key project items such as R/W, large amounts of capital for equipment, or known difficult community areas. The team assigns a consistent set of probabilities to each project, sort of handicapping the chances for completion. They then add the probabilities to determine statistically how many generator projects may be needed the following year. This is one of elements of the budget. The group typically asks the planning engineer and project management engineer for guidance and an estimate of probabilities. ***This approach does more than just develop a budget,*** it preplans a disaster recovery and brings each planning engineer and project manager on board with DER solutions.

Each project alternative is examined for larger customers, existing sources of customer generation, interruptible customers, sites for placement of DER.

Table 2-2
Probability Analysis of Next Year's New Business and Overload Projects

CAPITAL PROJECT SUMMARY		Probability of NOT Completing Projects with 2006 Completion Dates		
PROJECT	Project Description	DER Group Estimate	Proj Mangmt Group	Notes
Substation A Expansion	Replace two transformers and establish two new circuits	15	10	Maj Equipment and lots of underground
Substation B Expansion	Add one transformer, 9 positions of switchgear and 4 circuits	30	100	Land/RW Required
New Substation C	Construct Class R-R substation with 2 overhead circuits and 2 underground circuits	15	10	Maj Equipment and lots of underground
Substation D Expansion	Install third transformer and nine positions of switchgear	30	20	Land/RW Required
Circuit X Relief	Rebuild and convert backbone on circuit & install ISO equipment	5		
New Ckt A	Build new circuit out of Existing Substation for Development - City of Royal Oak	5		
New Ckt B	Build new circuit out of Substation to relieve overloaded ckt & then provide service to new Dvlp.	5		
Substation E Expansion	Install third transformer, 12 positions of switchgear, conduit and cable	30	20	Land/RW Required
Substation F Expansion	Install a 3rd transformer (10/ 12.5MVA) with split double bus and 9 new positions of switchgear.	5		
Substation G Expansion	Install 3rd 24/ 4.8 kV trf (10MVA), nine positions of swgr, & three ckts	5		
Substation H Expansion	Replace Hurst 10/ 12 trf's w 15/ 20/ 25's, move 10/ 12's & add 2 ckts to Hambg	5		
Substation I Expansion	Install 120kV circuit switcher/ DS, 3rd trf, 9 pos swgr, and three ckts.	5		
Add 2 New Ckts	Add two new circuit positions & two ckts.	5		
Substation J Expansion	In 120kV bkr, bus, DS, circuit switcher/ DS, 3rd trf, 9 pos swgr, and five ckts	15	10	Maj Equipment and lots of underground
Substation K Expansion	Rp 40/ 13kV 2 ckt CL T-Tw CL A 9 Pos, 5 ckts & rp 10's w 15/ 20/ 25 trf's	15		Maj Equipment and lots of underground
Rebuild Ckt for Customer	In 3600ft sys conduit & 8 mh, 5240ft cable & 3 ca po & 7 pri swcab; rem 2900ft oh pri & sec.	15	10	Maj Equipment and lots of underground
	Estimated % Probability of Capital Projects not getting done on time	**205**	**180**	
	1 DG will definitely be required and an estimated 1 more maybe required			

A 5% chance of not being completed on time is given to all major projects scheduled for completion in the next year. A 15% (an additional 10%) is given to all projects that require major equipment and/or system underground. Finally, a 30% (an additional 25%) chance of being late for any project requiring Land/RW. The DER Group's evaluation is similar to our Project Management Organization assessment. A budget estimate for two DER installations is submitted. If previously purchased generators are available, no DER is purchased. If a new DER is needed, its cost is folded into the Capital Budget Request.

Capital projects not funded. After the capital budget process is complete, some projects are left unfunded and these become potential projects for the succeeding year also.

The DER group takes over the complete project management duties, contracting out much of the field work (most of the DTE Energy project management and construction work force are distribution personnel) and minimizing the need for internal resources. This seems to be a good strategy, particularly for the first few projects. It is easier for the group responsible for DER to project-manage the installation.

Bottom-Line Messages

DER is just another tool (like a capacitor) that helps to solve some distribution problems. It is not a cure-all and it should be used if economically viable.

Distribution DER is not generation for generation's sake, it is really *distribution capacity*—an economic replacement for poles, wires and substations.

Project economics should consider

- The cost per projected criteria shortfall, not just by cost per capacity added
- DER cost versus consequences of "doing nothing"
- DER and defer

DER will never replace distribution any time soon—in fact, DER will initially only be viable a small percentage of the time.

3
PLANNING AND PROTECTION

Chapter Organization

This chapter discusses the distribution planning and protection aspects of installing DER. It covers planning studies and the responsibilities of the planning engineer, estimating loads and load analysis; circuit analysis: low voltage, overloads and reliability; placement of DER and impacts; protective equipment and protection issues such as selectivity, sensitivity and islanding.

Additional reference information is provided in Appendix A.

Introduction

With the aid of new communication and monitoring technologies, DTE Energy has automated the operation of DER. In essence, the DER should act like fans on a transformer that come on and off automatically when needed. The operator should only be needed if the DER fails to operate properly. When the load on a circuit reaches its day-to-day level, the DER senses this and turns on to maintain this level of load on the circuit. Furthermore, DTE Energy developed a load-following strategy to provide freedom from transfer trip and at the same time minimize fuel expenses. The automatic load following strategy without transfer trip required protection engineers to think differently about DER. In the past, protection engineers were hesitant about DER because they had no input into the operation and design of customer-owned DER on distribution circuits. Now that the utility owns and operates the DER, the protection engineers are more accepting of DER equipment since they are assured of input into the design and operation. It's important to involve the protection group in the planning and site selection of the DER installation.

Key Issues for Connecting DER

There are basically three categories of trouble that must be addressed: Planning Issues, Power Quality Issues and Protection Issues. As a utility, we have confidence that all of these issues will be addressed even after the installation of the DER. Note that this may not be the case when dealing with customer-connected DER. The planning engineers will do their best to preplan the distribution system, taking the planning and power quality issues into account. The protection engineer will do the same for the protection issues. Since DTE Energy currently uses only synchronous generators, only those will be discussed in this chapter.

The following table presents 29 Key Issues for Connecting DER on the electrical system. The issues that are displayed in bold type are primarily protection issues.

Table 3-1
DER Connection Issues

Key Issues for Connecting DER	
1. Improper Coordination	**16. Isolate DER for Upstream Fault**
2. Nuisance Fuse Blowing	**17. Close-in fault Causes Voltage Dip, Trips DER**
3. Reclosing out of Synchronism	**18. Switchgear Ratings**
4. Transfer Trip	19. Self Excited Induction Generator
5. Islanding	20. Long Feeder Steady State Stability
6. Equipment Overvoltage	21. Stability During Faults
7. Resonant Overvoltage	22. Loss of Exciters Causes Low Voltage
8. Harmonics	23. Inrush of Induction Machines Can Cause Voltage Dips
9. Sectionalizer Miscount	24. Voltage Cancelled by Forced Commutated Inverters
10. Reverse Power Relay Malfunctions	25. Capacitor Switching Causes Inverter Trips
11. Voltage Regulation Malfunctions	26. Flicker from Windmill Blades
12. Line Drop Compensator Fooled by DER's	**27. Upstream Single Phase Fault Causes Fuse Blowing**
13. LTC Regulation Affected by DER's	**28. Underfrequency Relaying**
14a Substation Load Monitoring Errors	**29. Distribution Automation Studies**
14b Cold Load Pickup with & without DER	
15. Faults within a DER zone	

Planning: Responsibilities of the Distribution Planning Engineer

"Risk comes from not knowing what you're doing."
—Warren Buffett

Distribution planning has become much more complex today. Planning is no longer just about solving overloads and low voltage; it is also about making business decisions. The engineer must quantify distribution problems, the associated risk, and then communicate this in investment terms to non-engineering personnel that control the corporate budget. To further complicate this, the utility capital budgets are declining at the same time that customer expectations are increasing.

The distribution engineers now must also balance the need to build new distribution infrastructure as well as provide for the existing system. For instance, they must juggle between serving the continuously growing load and solving reliability concerns of the existing load. We may not have the resources to solve all of our 1 MVA criteria shortfall problems with 30 MVA solutions. For the 1 MVA problems that only exist for a few hours a year and 30 MVA solutions that will not be fully utilized for several years, installation of DER may be a way of avoiding distribution problems cost effectively.

In areas where more than one circuit is in need of relief we recommend circuit reconfiguration, if possible, placing the overload on one circuit to facilitate locating a DER site.

DER is one alternative for delivering just-in-time right-sized capacity at lower initial cost. The challenge is to demonstrate how DER can fit into the distribution engineer's tool kit as a means of solving distribution problems. The best way to do this is to lead by example and teach others how we are utilizing it. The idea here is to sell DER as a distribution solution.

As a side note, we are pushing our existing system more today than ever before. We are forcing our system closer and closer to the edge. The questions every planning engineer must ask are, where is the edge and how close are we? With this not being well defined, can you blame a distribution engineer for wanting to err on the side of conservatism? As the industry becomes more populated with newer distribution engineers who may be computer literate but lack distribution savvy, it is important to supply them with the adequate tools. To help them become more comfortable with operating close to the edge, we must continue to harness the data in our corporate computers and make it available for analysis in distribution system models such as the Distribution Engineering Workstation (DEW) that DTE Energy uses.

Harnessing our data and making it available for computerized distribution modeling tools is a means to manage distribution with technology. The development of intelligent analysis tools will help us quantify the extent of our distribution problems, determine how close we are to the edge and help develop innovative solutions such as DER to resolve them.

Distribution Planning With DER

It is assumed here that the distribution planning engineer is familiar with load flow/power flow analysis for the peak load. Therefore, we will only focus on the aspects of planning that are unique to DER. These include the evaluation of the load over the entire spectrum of load that the problem is present, not just for the peak load. We are of course interested in quantifying the following:

- The peak load
- The minimum load
- The minimum load during the peak time period

Some other items that the distribution planning engineer must pay particular attention to are listed below:

- Capacitors and capacitor switching
- Regulators (unidirectional and bidirectional)
- Single phase operating devices
- Voltage and current imbalances

Estimating Loads and Load Analysis

"Education is a progressive discovery of our own ignorance."
—Will Durant

Distribution planning engineers must be aware of the loading at the substation, as well as out on the circuit. Due to limited resources, most distribution planning departments focus their studies on one particular load point, the point when the load is at its peak. Peak load is the worst-case scenario; if departments plan for the peak load they should be able to rid themselves of overloads.

Traditionally, planning engineers used circle charts (shown below) from substations in order to understand what the loads were on each distribution circuit. These charts can be converted into current (amps) or power (MVA) values.

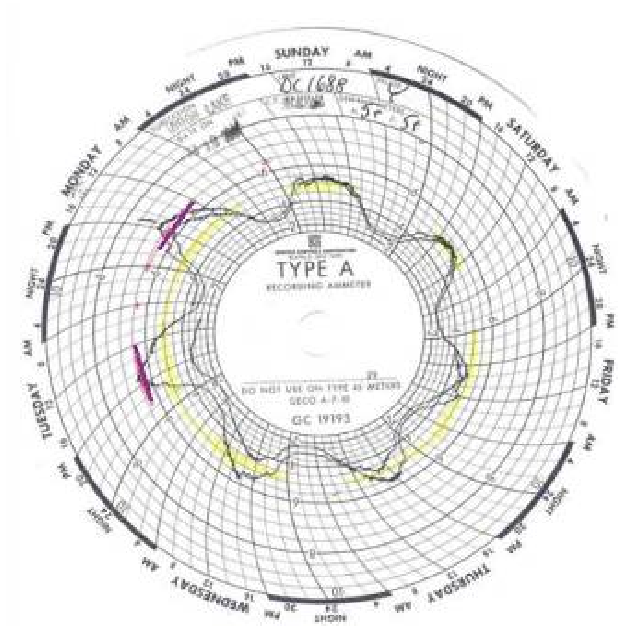


Figure 3-1
Circle Chart for Load Estimation

As technology develops, the use of SCADA (Supervisory Control and Data Acquisition) has become more widespread in monitoring the load. SCADA gives the planning engineer an opportunity to analyze the load throughout the entire year, rather than at just one time point. Having SCADA information time stamped and entered into a database allows the distribution planning engineer to better understand his load. They can analyze their peak load, minimum load and the times at which these loads occur. Another way engineers can interpret the load is to combine customer usage data with load research statistics and use a computerized distribution system model, like DEW, to analyze the load over an entire year. After getting a handle on the loading conditions, the engineer should be equipped to determine whether or not DER is a viable solution from a load standpoint.

Note: It is essential to do load correction before performing load studies for future years. Load correction is aggregating the generator's output with the circuit load to determine the total load on the circuit.

Addressing Power Quality Concerns

When installing a DER there are concerns that must be accounted for with nearby equipment such as capacitors, voltage regulators and single-phase operating devices. The voltage rise of a capacitor should be calculated and then added to a base voltage. An example of this would be a 6-volt flicker added to a 126-volt base; the resultant is a 132-volt state. The over/under voltage relay that protects the system from the generator is set to trip if it sees 132 volts for one second. Thus, if the voltage stays at 132 volts for one second, the relays would trip, preventing the generator from being able to operate. Now it is true that the regulators on the circuit, if there are any, would regulate this over voltage, but not in time to avoid tripping the relay. In the case of having a DER on a circuit with unidirectional regulators, if the power flow reverses it can cause the unidirectional regulator to improperly operate. Therefore, an engineer must be aware of voltage regulators on the circuit before installing a DER.

In the feed forward path from the substation to the point of interconnection, the DER should not have a single phase operating device. If a single phase operating device is present, the DER would have the potential of being single phased and all of the problems with being single phased. The engineers at DTE Energy will make sure that there are no single phase operating devices between the DER and the substation. If there are single phase operating devices, they are either jumpered out during DER operation or replaced with three-phase gang-operated devices. Of course, jumpering out a single-phase device will have a negative effect on reliability downstream from where that device formerly operated. The protection subsection of this chapter will cover this topic in much more detail.

Planning/Protection Example: Determining the Need for Transfer Trip

Following is a brief example showing the necessary steps in deciding whether or not transfer trip will be required. In the following case, the circuit, P1 operating device and P5 operating device are analyzed to determine the maximum and minimum loads seen at those locations.

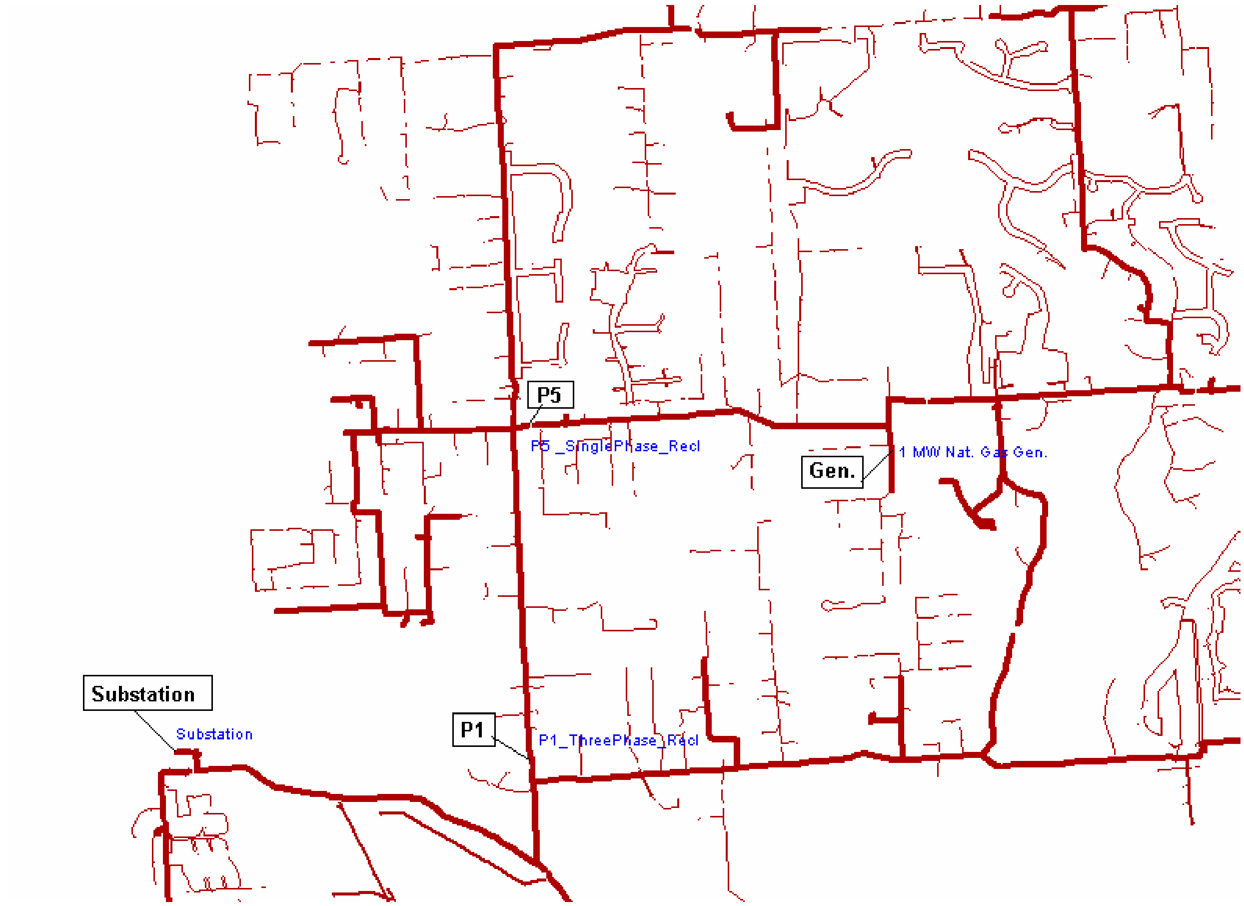


Figure 3-2
Determining the Need for Transfer Trip

The following table displays the values that were determined through load analysis at each point. Make a note that the minimum load value is important if a DER is going to be used. The minimum load must be four times the output of the generator; otherwise transfer trip is necessary on the generator. This will be discussed further in the protection subsection. Per IEEE 1547 a 3:1 ratio is required in order to avoid installing transfer trip. The DTE Energy policy includes an additional margin of safety by using a 4:1 ratio to evade unintentional islanding.

Circuit Section	Peak Load	Minimum Load	Transfer Trip Required
Circuit	13.6 MVA	2.6 MVA	Yes
P1 Operating Device	9.7 MVA	1.9 MVA	Yes
P5 Operating Device	5.6 MVA	1.1 MVA	Yes
Generator	1.0 MVA	0.3 MVA	N/A

The options that can be considered for this example are as follows:

1. Use transfer trip from P5
2. Jumper out P5
    a. Use Recloser Form 5 Control to Coordinate DER output level.
    b. Use transfer trip from P1.
    c. Use a triple-single recloser to restore single phase reliability when DER is not in operation.
    d. Return to service outside the summer period to restore single phase reliability when DER is not needed.
3. Use form 5 recloser at P1.

The previous example is a good lead-in to the next subsection, which discusses all of the protection issues surrounding the interconnection of DER. The following segment will address protective equipment, as well as the major protection issues such as: selectivity, sensitivity and islanding.

Interconnection Protection

"Protection is not a principle but an expedient."
—Benjamin Disraeli

Basic Protection Analysis

This subsection outlines and provides key details and considerations to be included in an analysis that will determine the protective relay requirements for the installation of the DER.

Comparison to Customer-Owned and Operated DER

It is a practical reality that the DER Planning Engineer at DTE Energy usually seeks the advice of the protection engineer as part of the site selection process. In this way, the protection engineer is guiding the potential site selection process by steering it toward a site that is easier to equip with the necessary interconnection protection.

The protection analysis for the installation of a DER operated by the utility must be done with the same accuracy and considerations that are applied to DER owned and operated by a customer. IEEE Standard 1547 has become widely used to determine the protective relay requirements for customer-owned DER. This standard provides sound electrical requirements. IEEE 1547 is used by Detroit Edison in the implementation of utility-owned DER.

Similar to the installation of customer-owned DER, a design goal should be to maintain or improve the present levels of fault sensitivity, system reliability and power quality. As always, safety should not be compromised.

While contractual issues may be completely eliminated in some cases, certain other requirements for customers, such as billing metering, may be helpful if not required for the utility installation also. Accurate monitoring and recording of supplied energy and fuel use may be needed for load flow studies, performance analysis, operating agreements, or fuel cost allocation.

Utility Operation and Ownership May Simplify the Protective Relay Installation

The protective relay engineer should seek opportunities to simplify the protective relay installation. Utility ownership and operation may provide opportunities to simplify the protective relay installation. Awareness of the DER operating modes and close cooperation with groups performing load analysis and project specification can help uncover protective relay options not normally available for independently operated DER.

This is particularly true with respect to anti-islanding protection. Utility operation can ensure the generator output remains less than one-third of the load that would be isolated with the generator upon operation of the substation breaker. This is done by restricting the output of a larger machine to a power export of less than one-third of the isolated load. This can eliminate the need for transfer tripping installation.

Also, it is not normally permissible to connect customer-owned protective relays to instrument transformers used for billing. The utility practice may permit the protective relay installation owned by the utility to utilize the billing instrument transformers if an analysis of the burden indicates the metering is not compromised.

Required Tools and Information

"Men have become the tools of their tools."
—Henry David Thoreau

The following are required before attempting to perform a fault current study:

Application Software. Application software is required to model the DER, the DER transformer and the distribution circuit for the purpose of calculating fault currents. The software must be capable of performing network calculations with at least two sources and satisfactorily model the type of DER and transformer connection being used. As discussed previously in this section, Detroit Edison utilizes the Distribution Engineering Workstation for this purpose.

Circuit Load Information. An accurate load profile of the circuit including minimum load values is needed. Minimum load values may be required to determine if the circuit load is sufficiently large to prevent an unintentional island. Otherwise, transfer trip equipment may be needed.

DER Mode of Operation. The mode of operation of the DER must be well defined. The following questions should be answered early in the process:

- Will the DER be operated as standby, peak shaving, load relief, dispatchable, power quality improvement or some other mode?
- How long will it operate in parallel with the system?
- Will the utility have sole control or will control be shared with the customer or even a third party?
- Will the DER operation be completely automatic, SCADA controlled, or by local manual control?

While some of these considerations are usually considered contractual issues, certain operating modes may provide options for the DER's protective relay system.

DER Configuration. An accurate one-line diagram is required that indicates, but is not limited to, all of the following:

1. Electrical energy producing devices (e.g., synchronous generators, induction generators, fuel cells and batteries)
2. Prime movers (e.g., internal combustion engine, combustion turbine, steam turbine, wind turbine or water powered dynamo)
3. Inverters
4. Auxiliary load
5. Customer or other local load
6. Breakers

7. Transformers
8. Voltage levels
9. Grounding configurations
10. Instrument transformers and associated ratios & configuration
11. Protective devices (e.g., fuses & relays)
12. Metering points

Step-by-Step Process

Perform Fault Studies

1. Review the distribution circuit model to be used for the analysis for accuracy. Make all needed corrections.
2. Establish the DER in the distribution circuit model by connecting the DER and any associated transformer(s) to the node corresponding to the connection point in the field.
3. Execute separate fault studies for <u>all</u> modes of DER operation.

Address all of the applicable 29 issues (See Table 3-1) as follows:

1. Verify that all faults will be sensed and cleared within established guidelines. See Table 3-1, Issue 1.
2. Verify that fault current interrupting capabilities of equipment are not exceeded. See Issue 18.
3. Determine what island detection method will be utilized. See Issues 4 and 5:
   a. Tripping for under/overvoltage and under/overfrequency where the minimum load that would be isolated with the DER is three (3) times the DER capability.
   b. Transfer tripping of the DER from the isolating breaker
   c. Approved island detection systems that detect an island condition by momentarily changing the real and/or reactive power output and noting changes in real and reactive power flow or frequency and voltage. Changes in real or reactive power flow indicate connection to an larger system. Significant changes in frequency and voltage indicate an island condition
   d. Fixing the DER power factor to a value significantly different than the expected isolated load. This will force an under or over voltage condition upon isolation that will be detected by voltage relays.
4. Determine if the DER configuration and protective device operation is likely to cause an overvoltage condition. This can happen when the isolation transformer is connected to a 4 wire grounded distribution system through a delta winding. Ground faults on the system that isolate the DER may elevate the unfaulted phases to near phase-to-phase potential. See Issue 6.

5. Determine if reclosing or momentary faults are likely to cause loss of synchronism by the DR. See Issue 3
6. Consider removing or replacing single phase devices between the DER and the substation if single phase loading of the DER may cause damage or undesirable operations
7. Determine if any protective devices will become overloaded due to the DER operation. Recommend protective device modifications as required.
8. Determine if any protective devices become inselective. See Issue 2.

Protection Analysis Example

The following provides an outline of key steps in the protection analysis.

Circuit Model and DER Addition

"Software comes from heaven when you have good hardware."
—Ken Olsen

The following screen shows a graphic display of land-based data for a distribution circuit. The database for the circuit utilizes the same software (DEW) used in the previous load flow example. DEW is capable of performing fault studies suitable for determining the effects of the addition of DER. Ideally, the person performing the load flow study and the person performing the fault current study are either working closely together or the same person is performing both studies. Shared understanding of the load flow and fault studies can help lead to the most economical and best performing installation.

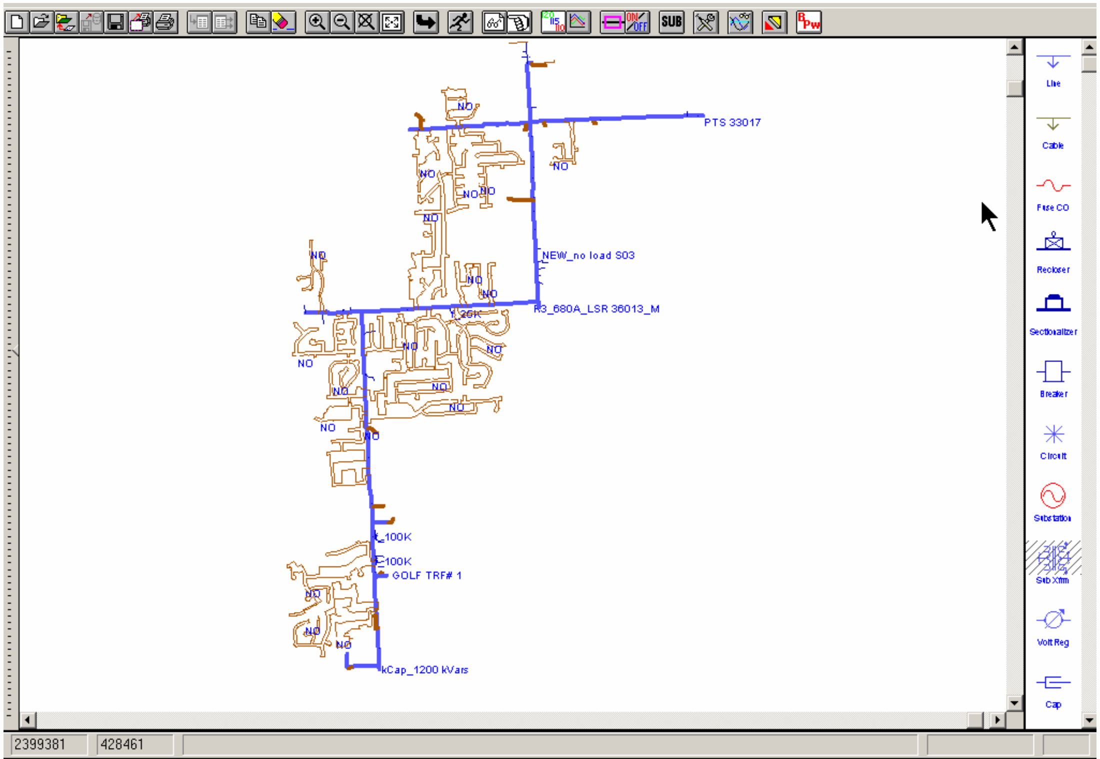


Figure 3-3
Land-based One-line Circuit Diagram

If the load flow study has already been performed with the DER connected to the system, the same circuit model should be used to perform the fault studies.

The following screen (Figure 3-4) shows the results of a fault analysis without the DER connected, or turned off if already added to the model. The DEW software provides a feature that will color the circuit elements based on the respective fault current level. This might be considered to be a "nice" feature and not really necessary. However, adding color to the map can give all concerned a quick, educated picture of problems that may exist. An example would be identifying areas where equipment does not have sufficient fault current interrupting capability.

After the DER has been added, fault studies should be run for all operating modes of the DER including off-line or disconnected mode.

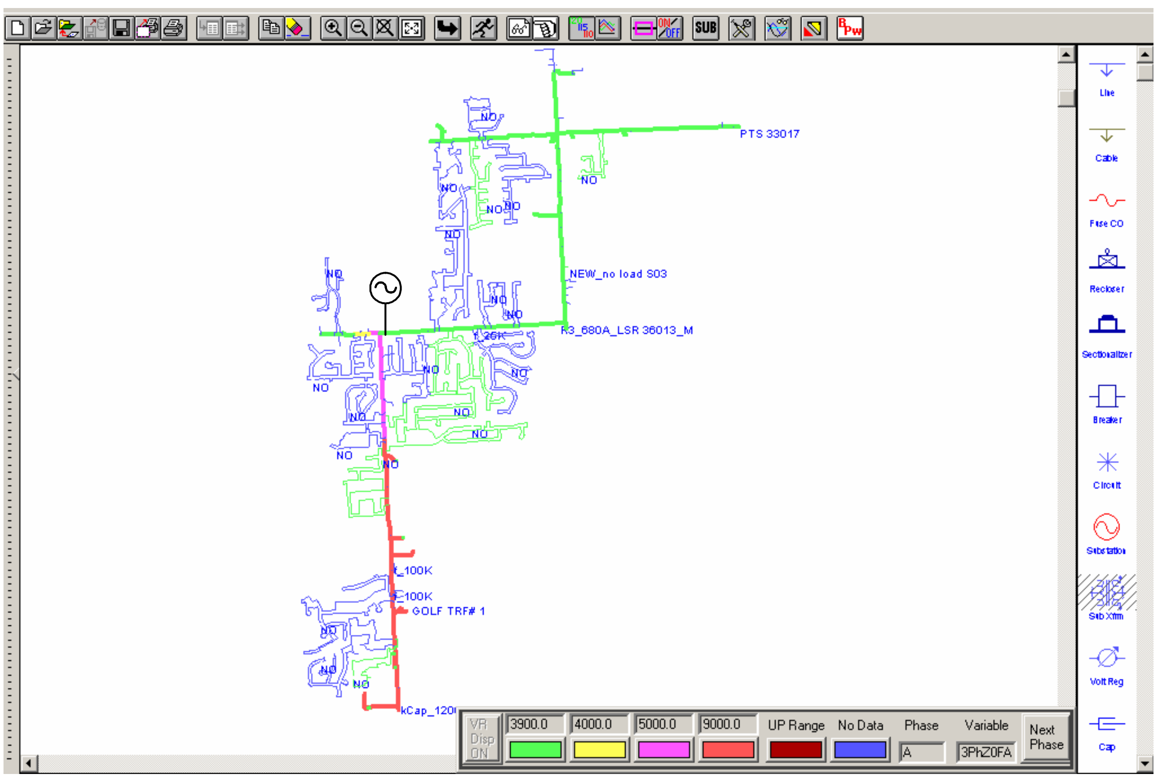


Figure 3-4
Color of Circuit Elements Indicates Fault Current Level

Fault Current and Interrupting Rating

The following diagram (Figure 3-5) indicates a simplified study for a 4.8 kV substation with a 2 MW synchronous generator added. The three phase fault currents shown are for conditions with the generator off. Note that the 40k fuse link is near the interrupting rating of 8,000 amps for a universal link fuse. Replacement with a fuse with higher interrupting rating should be based on the utility's practice for marginal conditions. The 80k link fuse is definitely over its rating and should be replaced with a fuse with a higher interrupting rating.

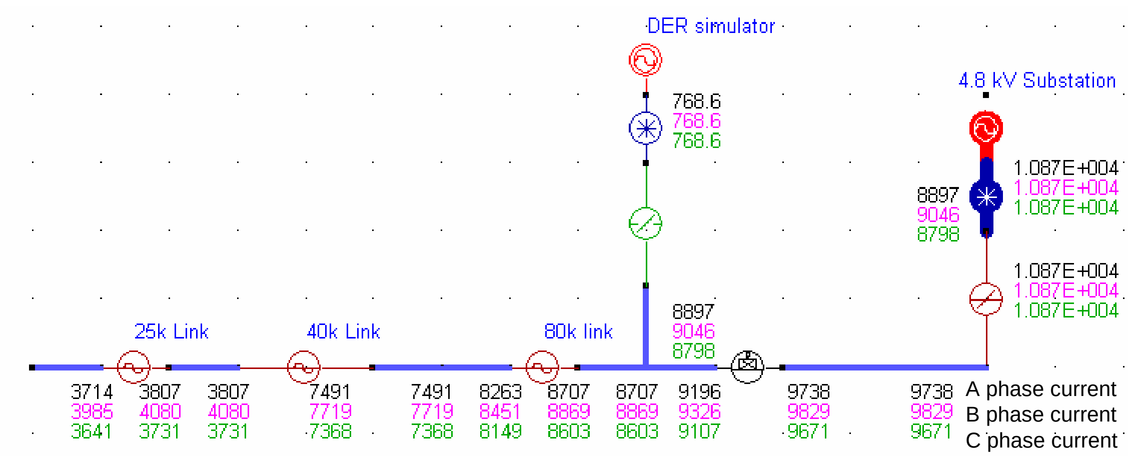


Figure 3-5
Fault Currents on Each Phase for a 3-Phase Fault at That Element (Generator Off)

The following screen shows the effects on fault current with the generator on. Note that the additional fault current from the generator has caused the 40k link to be subjected to fault duty definitely over the 8000 amp interrupting rating. This fuse should be replaced with a fuse of higher interrupting rating.

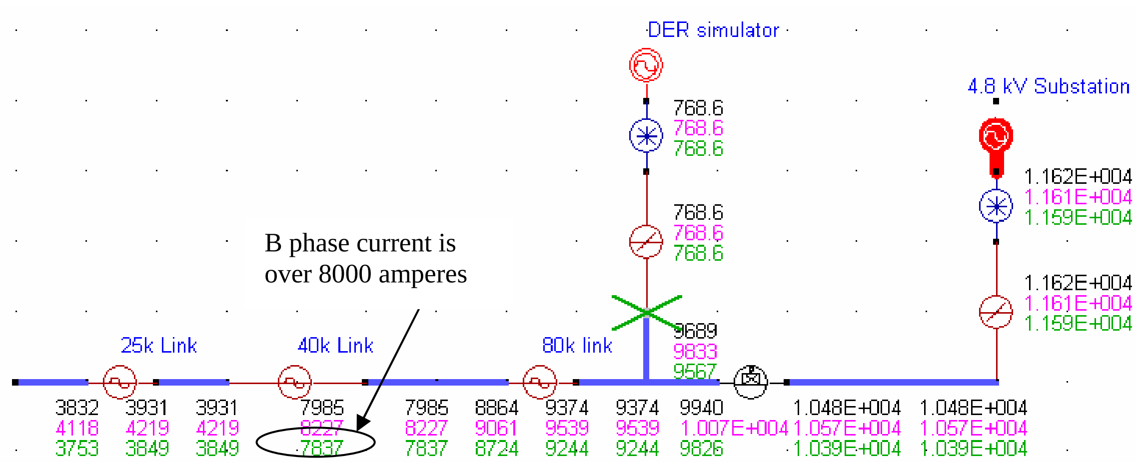


Figure 3-6
Increased Fault Currents on Each Phase for a 3-Phase Fault at That Element (Generator On)

The following screen utilizes a feature that changes the color of the circuit element to indicate the fault current level. In DEW, the levels are fully adjustable to permit setting of the color breaks at exactly the desired critical fault current level. The color breaks can be set right at the interrupting rating or at the utility's acceptable margin. For example, if the utility's safety margin is 10%, for fuses with a published interrupting rating of 8000 amperes, a color break would be set at 8,000 amps – 800 amps = 7,200 amps. Note that the 40k and 80k fuses are indicating a fault current of over 8,000 amps. The color code feature permits "trouble" areas to be identified quickly .

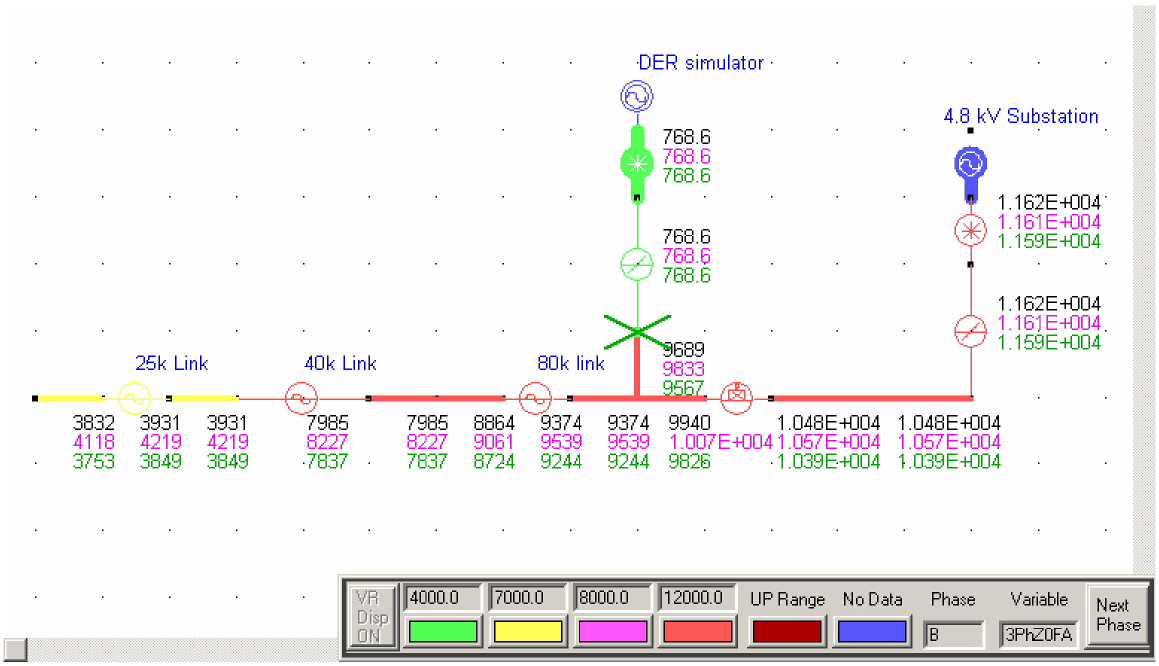


Figure 3-7
Color of Circuit Elements Indicates Fault Level

Advantage of Utility Ownership

To date, DTE Energy has not utilized inverter based generation. However, inverter based generation will supply significantly lower fault current than a synchronous generator of the same real power output capability. Therefore, in cases where interrupting rating of devices may be exceeded due to the addition of a synchronous generator, the utility that has an inverter based generator in its "tool box" may choose to use the inverter based system.

Fault Sensitivity

The next diagram indicates the fault current contributions for a 3 phase fault at the end of the line with the generator off. A phase conductor has 3,714 amperes flowing from the substation to the fault.

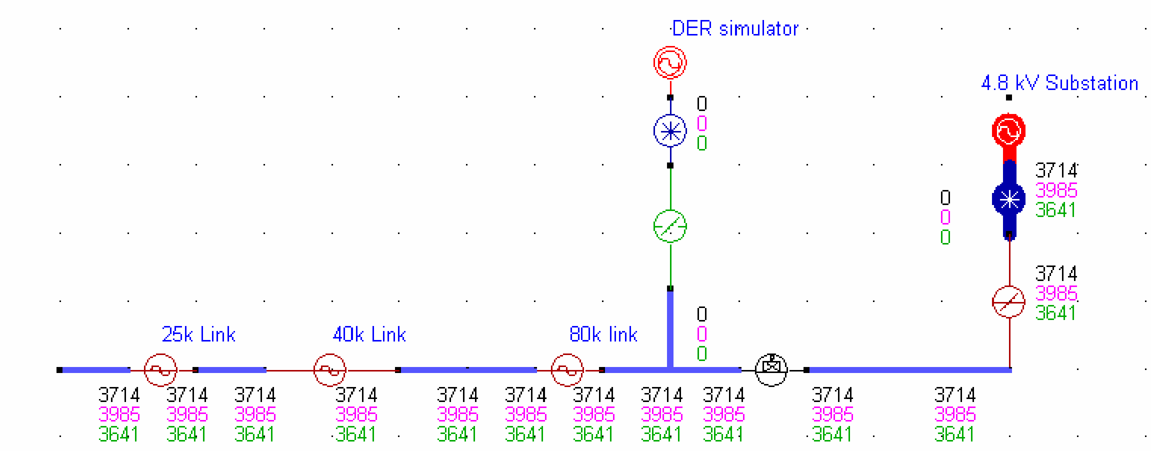


Figure 3-8
Substation Fault Contribution to Fault at End of Line (Generator Off)

The following figure demonstrates the effect of additional fault current contribution from the DER. With the generator on and the fault in the same location, the fault contribution from the substation is now reduced to 3545 amperes on A phase. When a DER and substation supply fault current to a fault through a common impedance, the substation contribution will decrease as the DER size (and short circuit contribution) increases. The utility should determine if the reduction in fault current for this fault and the associated reduced relay sensitivity is acceptable by their protective relay standards. If IEEE 1547 defined undervoltage tripping is utilized, the DER will trip off in 0.16 seconds when the voltage falls below 50%. After the DER is off, the condition reverts back to that shown in Figure 3-8 with a corresponding increase in fault current contribution from the substation. The utility should decide if this sequential operation is acceptable.

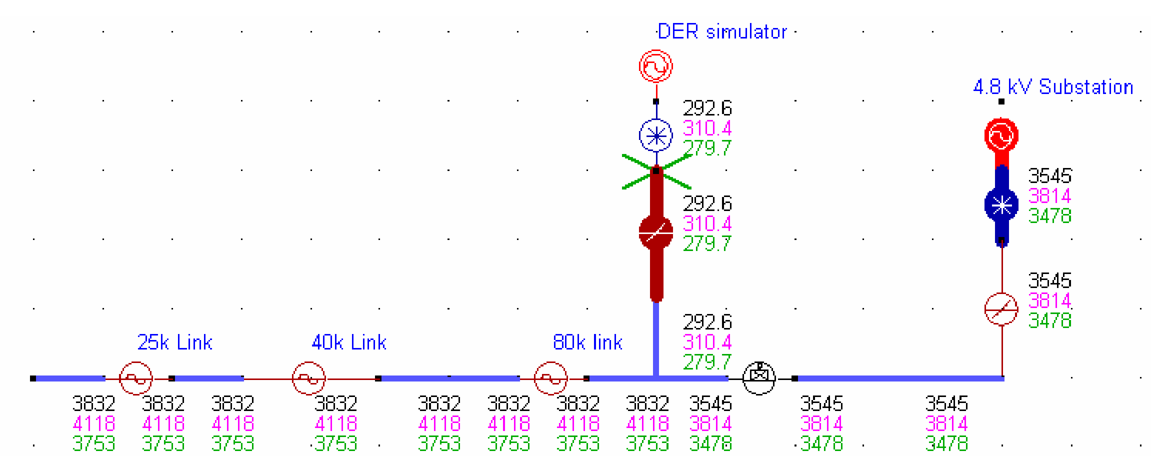


Figure 3-9
Reduced Substation Fault Contribution to Fault at End of Line (Generator On)

Advantage of Utility Ownership

In cases where fault sensitivity becomes a problem, special protection schemes may be employed if the utility owns the DER. For example, if the DER is on the substation property, current circuits may be installed to sum the fault current from the DER and the substation transformer. This current would be fed into a dedicated overcurrent relay. This would eliminate the desensitizing effect of the DER.

Also, the utility may set the protective relays for quicker tripping of the DER than required by IEEE 1547. This would quickly eliminate the desensitizing effect from the DER and permit the substation relaying to operate quickly.

Generator Contribution and Generator Overcurrent Protection

In the following diagram, the fault current from the generator is shown with the contribution from the substation removed. Note the increase from 292 to 690 amperes on A phase once the substation contribution is removed. Ideally the overcurrent protection in the generator will be able to sense this lower value. If IEEE Standard 1547 undervoltage tripping is employed, the undervoltage protection is likely to be the first to operate. The utility may decide it is acceptable to rely on the overcurrent protection of the generator that is only capable of tripping after the substation has cleared. In this case, a generator tripping value of 300 amperes may be acceptable. The generator overcurrent function would not operate until the substation tripped (should the undervoltage function fail).

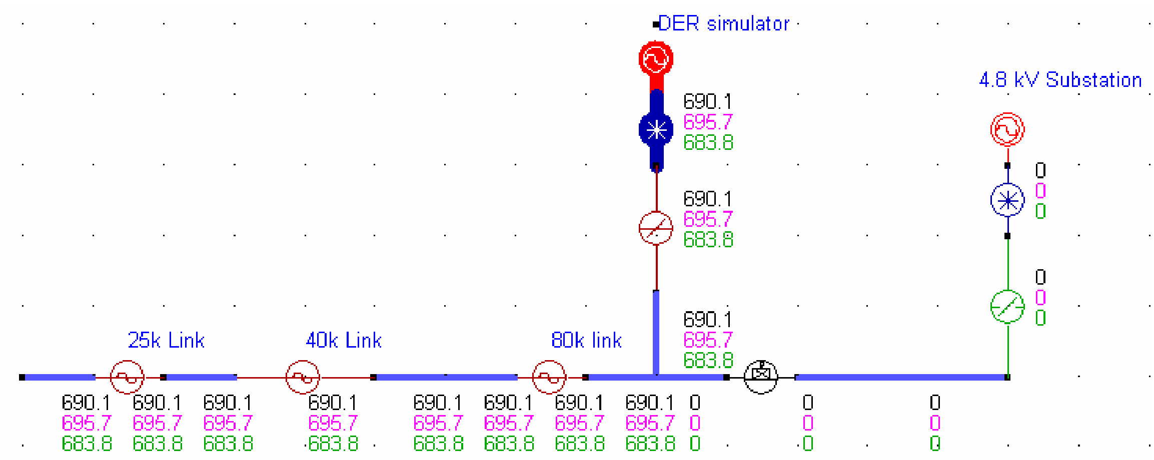


Figure 3-10
DER Fault Contribution to Fault at End of Line (Substation Off)

Advantage of Utility Ownership

In this case, the utility may decide that additional overcurrent protection is warranted to protect the investment the utility has made in the DER. A voltage controlled overcurrent relay could possibly be used with a current sensitivity (pickup) of about 200 amperes which would not be enabled until the voltage fell to about 60% of nominal. The voltage controlled overcurrent function may not be required if the DER is customer owned.

Protective Device Selectivity

Considering the same circuit used in Figures 3-8, 3-9 and 3-10, protective device selectivity should be considered. Because of the relatively high fault currents available, the fusing selectivity shown on the diagram is poor. For faults beyond the 25k fuse (almost 4000 amperes) even without the generator all three fuses may operate. The additional current from the generator will make the problem worse.

At 2000 amperes there is some minimum margin between the total clearing (blue tc) time of the 25k fuse and the minimum melt (pink mm) time of the 80k. In some cases this might be considered acceptable, particularly if the 25k fuse is protecting a pole-mounted transformer for secondary faults that would not cause even 1000 amperes to flow. The utility operation of the generator versus customer operation is not very different in the consideration of fuse coordination. However, if the generator will only be used a few hours a month by the utility and increased fault current causes some marginal selectivity concerns, the benefits of operating the generator may dictate that the marginal selectivity be accepted. This is particularly true if the solution to the selectivity problem becomes relatively expensive.

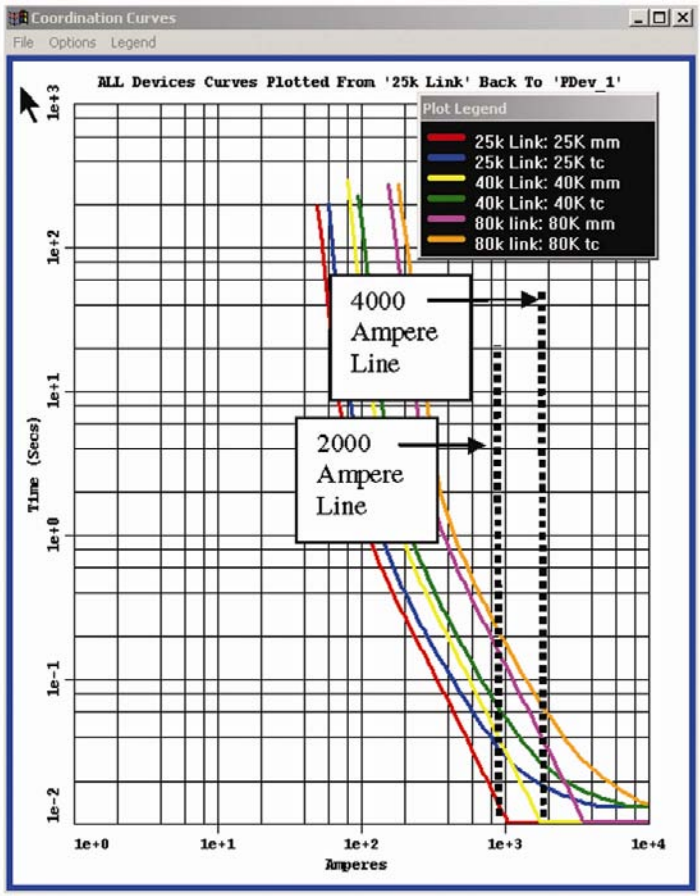


Figure 3-11
Lack of Fuse Coordination Due to High Fault Current

The addition of a generator downstream of a hydraulic recloser may jeopardize the recloser's ability to automatically clear faults downstream of fuses and thus save fuses from blowing unnecessarily. The diagram that follows plots the minimum melt (red) and total clearing time (blue) for an 80k fuse and 200 amp recloser with a fast tripping characteristic (yellow) and the slower (green) characteristic. The recloser will trip on the fast curve 1 or 2 times and then trip on the slower curve after that. The fast curve is intended to clear a fault downstream of the fuse without the fuse blowing. Note that above 1,000 amperes the fast curve (yellow) begins to approach the minimum melt time of the 80k fuse.

The additional current from the generator will increase current flowing in the fuse but not in the recloser. This will decrease the effectiveness of the fuse saving capability of the recloser.

Advantage of Utility Ownership

If the utility has control of the DER operation, the utility may determine that it should not run during storm conditions. This would reduce the likelihood of reduced selectivity between sectionalizing fuses becoming a problem.

The benefits of operating the generator by the utility should be weighed against the reduced fuse saving capability and cost of any circuit revisions to maintain the fuse saving capability. Because the generator may only be on a few hours a month, the likelihood of the fuse saving situation even arising will be small and the reduced effectiveness of the recloser may be acceptable with no other revision.

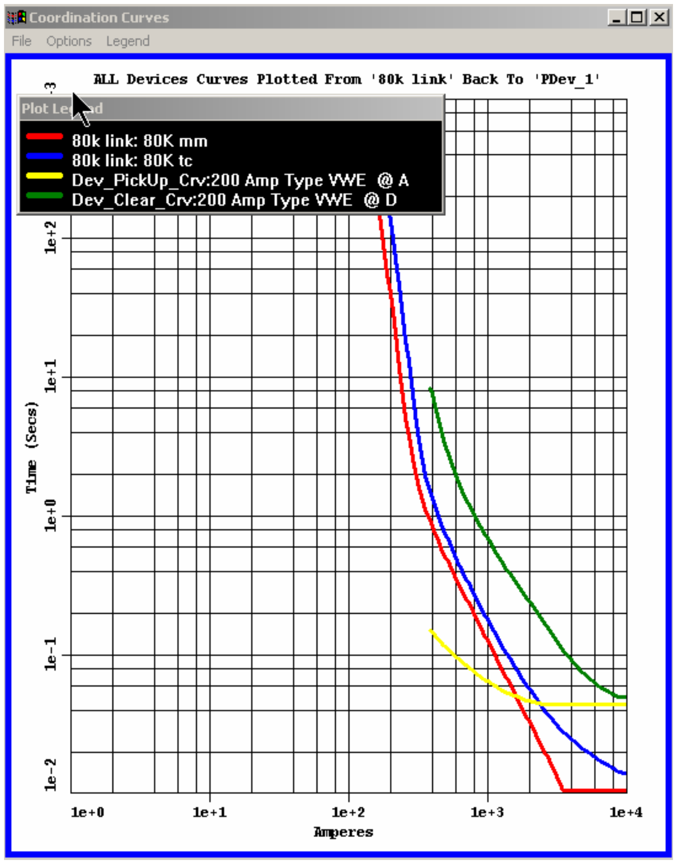


Figure 3-12
Fuse Saving Margin Decrease Due to Increased Fault Current

Other Protective Relay Issues

The above examples provide details on selected protection issues that can be addressed differently when the utility controls the operation of the DER. This set of examples is not intended to be complete. More examples are provided in Appendix A.

Summary

Design for the installation of utility operated DER should address all the protective relay issues in a manner consistent with that required for customer installations. However, the designers should maintain an awareness that utility control of the operation of DER provides increased flexibility in addressing the protective relay issues. The flexibility has been most noted in the following areas:

- Island Detection and Prevention (Issue 5): Restrict generator output to less than ¼ of respective circuit load)
- Reduced Sensitivity (Issue 1): Install special protection schemes for fast tripping.
- Inselectivity. (Issue 1): Restrict generator times of operation.
- Nuisance Fuse Blowing (Issue 2): Restrict generator times of operation.

Also, substation load monitoring errors (Issue 14a) should be much less of a problem because the utility will be very much aware of the times and operation levels of the DER. Assuming consistent databases are established for substation and generator loading, it will typically be easier to compensate load readings at the substation for the operation of the generator.

References

IEEE Std 1547-2003, Standard for Interconnecting Distributed Resources with Electric Power Systems

EEI Paper, *Method for Determining Electric Utility Requirements for Connecting Distributed Resources to the Utility System*, presented by Murray W. Davis, September 27-29, 1999 Arlington Va. (29 Issues Report)

4
DESIGN

Chapter Organization

This chapter covers DER system design considerations, including design of generators, connectors, monitoring and control equipment, and physical design.

Introduction

"Design must reflect the practical and aesthetic in business but above all…good design must primarily serve people."

—Thomas Watson

One of the initial steps in the DER project process is designing both the generator and connection skid. These are the two major components in the construction of a DER. This chapter will discuss the steps involved and the processes included in any design. There are several different types and various sizes of generators that could be used and this chapter will discuss the advantages and pitfalls of several of them. First, a type of fuel needs to be chosen for the generator. It can be natural gas, diesel, a combination of both, or possibly a more esoteric, green form of power such as biomass or fuel cell. For brevity's sake, we will leave out the more specialized generators and discuss natural gas and diesel units exclusively. The other consideration is the size of the generator needed. This will depend on the shortfall on the affected circuit that the DER is planned for. All design considerations must be compliant to all applicable regulations including Department of Environmental Quality (DEQ), federal and state regulations.

Generator Design

DTE Energy started with a standard rental unit as its first DER installation. This package was modified based on experience and operating needs. Below is an outline of lessons learned from these experiences.

The first piece of equipment to design is the generator itself. As mentioned above, the type of fuel or fuels that will power the generator must be decided upon early in the process. It is relevant to consider that diesel will generally provide a higher kW output than natural gas. Two and five MW units are not uncommon. Also, diesel fuel engine is more versatile because it has greater step loading potential than natural gas engine. The disadvantage of the diesel generator is that fuel must be stored either in the ISO container, in an outside fuel tank, or a combination of both. In any event, the fuel must be stored on-site and that adds to the overall footprint of the generator. Natural gas generators avoid the added space for fuel containment, however they must be placed close to a natural gas source. This will limit the effectiveness of the unit. Also, natural gas, by its very nature, will not provide as much power as diesel due to diesel fuel's higher combustibility. Natural gas generators, however, tend to be quieter and less polluting than their diesel counterparts. This chapter will discuss the design requirements of both types and also provide a cursory glance at the bi-fuel alternative (natural gas with diesel blend). As far as the parts of the generator itself, it can be subdivided into the following categories: Container, Fuel, Engine, Alternator, Switchgear, Customer Interface, Tagging Points, Protection, Communication and Power Terminations. Careful attention must be placed to each element of the generator design including safety, environmental and community concerns.

Diesel

The main issue in designing a diesel generator is the storage of the fuel. There are three ways to accomplish this: inside the generator container, outside in a tank, or a combination of both. Generally speaking, fuel storage is best placed outside the container. One advantage of an external tank is that the size of the tank can be varied dependent upon the demands of the project. It can be a rather large tank if the site can accommodate it. The external tank will cut back on the size and weight of the generator itself. Inversely, storage inside the container requires special provisions regarding fire protection from the DEQ. All storage tanks should be double walled with an acceptable fire rating. Fuel piping shall be rigid piping and "fire-flex" limited to nine foot lengths. Venting of the storage tank shall exhaust to atmosphere. An external fill is required allowing for a visual clock gauge on the tank, overfill audible alarming and mechanical overfill protection. Below is an example of an external fill.

Figure 4-1
External Fill Box: Containment, Overfill Alarm and Quick Disconnect With Shut-Off

Figure 4-2
External Fill Box: Cradled in a Locked Position for Transportation

Figure 4-3
External Fuel Box: Full Pivot to Allow 6 ft. Clearance to an Opening, Break-away Pivot With Check Valve, Wheeled Support

Natural Gas

The major concern with natural gas generators in the design process is the placement of the external piping on the ISO container. Regulators are best placed outside of the container. Interlocking of natural gas detection (sniffer) and the main gas valve adds an extra measure of safety. Gas venting shall be placed to atmosphere.

Container

"Every sound alarms."
—Virgil

While it may not seem like a major concern, the type of container that the generator is contained in is very important. For maximum versatility, the container needs to be designed to accommodate the functionality of the generator. ISO containers are preferred for a standardized means of transportation. These containers can be modified and cut to any specification for any purpose that the generator needs, such as external ports, exhaust holes or cooling fan ducts.

For purposes of lowering the profile of the final construction site, the container should be removable from the trailer. In order to achieve this requirement, locking mechanisms are necessary between the trailer and container. Opposing ground strap provisions are required between the container and the trailer and between the trailer and the ground mass.

Another point of interest, with regard to the container, is the consideration of internal temperature control. The container needs to be insulated and closed off from the outside environment in order to maintain operational temperature inside the unit.

Another purpose of the container is sound attenuation. This can be achieved by placing sound insulating materials around the inside of the container. Over the course of its projects, DTE Energy has learned, however, that the insulating materials tend to not be fireproof and thus should not be placed close to any internal diesel fuel containers. This was a requirement that the DEQ placed on all of our generators. To maximize the reduction in sound attained by the ISO container, a minimum number of penetrations should be made into the container.

A final issue regarding the container is the accessibility to maintain and replace major engine and alternator parts. The ISO container should have doors on all sides, except possibly the very front, in order to have easy access to all of the generators parts and compartments. This will save time and money if there is a major incident with the unit and large parts need to be replaced. Additionally, the top of the container should have a means for removal so that large engine parts can be lifted from the top with a crane.

Engine

"I put a new engine in my car, but forgot to take the old one out."
—Steven Wright

The type of engine that is needed is directly related to the type of fuel that will be used. As noted previously, there are three major types of fuel choices: diesel, natural gas, or blended. The diesel engine provides the greatest step loading capabilities combined with the smaller footprint per kW. Sound and exhaust emissions are a concern when choosing this package. Natural gas engines provide continuous duty capabilities with reduced sound and exhaust emissions. The evolving engine package of choice may be the blended fuel package. The blended fuel unit consists of a standard diesel package with an added bi-fuel unit. The bi-fuel unit blends in natural gas into the air intake of the diesel engine. The diesel throttles back on the usage of diesel fuel and the separate blended fuel unit supplements the needed horsepower requirements with natural gas. Blending is limited to less than 90% natural gas and 10 % diesel.

Alternator

One of the major considerations in the design process is to remember that space is at a premium when dealing with a mobile generator package. Every component must be contained in a small enough area that portability is maintained. With this in mind, alternator voltage should be limited to less than 5kV. Alternators come in different types and the right configuration is dependent upon the application. A choice that needs to be made is whether a Wye or Delta configuration best suits the need of the generator. Along the same lines, the alternator can be either grounded or ungrounded. Again, choose the type that best fits the project scope and budget.

Insulation requirements of the alternator may limit the design of the generator. With a higher voltage class, the greater demand on insulation, which increases the physical size of the alternator. The greatest power density is achieved by utilizing the 600 VAC class insulation. Consider purchasing an alternator at the application operating voltage against the standard 480VAC package.

Switchgear / Protection

One aspect of the generator design process that requires referencing company policy is the protection of the generator. DTE Energy requires protection in the form of visible break provisions. This manifests itself in several areas including rack-out breakers, potential transformer drawers, battery disconnects and current transformer fusing.

The rack-out breaker is the main breaker between the generator and the connection skid. This needs to have rack-out capabilities in order to allow for generator testing without connection to the grid. Some generator packages have the rack-out breaker standard with the package. However, most generators do not have this feature. For the purposes of DTE Energy, it became necessary to modify several generator packages to include this feature in order to comply with company standards.

Rack-out Breaker

If using a diesel storage tank internal to the container, separate the switchgear room from the tank with a bulkhead, to address flammability concerns.

Customer Interface

Create a customer interface box for all interconnections between the outside world and the generator. Segment the box into communication, protection, alarming and relay functions.

Figure 4-4
Square D Rack-out Breaker

Tagging Points

Visible breaks extend into all power sources for isolation (battery, house service, 480VAC buss and generator pots). An external tagging point box as shown in figure 4-5 adds a level of safety. An operating agent can create the visible break without entering the container.

Figure 4-5
Tagging Point Box: Shore Power Connection and Visible Breaks

Communication

Communications to the generator can utilize many paths (cell phone, satellite, cable and internal SCADA/RF networks). Site specifics and installation purpose help guide the communication choice. Real-time monitoring and operation require high reliability and redundancy. SCADA / RF networks combined with satellite communication can provide that redundancy. Availability of each communication technology and cost is a major factor when determining the best-fit combination.

Power Terminations

Cam-Lok connectors are ideal for the terminations between the step-up transformer and the generator. They offer an ease of installation (color coded per phase) and a time saver. Power cables can be challenging—21 power cables are needed for a 2000kW unit.

Control Scheme

Take consideration in determining the desired use of the generator. Include the future design schemes in the original purchase. The ability to start a generator package without use of distribution support is called Black Starting. If you wish to island (power a circuit solely from the generator package), Black Start is a desired feature. Other operating schemes include parallel to grid, voltage control load following and load following. Some enhanced features might include load shedding capabilities, sync and re-sync. Designing in common system protocols for communication and control is also a concern.

Connection Design

Connection Skid / Trailer Design

The connection skid converts the generator voltage (480VAC), to distribution voltages (4.8kV or 13.2kV for DTE Energy). In addition, the skid provides house service, communication, relaying, protection and metering. Note the use of utility accepted equipment. Utilizing the latest equipment will delay the acceptance of the equipment that the technicians are familiar with.

The design concept of the DTE Energy connection trailer and skid was as follows:

- The connection voltages were to be 480 volt to our two primary voltages, a 4.8 kV delta and a 13.2 kV multi-grounded Y.
- It should be dual voltage and easily switchable between voltages
- It should be removable from the trailer
- It should be transportable over the road
- It should accommodate either overhead or underground connection
- It should be easy to maintain
- It should use stock components wherever possible
- It should be designed for electrical and physical clearances
- It should use meter grade CTs
- It should be capable of providing house service

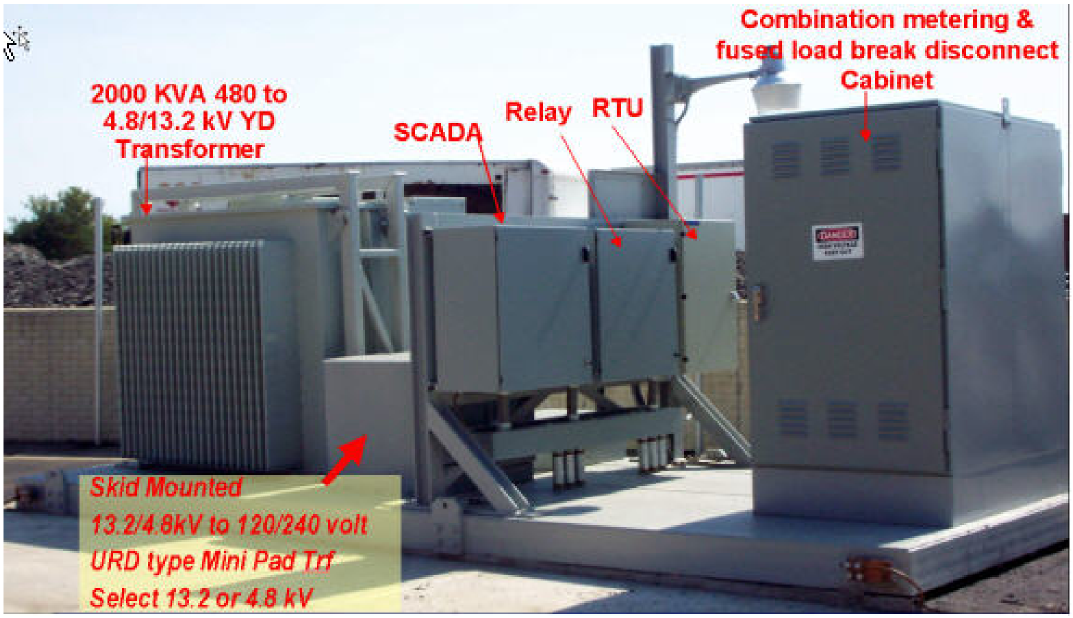


Figure 4-6
Skid: Component Layout

Typical applications utilizing the skid allow switching from 4.8kV to 13.2kV within 4 switch / jumper movements as illustrated below:

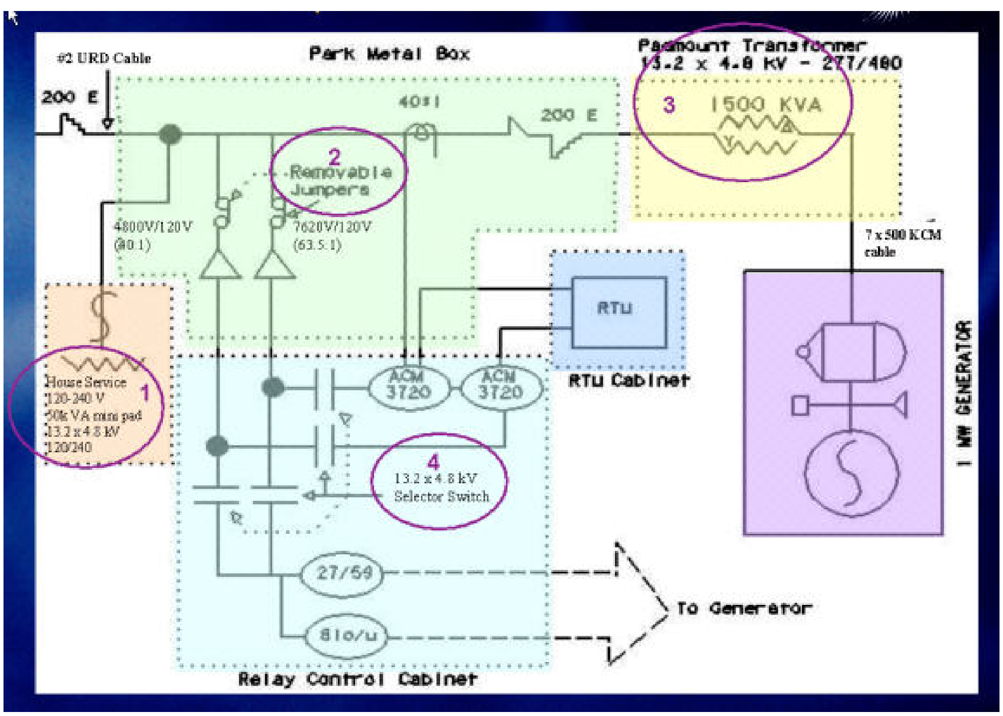


Figure 4-7
Skid: Electrical One-Line Drawing With Selector / Jumper Provisions

Figure 4-8
Skid: Dual Voltage House Service Transformer

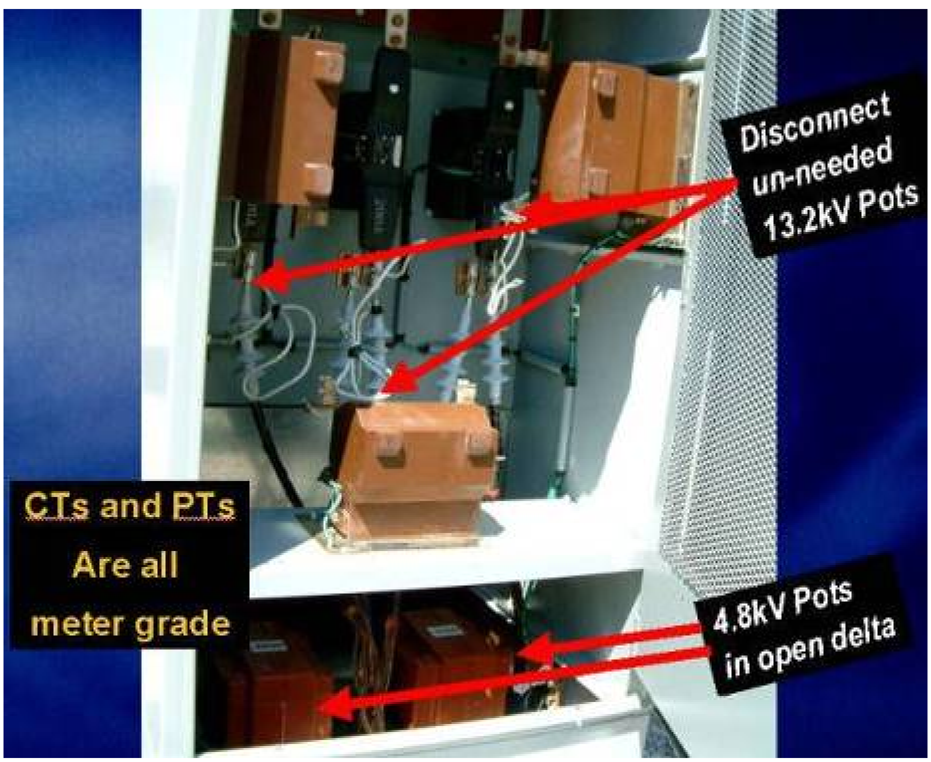


Figure 4-9
Skid: Fused Disconnect and Metering Cabinet (13.2kV and 4.8kV CTs and PTs)

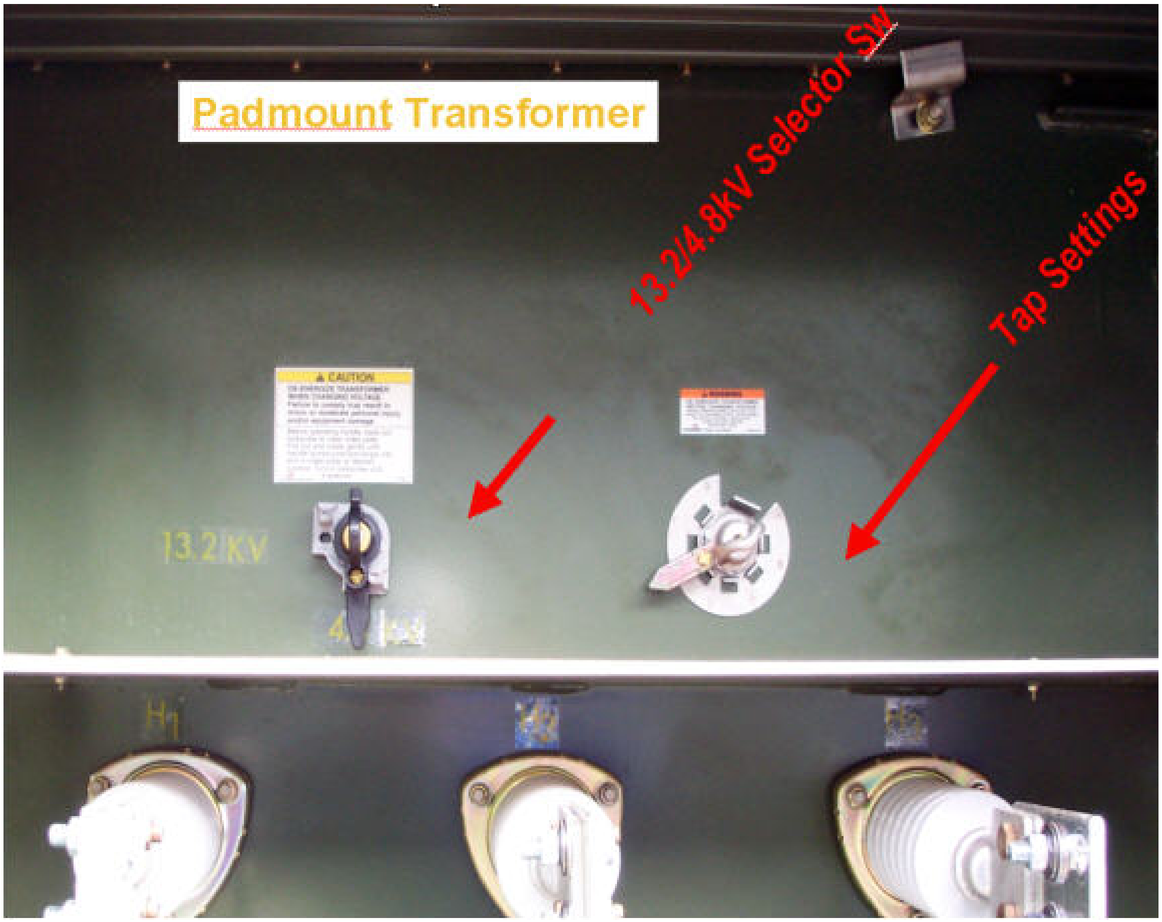


Figure 4-10
Skid: Padmount Primary Transformer With Selectable Voltage and Tap

Voltage taps allow for +10% / -5% on the 4.8kV distribution system and +3.6% / -1.8% on the 13.2kV distribution system. Transformer size is 1000kVA or 2000kVA. (See Figure 4-10.) Purchased transformers could benefit by the addition of cooling fans (25% overload).

DTE Energy's typical dual voltage transformer fixed taps are normally only brought out on the 13.2kV voltage. The generator transformers were purchased with 4.8kV taps put in for less than $200 per tap.

Figure 4-11
Skid: Metering Voltage Selection

Figure 4-12
Skid: Relay Voltage Selection

Additional features include: Metered house service, Safety Switch to allow alternate feed for house service power and a 120/240 Square D circuit panel. An RTU communication cabinet is also available to allow remote communications and control.

The skid and trailer setup was designed to allow rapid deployment and installation of the mobile generation package. It allows an overhead connection to the distribution grid as well as on-board storage for the required interconnection cables.

Figure 4-13
Interconnection Trailer for 4.8 kV and 13.2 kV Distribution Support

Future Generation Package Design

Consider combining all of the best features of the present production generator packages with the knowledge learned utilizing the skid and trailer combination. Also, what if you could get the air emission benefits of a natural gas engine but the step load capabilities of a diesel engine? The next generation package is "fuel to grid" in one box. A 1500 kW diesel genset with an output voltage of 4.8 kV is joined with a bi-fuel unit capable of running greater than 80% natural gas / 20% diesel fuel. This greatly reduces the needed storage capacity for diesel fuel on sites that have access to natural gas. All the internal gear is rated at 5 kV and has the required visible breaks. Connection to the distribution grid is accomplished through an underground connection point or an overhead connection point utilizing a jacketed three-phase conductor. Tagging points and customer interface are integrated into this package.

Monitoring and Control: Communication Path

Many means are available to communicate with a remotely monitored and controlled generator and skid package. Each has unique characteristics, which will result in the best possible communication path for the desired application.

Radio: Provides a wireless means of communication. Unidirectional is available for short distances, but directional is available for longer distances. Directional radio requires line of sight between the antennas.

Satellite: Provides a wireless means of communication. Available for long distant communication where line-of-sight may not be available for radio. Signal bounce times prohibit real-time data and/or control. The Web (Internet) is used to retrieve / send the data and control.

Cell Phone: Provides a wireless means of communication. Available for areas that maintain a consistent cell signal strength. Provides an economical means to establish near real-time data and/or control.

Cable: Where available, cable provides a real-time link for data and/or control. Installation and isolation are required, coordinated with the cable provider.

Telephone: Where available, telephone provides a real-time link for data and/or control. Installation and isolation are required. Service lead times and line clarity must be verified when selecting this technology.

Communications – Fiber and Hardwire

Communication and control isn't complete without the required equipment. SCADA monitoring of generator status, electronic meter providing metering data and RTUs to get the data and control out / in. Each component should be selected for ease of integration into the utility network.

Monitoring & Control – Circuit Data

SCADA monitoring isn't complete without the circuit data. How does one get access to a distribution circuit when the loading doesn't allow a bus shutdown for access to the current transformers of the circuit? One should use what is already available by using the existing current transformer test jacks and a portable electronic meter. Circle charts typically utilize only one phase for measurement. The portable electronic meter utilizes the data of the remaining phases.

If you are fortunate enough to have remote monitoring of distribution loading available, the portable electronic meter can be eliminated. Integration of existing data faces the challenges of data capability, update frequency and accessibility.

Monitoring & Control via Internet

The Internet allows complete access to a remote distributed generator. Using the appropriate equipment allows access to site alarms, health monitoring, fuel usage, breaker positions, site security, heat exchangers and chillers.

A selected vendor can provide 24-hour coverage to monitor sites and report directly to a utility operations contact. This coverage allows a second unique path of communication.

Speed of data transfer can be a limiting element. Internet updates and signal bounce times can take minutes. Internet operation is preferred as a backup means to communicate unless a hard-wire transfer trip scheme is utilized.

5
SITING AND APPROVAL PROCESS

"For every problem, there is one solution which is simple, neat and wrong."
— H. L. Mencken

Chapter Organization

This chapter describes the siting and approval process, including locating appropriate sites, securing customer approvals, building community partnerships and environmental permitting.

Introduction

A key aspect of the DER process is for the utility to build good relationships with various community members such as municipalities, environmental agencies and customers. DTE Energy has partnered with schools and churches in the site selection process. Typically, schools and churches can be found in densely populated areas that may have temperature-sensitive short duration load problems. These organizations typically have enough available land to enable the DER to be *out of sight and sound* of neighbors. In addition, making a monetary land lease payment to these community-based entities is what a good corporate citizen might do anyway. DTE Energy found after siting its first DER at a school that the school officials became allies and helped in other DER sitings. Convincing a community's planning board that the project is only a temporary fix, that steps are being taken to minimize the impact to the neighbors and that all other alternatives are exhausted goes a long way to securing their approval. Similarly, the state Department of Environmental Quality (DEQ) and other environmental agencies have specific requirements that need to be met. Making the DEQ a partner instead of an adversary goes along way to making the next DER project easier.

DTE Energy has produced an informative video to introduce customers to DER. The video explains DER concepts and provides an overview of the company's DER installation procedures. The video is available The video is available by contacting Haukur Asgeirsson, Supervising Engineer – Distributed Resource Planning, 313-235-9371, asgeirssonh@dteenergy.com.

Approval Process Overview

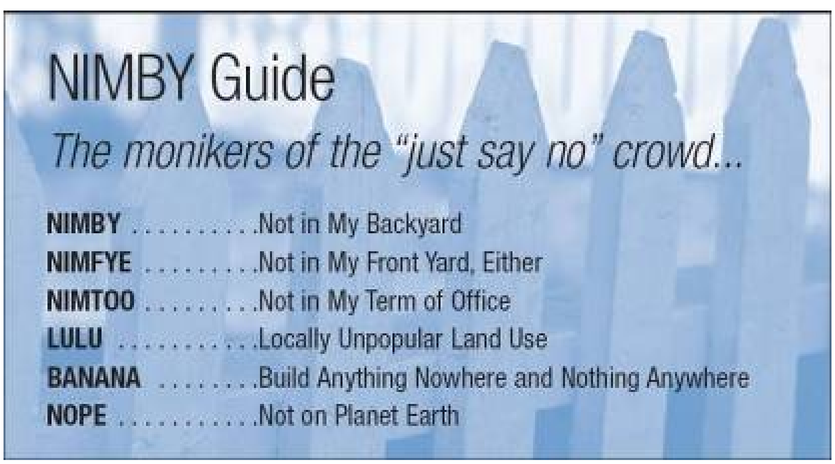
One of the most complex and frustrating aspects of a generator project is the approval and permitting process. If pursued in a haphazard manner, the approval process can lead to delays in the project and cost over runs. Thus, it is essential to know what is required for the installation of a generator. This chapter will give an outline of the permitting processes that generally apply to all generator projects. However, every project is unique and no single process can cover all potential aspects of a future project. The key then is to determine what is essential and to pursue it in the most simple and direct manner. What works for one project may be completely wrong for another. This chapter will try to help guide you through the often-confusing path toward an approved and permitted project. This chapter is broken up into two halves, the first dealing with Community Approval and the second with Environmental Permitting.

Community Approval

"Once you hear the details of victory, it is hard to distinguish it from a defeat."
—Jean-Paul Sartre

Overview

One of the most difficult aspects of a distributed generator project is obtaining community approval. Your path may be blocked by the **N**ot-**I**n-**M**y-**B**ack-**Y**ard crowd. It is a very powerful lobby when it comes time to seek the approval of a township supervisor or a community planning board. The elected officials must be cognizant of their constituency's wishes and this complicates the job of a project engineer. This is especially true when attempting to site a distributed generation unit. To the communities' residents, this is something new, mysterious and, to them, potentially dangerous. The job of the project engineer is to educate the public about this new technology and show them that it is a safe, clean and reliable piece of electrical equipment. It can be a long, difficult process to obtain community approval. So much so, that after you get approval you may feel you have been defeated in some way. However, perseverance, attention to details and compromising with the community are the keys to success. But before we even make it into the door of the township or city hall, we must first select an appropriate site.



Finding the Appropriate Site

"A person who never made a mistake never tried anything new."
--- Albert Einstein

There are many things to consider when attempting to place a distributed generator on a circuit for load relief. Should the utility lease land for the generator or place it on already owned property? If using a natural gas generator, is there access to natural gas at the site? How far away are the nearest neighbors? Is there room for the footprint of the generator on the site? These are all valid questions that need to be answered before deciding upon a location.

Substation or Customer Property

The first question that must be answered when deciding upon a location for the distributed generator is whether to place it at a substation or a customer site. There are many advantages and disadvantages attached to both options. By placing the unit inside of the substation, the utility avoids having to pay any kind of lease to a customer. You also do not have restrictions placed on you from an external source, such as fencing, security of the site or construction of an access road to the generator. Another advantage of placing the generator at a substation is that the property is already zoned for utility use and this helps out later when seeking planning board approval from the community. Placing the generator at the substation guarantees unfettered access to equipment. However, this ties in with a potential disadvantage. If the unit is placed in the substation, a substation operator must be present to access your equipment. The substation operator will be the operating authority over the equipment. This may be a tedious arrangement to be forced to have an operator at the location for every site visit regardless of how minor it may be. However, the major disadvantage of placing the generator inside the substation fence is that in most instances, the utility may not be allowed to use contract electricians to perform the work (based on contractual agreements). This is counter to the original purpose of the generator. In most instances, one of the deciding factors in using a distributed generator was that company resources did not have time to complete an upgrade to the substation, which would alleviate the overload situation. A solution intended to free up company resources in actuality still uses up their time. In addition, there are generally more rules and regulations that must be followed whenever one constructs anything inside the substation fence. Everything must be done to substation standards and this may increase the costs of the project. Also, if the object is to relieve a circuit exit cable, it maybe difficult to connect to the circuit beyond the cable.

Placing the generator on customer property is another option in a project engineer's arsenal. One distinct advantage of using customer property is the freedom to place the unit wherever one wants and not be tied to a singular substation location. This allows one to maximize the benefit of the DER. By running load analysis, one can find an optimum location on the circuit where an injection of generation will most affect the overload problem. This is typically at the end of the circuit where there is less voltage and poorer reliability. By placing the unit on a customer location, one is free to place it where it will have minimal impact on the residents of a community. Many sites can obscure the unit in both sight and sound. Whereas a substation is a fairly open property, a customer location may have large berms, trees or buildings that hide the generator from the public. Large customer locations such as medical facilities, industrial customers, municipal yards, schools and churches allow for deeper setbacks of the generator. There are distinct disadvantages of using a customer location as well. One obvious hurdle is that most cases involve working out a lease agreement to use the property. This increases the cost of the project since very few customers will accept a large piece of equipment onto their property without a monetary incentive. A fair lease agreement should only take into consideration the footprint of land that the generator occupies. A typical lease in the Detroit area is around $1000 a month for the approximately 55’ x 30’ generator footprint. Finally, fencing and security of the site may increase the cost of a project when using a customer location. Whereas a substation has already in place fencing and security, a customer location does not. The type and size of the fence is a detail that must be worked out with the property owner. Some locations have built-in security or do not require any additional measures; however, this is a place where one may run into unforeseen costs.

Figure 5-1
Example of DER Inside of a Substation

Figure 5-2
Example of DER at a Customer Location (Church)

Access to Natural Gas

One other major consideration when selecting a site is whether or not there is easy access to natural gas. Obviously, this is only important if you are using a natural gas generator, however there are other considerations we will talk about for diesel generators as well. Many utilities today are diversified utilities in that they have both an electric and natural gas side of the business. In your quest to determine the location of natural gas in the area, it could also be prudent to determine if your company's natural gas lines run through any part of the circuit. This could influence where you place a DER for overload relief. Another consideration is to determine if there is adequate gas pressure in the area. Some units, like micro-turbines, may need transmission-level gas pressure and thus cannot be placed just anywhere on a circuit.

Protection Related Concerns

It is a practical reality that the DER Planning Engineer at DTE Energy usually seeks the advice of the protection engineer as part of the site selection process. In this way, the protection engineer is guiding the potential site selection process by steering it toward a site that is easier to equip with the necessary inter-tie protection. The protection portion of the DER project which was discussed at length in Chapter 3 involves all the necessary changes that need to be made to the relays, reclosers, fuses and other protection devices on the distribution circuit. These devices play a role in the ultimate selection of a DER site. The selectivity and sensitivity of the protection on a given distribution circuit will hinder the placement of the DER in certain parts of the circuit.

Location of Wetlands and Endangered Species

A consideration specific to diesel generators is the location of nearby wetlands or endangered species on the potential location. While this will be covered in more detail in the Environmental Permitting section, it is something that needs to be considered early on in the siting process. In general, it is always good to avoid properties with wetlands or endangered species due to the possibility of contamination from a spill or leak of diesel fuel. In most instances, the community siting board or the state's Department of Environmental Quality (DEQ) will not permit placing the generator on these locations at all or only after expensive wetland mitigation.

Being a Good Corporate Citizen

Another consideration when placing a generator is finding a location where the utility can be viewed as a good corporate citizen. This means that if the utility is going to place the generator on a customer location and pay the property owner a lease, it makes sense to find a property owner that serves some public good. Schools, hospitals, churches, municipal yards and other such customers that serve the greater public are all customers who could use money from leasing a part of their property. These types of properties look better in the eyes of a township or city planning board than land leased from a private business or resident. As such, there is a greater chance of success in the permitting process by siting the generation on properties that have a public benefit.

The Presentation to the Community

"Divide each difficulty into as many parts as is feasible and necessary to resolve it."
--- Rene Descartes

The presentation to the community is one of the crucial processes in the distributed generation project. It can make or break any project. It can place unnecessary delays or cost over runs on a project. Therefore, it is important to go into the meeting prepared with a convincing and non-threatening presentation. Having the answers to all of the communities' questions in advance will make for a smooth permitting process.

Defining Terms

One of the first things to consider before going in front of the community with a proposal is what exactly the utility is asking for. In the world of Distributed Generation, there are basically three types of projects and it is critical to know which one to pursue.

The first type of project is the *emergency* distributed generator. This is defined as an immediate relief of an emergency problem using a portable generator or leased unit. This type of situation could be due to a storm, blackout, or other unplanned events. Most of the time in this situation one will not have any time to go through a full site plan review and community board approval process. These are projects that require special consideration when it comes to permitting from the community. Make sure the Community Affairs department understands the need for a quick approval in these situations and can communicate that to the communities in the area.

The next type of project is the *temporary* project. This type of project is defined as a project that lasts one to four years that provides relief of a problem using leased or purchased DER to return loading levels to within planning criteria. This type of project should also be given an abbreviated community approval process since it is an essential need and will not affect the community for a long period of time. This may mean asking the community for some relaxing of the requirements for filing the site plan or for a faster response than for a more permanent facility. However, expect to go through some community review since this is a more planned fix than an emergency project. Every community will have slightly different requirements and some will be more understanding than others.

The last type of DER project is the *permanent* DER project. This is defined as a project that will be used to provide relief of a problem that returns loading to below criteria for five years or more. When preparing to get community approval for a permanent project, expect to follow the exact requirements of the community. It will be similar to the conditions that must be met when petitioning the community for a substation expansion project.

Load Analysis

One of the key pieces of information that should be acquired before meeting with the community is load analysis of the circuit on which the utility intends to place the unit. This analysis will provide crucial details that will be valuable to utility personnel and the community. This includes probable run times, size of overload on circuit and number of run hours predicted for the summer peak. As shown in Figure 5-3, load analysis will also help in finding a location on the circuit that provides the most "bang for your buck", the spot or spots where an injection of generation will be the most beneficial.

Date	Time	Hours	Day	High Temp (°F)
7/1/2002	3pm - 9pm	6	Monday	95
7/2/2002	1pm - 10pm	9	Tuesday	96
7/3/2002	1pm - 9pm	8	Wednesday	97
7/4/2002	1pm - 7pm	6	Thursday	95
7/29/2002	3pm - 4pm	1	Monday	91
7/31/2002	3pm - 9pm	6	Wednesday	93
8/1/2002	1pm - 10pm	9	Thursday	92
	Total Hours	**45**	**Avg Temp**	**94.1**

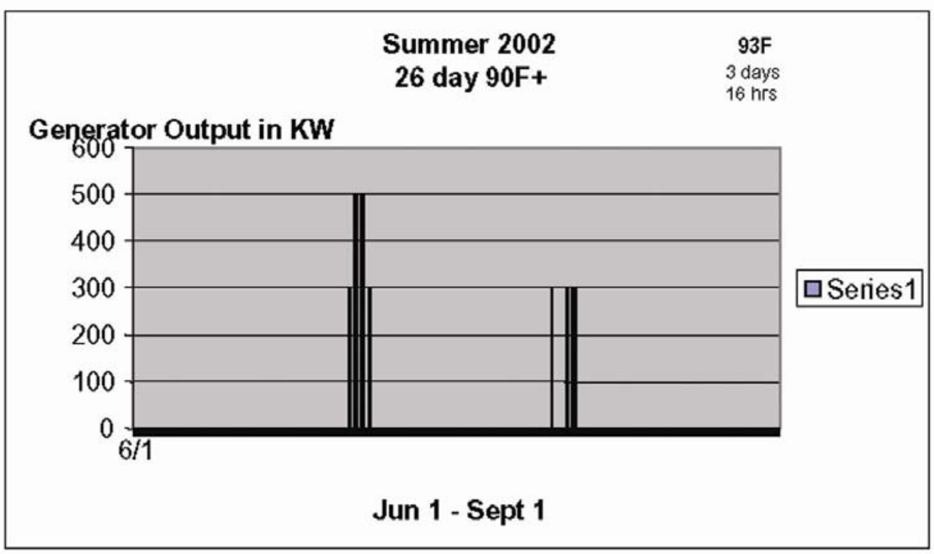


Figure 5-3
Load Analysis Provides Crucial Details

Fulfilling Community Requirements

Once it has been determined where to place the generator on the circuit and load analyses have been run to verify that it is an appropriate location, the next step in the permitting process is determining the requirements of the community. Some communities are extremely lenient when it comes to placing a DER on a circuit. They may waive all usual requirements such as site plans and maintenance agreements. A simple meeting with the township supervisor or mayor may suffice to get the project rolling. All that may be needed in these circumstances is a sketch of the project and some information on the units themselves. In these instances, a good tool to have would be a simple and direct video of the DER that shows the relative noise levels that are to be expected and the emissions of the units.

DTE Energy discusses with community leaders its obligation to serve its customers as defined by the state Public Service Commission. We share with other community leaders contact information and reasoning for waiving full planning review and granting us temporary variance. The basis for temporary variance is that electricity is an essential service enabling the community's board to waive full planning review of this temporary DER installation.

However, if it is planned to put a DER system in a residential or highly populated community, it is better to follow the letter of the law as it applies to new construction projects. It may be required to have a survey of the site with locations of trees clearly denoted, spot topography, uses and sizes of buildings on the property, metes and bounds of the property and many other things. A complete, professional site plan may be needed as well as an information package on the DER units. Things that they will be interested in are sizes, noise levels, emissions, security, lighting and the amount of traffic to the unit. Instead of presenting your case to the township supervisor, you may have to get siting board approval.

It is always good to involve the community leaders early on in the process. Offer them a list of other customers and communities that have been partnered with already. When the opportunity to present the case arises, make sure to stress that the DER is only needed a few hours a year, that it's for local use only and it will only be needed on hot summer days when everyone's air conditioners are running.

Sound Demonstration

One of the key issues that communities and neighbors have with DER system siting concerns sound. Above all else, they want to know whether the unit will be a sound nuisance to them when it is running. One way to alleviate their concerns is to perform a sound demonstration. Set up an amplifier calibrated to 74 db at 7 meters or set to however loud the unit happens to be. Bring a handheld dB meter to measure the sound and to provide a visible check that the sound level is as claimed. Have the neighbors stand on their property lines and turn on the amplifier. Ask them if they can hear the sound or if it is a huge nuisance. In most instances, if the chosen site has at least some separations and setback, their fears will be assuaged. It is also good to remember that noise decreases 6 dB as you double the distance from the source. So a noise that is 74 dB at 7 meters from the source will be just 55 dB at 56 meters from the source. Most communities have a noise level maximum dependant upon the time of day. Most fall within 65-

50 dB for daytime hours and 55-45 dB for nighttime hours. It is essential to pick a property that can meet these requirements or to set the unit back far enough to meet them.

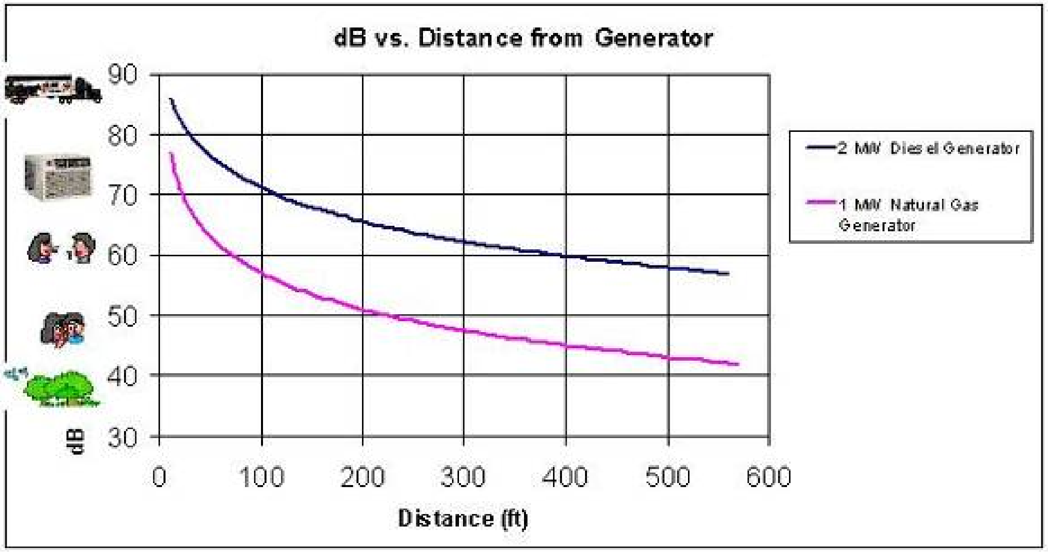


Figure 5-4
Sound Attenuation With Distance

Community Approval Summary

The community approval process is one of the most challenging tasks for a project engineer when trying to place a DER system on a circuit for load relief. However, there are several things that can be done to make the job a whole lot easier. The first thing would be to select an appropriate site for the DER, not only from the utility's standpoint, but also from the community's standpoint as well. This may mean setting the unit far enough back and with enough visible obstructions so that it does not intrude upon the aesthetics of the neighborhood. Obviously, it is also important to make sure the site meets the needs of the project itself. Once the site is picked out, it is crucial to be prepared to present the utility's case to the community. This manifests itself in several ways. One is the application process to the city or township. The next is a sound demonstration for the neighbors. Finally, before going into any meeting with a community representative, make sure to have run load analyses on the project and have all pertinent information to present. If one is prepared, the community approval process is not the daunting obstacle that it originally may appear to be.

Environmental and Fire Safety

"Don't find fault, find a remedy."
— Henry Ford

Overview

Now that community approval to put in the DER system has been obtained, one must also obtain environmental approval. This should be done in parallel with the community approval process. The environmental approval process is every bit as challenging as the community process. There are several permits that must be obtained in order to legally run a DER unit. These are dependant upon the type of fuel being used, whether it is natural gas or diesel. Not only that, but environmental approval can be site specific and more stringent requirements may be applied at different sites. Although approval from only one community is required, one may need to get environmental approval from several different agencies and for several different permits.

This subsection will discuss the various permits required for DER such as Air Permitting, Storage and Spill, Fire Protection, Wetland Mitigation and others.

Air Permitting

The air permit for a DER unit refers to the emissions permit that generally goes through the DEQ. While different states may have different criteria for the emissions of a generator, the general rule of thumb is that the sulfur content of the fuel must be less than 0.05% of the total content. This applies mostly to the diesel units but could also play a role in natural gas units as well. This is especially true if the heat rate of the unit exceeds a certain threshold. In Michigan, the threshold is such that a 1 MW natural gas unit falls just below the level that would require air permitting. A 2 MW diesel generator, however, falls within the parameters for DEQ to require an air permit. Since the heat rate of these units is higher, it is essential to purchase low sulfur diesel fuel. Not only that, the DEQ usually will require documentation on the sulfur content of the fuel from the fuel distributor. This can be shown in a batch sample report or could be done in a lab by doing one's own batch sample analysis. The issue with doing the analysis internally, in addition to the inconvenience of it, is that one must have documentation of the sulfur content before the generator can be run and in some cases, before the fuel can be accepted.

In addition to the sulfur content requirement, the Michigan DEQ has other requirements for generators and their emissions. Unless the unit is going into a rural area, the generator stacks must be at least 50 feet from the property line and 150 feet from residential or commercial establishments or places of public assembly. The stack must discharge vertically with a minimum height of 15 feet above ground level. Another limitation placed on generators in Michigan is that the total combined diesel fuel use must not exceed 136,000 gallons per 12 months. While not all of these requirements will be the same for every state or district, most of them will be enforced to some degree and extent. This is even true within the state of Michigan itself. The air permit is equipment specific and location specific. Each new piece of equipment requires a new set of data be submitted to the DEQ for approval of the unit. There are many different kinds, sizes and types of generators and in most cases each one will require its own submittal for approval. The location of the unit is also important. Obviously, the DEQ will have more stringent emissions requirements when placing a generator in a highly residential area than if you are placing it in a rural or industrial area.

Figure 5-5
Example of a Generator With Stack Extensions

A point to consider when going through the siting process is that in most instances, the DEQ will consider the DER as just an adder to the emissions of the site itself. So if there are already generators or sources of emissions on the site picked for the DER, the air permit for the site will be all inclusive. They may consider the entire site as one entity and one combined source of emissions. This may require going through more permitting than one would expect. This also is a good reason for seeking environmental permitting in parallel with the community approval and siting process.

Flammable and Combustible Permitting

"I think it's funny to be delicate with subjects that are explosive."
—Jerry Seinfeld

In addition to the emission or air permitting, the Michigan DEQ also requires a Flammable and Combustible permit for Distributed Generators. This permitting has many different facets. Ostensibly, the permit is to make sure that the equipment will not pose a danger to the community if there is a fire. It is understandable, but sometimes the requirements can be overbearing. In Michigan, the DEQ mainly focuses on the diesel generators. The natural gas generators do not require as extensive of an inspection as the diesels. The reason being is that the diesel generators require fuel storage on site and thus pose a greater danger. The Flammable and Combustible permit actually applies to the diesel fuel tanks themselves. And each tank that is used to fuel the generator is subject to the DEQ approval process. The easiest way to prevent headaches down the road is to only purchase pre-approved tanks and equipment. This may be difficult to do because what is approved for Flammable and Combustible in one state may not be in another, and even within a state the rules seem very nebulous and subject to change at a moment's notice. In general, states follow the National Fire Protection Association (NFPA) codes and standards.

One of the first considerations in the Flammable and Combustible process is the size of the tank being used. This is the key consideration because with some innovation, one can meet the requirements for the Flammable and Combustible permit. Most states will have a minimum storage capacity that will require a DEQ permit. In Michigan, this lower limit is 1,100 gallons. An interesting caveat, at least in this state, is that each tank is considered a separate entity and the permitting is for each tank. Designing a system that uses several 1,099 gallon tanks instead of one big diesel fuel tank may seem to be getting around the Flammable Permit, but it is working within the rules. But for the purposes of this discussion, consider the option of using one large tank for diesel fuel storage, or in the case of the following example, one large internal diesel tank and one large external diesel fuel tank.

The system that we will be discussing for Flammable and Combustible permitting had one 2,000 gallon internal tank and an external 6,000 gallon tank that provided fuel through a pump to the internal tank. This system was devised after considering the fact that the inside tank had only enough fuel to run for about 24 hours. On consecutive hot summer days, this would be somewhat impractical since a fuel tanker would have to be called out every other day to fill the tank. DTE Energy needed a system that would allow for at least a couple of days of operation and in most cases, the 8,000 gallons of fuel lasts all summer.

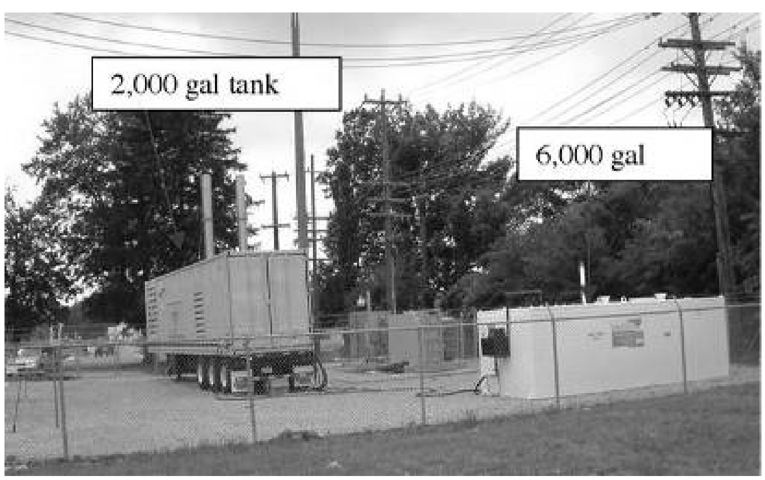


Figure 5-6
Internal and External Fuel Tanks

This set-up seemed to be very adequate to the needs of the site. That is until the DEQ performed an inspection of the site. Several deficiencies were found in the system as they pertained to the Flammable and Combustible rules. The first deficiency was that that the generator's insulation was not fireproof. The DEQ requires all insulation around the tanks to have a two-hour fire rating. It was the sound proofing insulation that was intended to muffle the sound of the engine. After being told that it could not be around the generator, DTE Energy had to hire an outside contractor to remove the insulation in order to meet the rules of the Flammable and Combustible permitting. This insulation, which was manufacturer installed, was then removed.

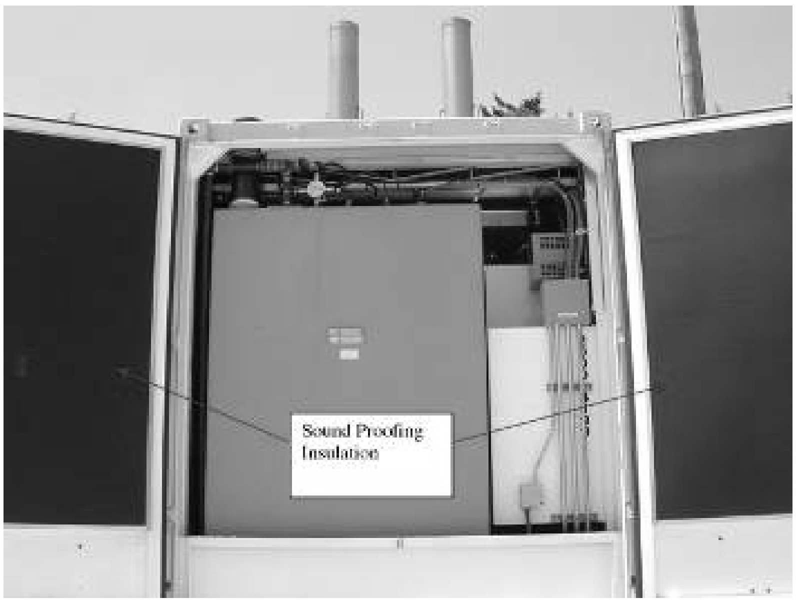


Figure 5-7
Sound-Proofing Insulation Did Not Meet Flammable and Combustible Rules

Another point of contention for the DEQ was the venting of the internal fuel tank. The DEQ required an external vent on the 2 MW diesel generator fuel tank. A hole was punched into the ceiling of the generator's shipping container and a new vent was installed to allow for the diesel fuel to vent to the outside in case of an emergency.

Figure 5-8
Installing External Vent on Generator Shipping Container

One of the major issues with DERs and diesel fuel containers is spill containment. The DEQ also has strict guidelines when it comes to fuel containment. The 2 MW diesel generator, used in the example, is equipped with a single walled fuel tank. According to the DEQ, this is not enough to meet the rules. However, the base of the shipping container has enough room for containment in the case of a fuel leak. The DEQ, however, would prefer a double-walled tank. That is why when purchasing an external fuel tank to complement the internal tank, a double-walled tank should be ordered. However, there are several monitoring features on the double-walled tank that the DEQ requires. One is the interstitial monitoring of the space between the tanks. This monitors for leaks in the inside tank and sounds an alarm when there is a breach. This is something that most fuel tank manufacturers can include in the package when the tank is being fabricated. The rules and monitoring devices required may be different depending upon which state or community the tank is being used.

Another requirement of the DEQ for the Flammable and Combustible permit is that the internal fuel tank inside the generator must be externally filled. This can either be done by using an external tank and a pump with both forward and reverse pumping capabilities, or with a portable fuel box connected to the generator. The Michigan DEQ does not allow the re-fueling operator to go inside the generator to fill the tank. In the example we have been discussing, the tank was filled using an external tank and pump system. In order to get Flammable and Combustible permitting for this setup several requirements had to be met. The first was that the piping from the two tanks had to be hard piped. Originally a flex hose was used, similar to a gas station’s fuel line. This was deemed unacceptable by the DEQ. They did allow for a small piece of flexible hose near where the piping connected with the generator to allow for some give when the generator starts and vibrates back and forth. However, this hose had to have a 2 hour fire rating.

In addition to this, the DEQ required that the tanks have 90% audible fill alarms and the external tank have a 95% automatic shut-off valve. The tanks also needed sight gauges so the operator at the site would know when to stop filling them by two different means.

Figure 5-9
Sight Gauge

Figure 5-10
External 6000 Gallon Double Wall Fireguard Tank

The second means to externally fill the diesel generators that would meet the Flammable and Combustible rules is an external fuel box. This can be constructed to have the audible overfill alarms and also a small containment area for spills within the box. The DEQ also allows for a small piece of flex piping near the connection to the generator, similar to the other example.

Figure 5-11
External Diesel Fill Box

Figure 5-12
Fill Box and Hard Piping to DER

Figure 5-13
Diesel Delivery

Another issue concerning the Flammable and Combustible Permit is to have the correct fire extinguishers on hand. If the generator is going to be stationed at one site for a long time, it is a good idea to attach an extinguisher to the outside of the shipping container, with clear indications and instructions.

One of the biggest points of contention is whether a generator in a shipping container is a Structure/Building or an Enclosure. Different rules apply depending on what you consider the generator housing to be. The DEQ will most likely try to categorize the shipping container as a Structure/Building. They define this as four walls or a roof or both. This is a very vague definition and leaves many questions unanswered. The requirements for a Structure/Building as it applies to the DEQ Flammable and Combustible permit are that only Class 1 Div 1 electrical equipment can be used, tanks over 660 gallons require a two hour fire rating, it must have secondary containment, the tank must be in a separate room from the engine, engine room must have one hour fire resistance rating and it must have adequate ventilation and automatic or self-closing fire doors or dampers. None of those requirements apply for an Enclosure. Obviously, it is crucial to get the local DEQ representatives to label the generators with the more utility-friendly Enclosure designation.

Wetland and Endangered Species Permitting

"When one tugs at a single thing in nature, he finds it attached to everything else in the universe."

—John Muir

One aspect of the environmental permitting process that can be easily overlooked is the Wetland Delineation and Endangered Species Permitting. However, if you get a certified specialist to determine that your potential site does not contain any wetlands, endangered species or other environmentally sensitive areas, then the approval process can go much more easily. Not only is this a state and federal requirement, doing the site inspections can fall under the category of being a good corporate citizen. Environmentally concerned neighbors and citizens will be less apt to challenge the construction of a DER installation if a little time is spent alleviating any of these concerns. When purchasing or leasing a site for placement of a DER, an environmental site assessment must be completed. The environmental site assessments are conducted by consultants who must follow the ASTM E1527 Phase 1 Environmental Assessment Standard. The ASTM 1527 Standard was written to be in agreement with the EPA's standards and practices for "All Appropriate Inquiry" as required by the Brownfields Revitalization Act.

Spill Prevention

One final environmental topic of discussion is the creation of a Spill Plan. This is something that is done in-house within the utility, working in conjunction with its environmental department. The Spill Plan for a distributed generator project is very similar to the plan one would devise for a new substation's transformer oil. It takes into consideration distances from sewers, drainage and other areas that could be contaminated. Also, the Spill Plan should have a basic topography of the land to determine where any spills will flow to. Most of the same concerns for the situation involving the transformer's oil spilling apply to the spilling of diesel fuel. The only additional consideration would be whether the diesel tank in question is double-walled or single-walled. If it is single-walled, a dike must be constructed around the tank. This can be done using earthen materials to construct a physical barrier around the tank. With a double-walled tank, no further protection is required.

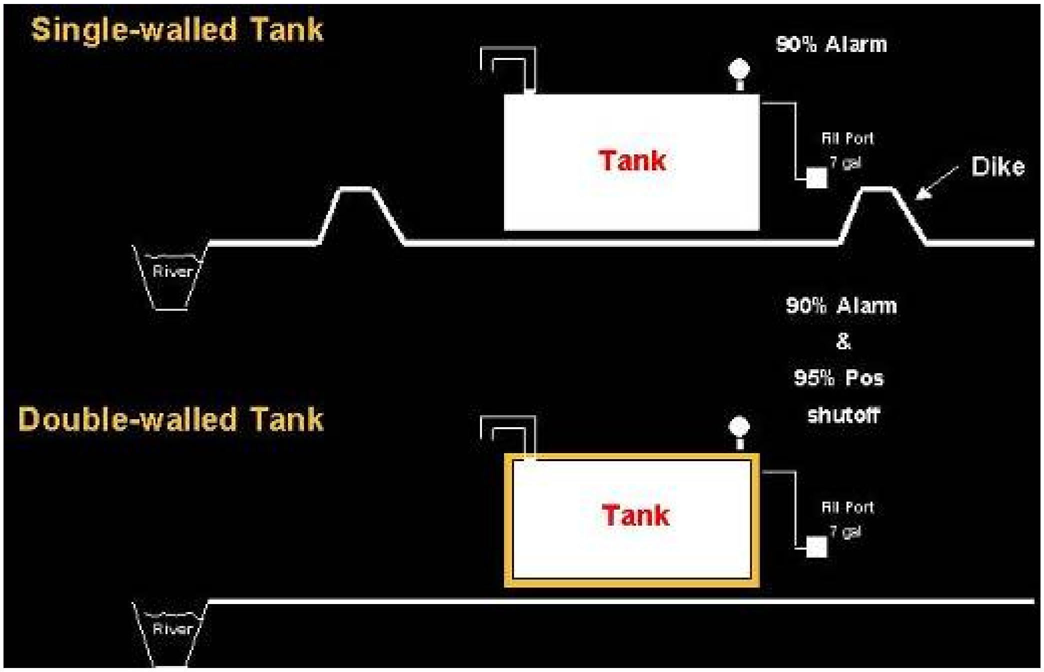


Figure 5-14
Single and Double-Walled Tanks

Environmental Permitting Summary

"In a mad world, only the mad are sane."
—Akira Kurosawa

While environmental permitting presents challenges, the process can be streamlined by knowing beforehand what to expect. It is essential to check with state and federal requirements as they pertain to air permitting, flammable and combustible permitting, wetland delineation and endangered species protection. Working in cooperation with the local DEQ representatives early on can result in smoother project. The main requirement for the air permit is the sulfur content of the diesel fuel to be used. Making sure to purchase the low sulfur fuel will be one way to demonstrate good intentions to the DEQ. The flammable and combustible permit is a little more complex and may require altering equipment to meet certain local standards. Being aware of wetlands and endangered species in the area can help alleviate the concerns of environmentally conscious residents. Finally, work with the utility's environmental department to devise an appropriate spill plan for the site. It will be similar to what is already done for new substations. If a utility follows these somewhat simple common sense guidelines, the environmental permitting can be effectively accomplished.

6
CONSTRUCTION AND IN-COMMISSIONING

"Genius is one per cent inspiration and ninety-nine per cent perspiration."
—Thomas Edison

Chapter Organization

This chapter describes construction of a DER installation including grounding, prep-work, overhead work, fencing and all other physical work involved in installing a generator. This chapter will also cover the in-commissioning sequence of the installation process.

Introduction

One of the key lessons DTE Energy has learned is to make effective use of manpower resources when undertaking a DER project. Remember, part of the reason for seeking the DER alternative is because the work cannot get done on time. Much of the utility work force may be unfamiliar with DER equipment. To make things easier, DTE Energy chose to standardize its design and, whenever possible, to use a construction contractor with generation experience. In addition, the DER group does most of the project management itself. The group did not want to use an already taxed distribution work force to design, project manage and construct this additional new and unfamiliar work.

Construction and in-Commissioning Overview

After all of the approvals and permits are acquired, it is time to start putting shovels in the ground. There are several steps involved in the actual construction phase of a project, however many of them should be familiar from the use of a portable substation and the construction of a traditional substation. The steps which will be discussed in this chapter cover things such as site prep-work, grounding, fencing, communication and overhead work. Each DER project is slightly different so this will serve as only a general set of guidelines for a typical installation. Other considerations and site work may be site specific and dependant upon the lease worked out with the customer, the terrain of the site or the limitations placed on you from the municipality. This chapter will finish up with a short reference guide for the in-commissioning of the DER. This part of the chapter will be heavily reliant upon the steps and procedures as they apply to the DTE Energy philosophy of in-commissioning and may be vastly different for other utilities or situations.

Construction

"I do not think there is any thrill that can go through the human heart like that felt by the inventor as he sees some creation of the brain unfolding to success. Such emotions make a man forget food, sleep, friends, love, everything."

—Nikola Tesla

The real essence of a DER project is the actual construction of the project. This process is filled with opportunities to perform real project management. There will undoubtedly be unexpected delays and problems that will crop up during this process. These delays will cause the usual headaches and may extend the timeframe of the project longer than expected. DTE Energy has tried to streamline this process as much as possible by developing a Checklist and Procedure Manual for the installation of a DER. This manual coupled with the experience gained from nine DER projects has cut the construction time down from several months to two weeks. This manual can be found at the end of this chapter. It outlines several of the major topics that will be discussed including prep-work, overhead work, fencing and others. In reality, this entire chapter is just an extension and elaboration of the manual into finer details.

The construction of a DER is dependant upon the type of DER that is required. For example, as discussed in the previous chapter, the installation can be permanent, temporary or emergency. The type of prep-work involved for a permanent installation is vastly greater than an emergency maintenance type of job. For clarity's sake, the chapter will try to seek the middle ground and will mostly describe the type of work involved in a temporary installation. However, special cases will also be touched upon.

Site Prep Work

Before any connections can be made and even before the generator can be delivered to the site, the site needs to be prepared. A good word to keep in mind is "temporary". A typical DER project is not intended to be there forever, so the site work need not be constructed to last an eternity. This means, for example, that conduits need not be placed in concrete even though the substation requirements may call for it.

Generally speaking, a contractor will be hired to do the entire construction of the site. One of the main reasons for installing a DER is that utility crews are tied up with other jobs and cannot complete the original project. However, the contractor must know what is required and therefore it is the project engineer's responsibility to relay this information to him. Having a good background in project management will greatly help this process.

One of the first things that must be done to the site is clearing it of brush and trees. This is, of course, dependant upon the location that has been chosen for the installation. An installation in a church parking lot will obviously require less prep work than an installation in a wooded area owned by a school. So assuming the wooded option is chosen, the first thing to do is to determine the placement of the generator and skid on the site. Pick a spot and configuration that will be the least intrusive with the least amount of prep-work involved. While discussed at length in the previous chapter, the site should avoid wetlands and provide the greatest visual and audio obstructions from the neighbors. The contractor will most likely have to bring in earth moving equipment and the site will have to be leveled. Utilize earthen berms to keep topsoil at the site and help to create a visual barrier for the installed site. Additionally, the contractor should provide a means for ingress and egress to the site. This should all have been laid out in the planning stages of the project. Soil compaction may be necessary to accommodate the weight of the DER, skid and crane (used for skid placement).

Figure 6-1
Example of Earthen Berm Made of Topsoil From the Site

Once the brush has been cleared and the soil has been leveled and compacted, some of the underground site work can be done. This includes putting in the conduit that will connect the skid to the generator. It becomes necessary to know the exact placement of the skid and generator so that these conduits can be laid exactly. Also, this is a good time to install the gas line going from the meter to the generator if you are using a natural gas generator. This will be discussed at length later on in this chapter. Another piece of prep-work that will be done at this stage is the underground feed going from the skid to the overhead buck-pole. Again, the overhead construction work will be discussed later in this chapter. It is generally a good idea to run the point of interconnection to the grid as an underground feed through a conduit up to a cable pole. This allows for more safety than trying to go the overhead from the skid to the pole route. However, DTE Energy does utilize an overhead connection on a portable connection trailer in emergency situations.

Figure 6-2
Underground Conduit for Connections Between Generator and Skid

The next step is that the site needs to have crushed stone laid over the generator footprint and the ingress and egress road. The depth of the crushed stone will vary from site to site depending on the compaction requirements, however a good minimum value would be four inches of crushed stone. This will prevent the generator and skid from sinking into the ground if the ground happens to be soft. The stone should allow for some room for the underground conduit to peak out. The extra length of conduit poking out from the ground will be helpful when trying to place the skid directly in place.

Placement of the Generator and Skid

"It's been a long way, but we're here."
—Alan B. Shepard Jr.

With the site prepped, the underground conduit laid and the crushed stone put down, it is now time for the generator and skid to arrive on site. The equipment should be moved to the site using a semi-truck for the generator and a flat-bed for the generator's connection skid. It is essential to have a 20-30 ton crane on site in order to place the skid in the exact location. Upon arrival of the equipment make sure to do a thorough inspection of it. Check and make sure that it is not damaged and that all parts are in place. After having the truck driver back the generator into the site, the use of treated planks may be necessary to assure the equipment is level and well supported. The use of chucks is required and wheel jacks are recommended for stability. Once the generator is in place, the skid can be lifted off the flat bed using the crane. It is important to have several contractors on site for this in order to line the skid up exactly with the underground conduit. If everything was measured correctly and laid out properly, the skid should slide into place over the conduit. Additionally, if the DER project is a diesel generator, a separate external fuel tank may be necessary for the site. With the crane on site, it would be advantageous to position this piece of equipment into place at this time as well.

Figure 6-3
Crane Moving External Fuel Tank Into Place

Natural Gas Pipeline Work

A step of the construction process that runs parallel with the rest of the site work is the installation of the natural gas line. Of course, this is dependant upon whether or not you are installing a natural gas generator. As mentioned previously, some of this work needs to be done before the crushed stone is laid down or it will just become more costly and complex. The best advice for the underground gas work is to be cognizant of the path of the generator placement, skid placement and crane staging points. The gas line should avoid having any heavy machinery over it and the ingress and egress path should not run over the top of it either. As far as the gas regulation goes, the local area natural gas supplier should be contacted and informed of the project in advance. They can help find the correct pressure and nearby gas mains that can be tapped for the new installation. Some generators require a very tight gas supply bandwidth, so look for a location for the generator that will have the adequate gas pressure. Otherwise, the need for several layers of gas regulators may be necessary and that can get very expensive and time consuming. In addition to the regulators, the local gas provider will need to install a gas meter for the site. Most of the time, they will request that the contractor on the project do all the gas piping from the generator right up to the meter. They may also ask that the metal support posts for the meter be provided from the contractor.

Figure 6-4
Example of Metal Support Posts for Natural Gas Meter

Figure 6-5
Example of a Natural Gas Meter for a 1 MW Generator

Installing Ground Mat

"Life is really simple, but we insist on making it complicated."
— Confucius

The installation of the ground mat is a step that could possibly be done before the crushed stone arrives at the site. However, DTE Energy has, at times, installed the ground mat later in the process. It all depends on the amount of trenching involved and the added cost of trenching through the already compacted stone. Every company has its own grounding specifications. When DTE Energy initially started doing DER projects, the grounding specifications were fairly minimal. They only required a single ring around the units and then two or three risers to each piece of equipment. The specs recently were altered to include more redundancy and a higher level of safety. Now, the specifications call for both a ring inside (a #1/0 perimeter ground loop) and a ring outside (a #4/0 perimeter ground loop) of the fence of the site. These rings are tied together. The equipment is bonded with three to four risers. The fence around the equipment is bonded at every corner and every connection point. The purpose of all the grounding is to obviously eliminate any touch potentials that may occur between the equipment and also between the equipment and an operator. Since the ground mat needs to be bonded to the corners of the fence, it is a good idea to have the fence boundaries marked off before the installation of the ground mat.

Figure 6-6
Example of Grounding Mat Tied to Fence Corner

Installing the Fence for the Site

Soon after the equipment arrives on site, the fence should be constructed to prevent any vandalism of the generator or skid. The need for a fence is determinate upon where the site is. If the generator is going inside a substation, presumably a fence will already be in place. Likewise, some very rural areas where site security is less of a concern may not require the fabrication of a fence. However, most applications that DTE Energy has used a DER for required a fence since the site was in a suburban or commercial area. The exact fencing requirements will be different for every site and should be coordinated with the local municipalities zoning requirements. Some towns and villages require barbed wire, some specifically ban it. Some cities require an eight foot fence, others a six foot fence. Also, the customer whose property the generator sits on may have their own preferences for the type of fence that they want on their property. Some customers may ask that green slating be used in the fence to shield the generator from sight. This is an added expense, but sometimes is necessary to close the deal with the customer in order to have use of their property for the placement of a generator.

Overhead Work

"Give me a lever long enough and a fulcrum on which to place it and I shall move the world."

—Archimedes

All generator projects require some overhead work, generally at least a connection to a cable pole. Dependant upon where on the distribution circuit the generator sits, other more intensive work may be required. Although covered in greater detail in the Relay and Protection chapter of this document, some of the overhead work involved deals with reclosers and sectionalizing devices. Coordinate with the relay department to determine if distribution circuit fuses need to be jumpered out, overhead reclosers need to be changed or have new settings applied or if capacitors or regulators on the circuit will interfere with the operation of the generator. All of these pieces of overhead equipment will alter the operation of the generator and in most cases overhead crews will be needed to make the appropriate adjustments to the devices. A good rule of thumb for these overhead devices is to only be concerned with equipment that is in between the generator and the substation breaker. Most devices "downstream" of the generator will have little to no effect on the operation of the generation. The only devices that may cause problems downstream of the site would be capacitors or bi-directional regulators since they operate in both the feed forward and backward paths. While all this work is site specific, the one constant in terms of overhead work is the connection to the cable pole. This can be done either through an underground connection or overhead from a connection trailer with overhead capabilities. In both instances, the service planner will be crucial in helping to design the appropriate connection and the necessary pole installations. Both the overhead and underground approaches will require a tagging point to the cable pole generally in the form of fusing. The fusing on the pole should coordinate with the generator equipment specifications.

Figure 6-7
Example of Fusing on Overhead Connection for Generator

Installing the Generator

Once the equipment is delivered to the site, the contractor can begin the process of installing the connections between the generator and connection skid. The connection skid, as discussed in the Design chapter of this document, contains the 480 V to either 4800 V or 13200 V transformer, the switchgear, the house service transformer, the relay cabinet, the SCADA cabinet and a fluorescent light. The connections made between the skid and generator will both provide house service to the generator and make the connections that ultimately provide power to the grid. While every site is different, DTE Energy has tried to make these cables and connections as secure and safe as possible. To this end, several different approaches have been tried to shield the cable from the outside world but also provide easy access and ease of installation. One technique was to use a metal cable tray. This provided ease of installation and removal. It also was re-usable and was easily stored with the connection trailer.

Figure 6-8
Example of Cable Tray for Interconnections

This technique was good for a site that was out of the way and more secluded. However, when we put a generator on school property like at the Milford site, the cable tray would not be so practical. We did not want children who may climb the fence to be exposed to any kind of risk at all. At this location, we devised a standing doghouse type design. It shielded the cables from any trespasser to the extent that someone would need to jump the fence with tools in hand in order to cause themselves any harm. The standing doghouse also shielded the cables better from the weather and animal intrusions.

Figure 6-9
Example of Standing Doghouse for Interconnection Cables

The type of cable used by DTE Energy in most cases is 500MCM superflex covered conductor. This provides enough flexibility to wrap around whatever conduit system is developed.

Miscellaneous Work at Site

One other piece of work to consider during the construction phase is the type of security for the site. At DTE Energy, we have used two different sets of locking schemes. When the generator is on substation property, it falls under the jurisdiction of our substation operators. For these projects, substation locks are used and only the substation operators can give anyone access to the site. The tagging schemes used on the generator conform to the Union Rules for tagging. At customer sites, the operating authority is our Primary Customer Service personnel. At these sites, the universal Core 50 locks are used. These locks are accessible by a wider range of personnel and allow for easier access in case of emergency maintenance. The tag-out procedure at this type of site relies on the Primary Service representative to provide adequate tagging.

Relay work should mostly be done by the time the equipment is delivered to the site. The o/u voltage and o/u frequency relays are installed on the connection skid in the shop during the fabrication stage. The only thing that needs to be done physically to the relays at the construction stage would be to physically set the relay settings to the appropriate setting as described by the relay department.

Similarly, most of the installation of SCADA equipment should be in place and ready to go from the fabrication stage. A SCADA tech will be needed to install any site specific equipment and to make sure that the SCADA is communicating and functional.

Communication work may involve placing a communication pole at the site for radio antennas. Or it may be that the site can use satellite technology to communicate with the Operations Center. Or maybe a cell phone technology might be used to achieve this function. DTE Energy has employed all of these techniques and more. Make sure to work closely with the communications department to work out a system that will be the most cost efficient while also serving the needs of the DER project. The communications aspect of the DER project is sometimes the most time consuming and can delay the project. In addition, it is prudent to involve the communications department in the project very early on.

Figure 6-10
Example of Satellite Technology Being Used for Communications Path

In-Commissioning of Generator

"Action is the foundational key to all success."
—Pablo Picasso

Once all the physical work is completed at the site, the generator needs to be in-commissioned. This process generally will take about a day and will utilize the capacities of several departments. The main players in the in-commissioning sequence are the operating authority (either substation operator or Primary Service representative), Operations Center personnel, contractor or utility crew, field operator (equipment tester), overhead crew and a technician familiar with the generator equipment.

The first step in the in-commissioning sequence is to check both the high voltage and low voltage cables. All the equipment should be meggered and verified by a field operator. The fusing on the pole can be connected only after these tests are performed and by making sure that the load break switch on the skid is open.

The next big step is checking to make sure that the equipment is set into the correct voltage class. The skids developed by DTE Energy have functionality in both the 4.8 kV and 13.2 kV voltage classes. All equipment must be set correctly before proceeding. This means that the voltage transformer jumpers for the unused voltage class are removed. The 2000 kVA transformer is on the correct taps. The pad-mount house service transformer connections are set correctly. The voltage selector switch inside the relay panel is set for the correct voltage class. During these checks, it would also be prudent to check that the correct fuses are in place in the switch cabinet and to make sure that the switch is in the open position.

After all these checks are made, the personnel at the site need to call the Operations Center to get permission to energize the equipment. This is done to inform them of the new load that will be added to the grid and that will show up on their monitors. If there is a condition on the circuit that prevents turning on the generator at that time, the Operations Center should inform the on-site personnel. The major issue would be that the circuit load is too low and the generator load will exceed the 4:1 ratio that is needed to ensure transfer trip of the generator in case of the loss of the circuit.

After permission is acquired from the Operations Center, the overhead crew can energize the cable from the cable pole to the load break switch. This is done by pushing the fuses hanging from the fuse carriers on the pole into place. At this time voltages should be checked at the electric power meter to insure proper functionality. It is important to make sure that the generator breaker is open before this process is done. If it is closed, there remains a possibility of damaging the expensive generator equipment.

The next step, after the voltages have been checked at the electric power meter, is to energize the transformer on the skid by closing the load break switch. After this is done, check the voltages on the transformer secondary. Now would be a good time to check the rotation at the transformer to insure that it will be the same when the generator is running. Make note of the rotation at this time.

The next step is to open the load break switch again, thus de-energizing the transformer and cables to the generator. Now start the generator up. After the generator is running, close the generator breaker so that it back feeds the transformer all the way back to the open load break switch. Check the rotation at the same place that the previous rotation check was performed. Make sure that the two rotation readings match. Turn off the generator at this time.

Once all checks are verified, the generator can synchronize with the circuit load. Close the load break switch again. Turn the generator back on with the generator breaker in the closed position. The generator should come up to speed and synchronize with the grid if all checks were performed correctly.

When the generator is synchronized to the grid, relay checks can be performed to ensure that the generator will trip off-line during over/under voltage and frequency conditions. Have the technician send trip signals from the relays to the generator and verify that the relays function as intended.

Removal and Site Restoration

"A thing is right when it tends to preserve the integrity, stability and beauty of the biotic community. It is wrong when it tends otherwise."

— Aldo Leopold

After the DER project has ended, it is crucial to have a strategy to remove and restore the site to its original state or a state deemed acceptable by the property owner. The equipment must be disconnected and moved from the site. The fencing must be taken down. The crushed stone must either be removed or left for the property owner at his request. All this work takes time and money, however it is crucial to know what can be reused. Finding ways to re-use the material on the site will the lower cost on future DER projects.

Removal of Equipment

Taking apart the DER site will require the use of either a contractor or a utility crew. The site needs to be de-energized before any removal of equipment. This means de-commissioning the site. This can be as simple as making a phone call to the Operations Center and submitting a de-commissioning report so that the generator can be scratched from any operating maps. Once de-commissioned, it is crucial that the removed equipment be either sent to salvage or reused on a new DER Site. Most of the cables, cable trays, doghouses, satellite and other equipment can be stored with the generator and skid and used again. The grounding mat and gas piping, however, should be sent to salvage. Finding a location to store the equipment is crucial too. The worst feeling is bringing a generator out to a site only to find out that the batteries are dead because someone failed to find an appropriate storage location where the batteries can be charged. Most service centers are good places to store the unit. They have large areas of land and most of them will have the capability to charge the generator batteries. Another potential overlooked item is the removal of any exhaust pipe extensions before removal of the unit from the site. A big, costly mistake like that could lead to the stacks hitting an overpass and damaging the equipment. The rain caps that came with the generator should have been stored on site and re-attached when the unit is moved. The stacks should be moved and stored with the rest of the reusable generator equipment. The fencing around the generator can also be removed and reused, especially if the fencing required expensive slating. This is something that should not be thrown away.

Site Restoration

Once the equipment is removed, it is time to restore the site to its pre-generator conditions. All installed poles should be removed including the guy wires. The crushed stone should be removed unless the property owner requests the stone be left for site development. It is usually a lot more expensive to remove the stone than any salvage value that can be obtained from the stone.

However, if the crushed gravel must be removed, taking it to a nearby substation would be beneficial for salvage. All the conduit and grounding should be removed and disposed of at this time. The site should be leveled and any topsoil berms should be spread out to return the sediment to its original location. The site should be reseeded upon the request of the property owner as well. Being a good corporate citizen by being cognizant of the property owners wishes will help maintain a valuable reference for any future DER projects.

Checklist and Procedure for Installing a DER

<u>Find property</u>

Locate several properties that may work

- ☐ Commercial property
- ☐ Government property
- ☐ School property

Make sure that gas is available

<u>Acquire Lease with property owners</u>

Work out special conditions of lease

- ☐ Determine if trees are needed for visual and audio blocking
- ☐ Determine the type of ingress and egress road to the site
- ☐ Determine if a fence is needed and the type (barbed wire, chain link, etc)
- ☐ Determine if slating is needed for fence to act as visual blocking and to impede climbing of the fence
- ☐ Make sure to provide a sound demo for the property owner to show the level of noise to expect (if necessary)

Acquire Lease payments from PDO Organization

- ☐ Determine if payments will be annual or lump-sum
- ☐ Make sure Accounts Payable cuts the check and sends it out

<u>Acquire all necessary permits</u>

Environmental Permits

- ☐ Air Permitting
- ☐ Spill Prevention
- ☐ Fire Permitting

- Wetland and Endangered Species Permitting

Municipal Permits

- Make sure Ingress/Egress Permit is obtained if site has entrance off county road (2 - 5 week time frame)
- Make sure you acquire curb-cut permit if a curb on a city street will be cut
- Make sure you acquire appropriate variance/permit/agreement with city or township

Any Other Permits

- Tree Removal Permit

<u>Hire contractor</u>

<u>Preliminary Engineering Work</u>

SOP

- Denote the procedures for manual/automated/automatic modes of operation of generator

EI Sketch

- Distribute EI sketch to PDP, Operating, Relay, Substation Proj., Regional Planning, Project Management, Primary Services, Arch/Civ/Towers and Pre-Arrangements
- Collect comments and signatures from various groups (1month)
- Distribute Final EI sketch to all the appropriate recipients

Unique set of prints for skid and generator located

- Make sure the set of prints has their own unique drawing number.
- Every time a new skid is constructed, it must have its own unique number and set of prints attached to it.
- If prints came from previous site, make sure that they are the latest, marked-up prints and they are submitted to Relay and PERT at the time of issuing the RFW.

<u>Construction</u>

Grounding

- Make sure Grounding meets with new specs (Drawing # 6E6000-84 or contact grounding engineer)
- Make sure PERT sends out a tech to check grounding connections and perform meggering and various tests on the grounding configuration (1 -2 days)
- Have PERT tech submit a completion report to Equip Performance Engineer.

- This completion report will be then sent in a package with the other reports to the Primary Service Representative.

Relay

- Make sure relay settings are appropriate to trip out generator on over/under voltage and over/under frequency
- Make sure wiring of skid is clearly marked with x-y-z stickers on appropriate wires

SCADA

- Make sure all necessary connections are made to maintain communication with substation so that 4 to1 ratio is met for the generation load

Communication

- Make sure satellite dish is aligned properly
- Make sure all hardware will be able to talk to each other (modbus, dnp, etc.)
- Make sure all paths of communications are set up

Generator Work

- Make sure the appropriate CTs and PTs are used and that both voltage classes are present
- Make sure connections into generator have a secure, enclosed box around them to ensure safety

Overhead Work

- Find appropriate pole to tie into the circuit from generator site
- Determine any sectionalizing devices that need to be jumpered out or replaced
- Order poles, sectionalizing equipment and any other material needed for work
- Make sure underground connection coming from the skid is on the appropriate side of the cable pole
- Coordinate antenna installation with pole work

Civil Work

- Install fence to the appropriate specs of the city or township in which the generator is in.
- Install road for ingress/egress using appropriate gravel and to appropriate depth in order not to sink the generator into soft ground. Min of 6” per substation design spec.

Natural Gas Work

- Make sure the appropriate pressure is set at the site (2.0- 1.5 psi at the gen)

- Determine if second regulator will be needed at the generator itself

<u>Incommissioning Sequence</u>

Completion reports

- Make sure Primary Services has completion reports from all PERT groups
- Make sure operating maps are field marked to convey current conditions of equipment

Pre-Arrangements

- Make sure overhead maps have been updated before commissioning
- Make sure System Operating Practice (SOP) has been signed by Relay, Operations…..prior to commissioning
- Make sure Primary Services calls Pre-Arrangements at least 24 hours in advance of any commissioning date
- ROC/SOC displays updated

Manual/Automated/Automatic

- Make sure SOP gives specific requirements for each 3 types of operation
- Make sure Site is Safe for all workers and all necessary Red tag protection at commissioning is complete.

7
METHODS OF CONTROL AND OPERATION

Chapter Organization

This chapter describes methods of control and operation, including communications and monitoring.

Introduction

"Communication is everyone's panacea for everything."
—Tom Peters

The operation and control portion of a DER project does not need to be overly complicated and the wheel does not need to be re-invented. The main point that needs to be driven home to the operations and communications departments is that it is just another distribution solution similar to a portable substation. Portable substations are installed in temporary and emergency conditions without constant SCADA monitoring and control. This is exactly how DER projects should be viewed since they comprise only a small portion of the total transformer or circuit load.

To help the system operators become more comfortable with the operation of this new tool, DTE Energy has documented a formal system operating practice to outline the DER operation. Not only automatic operation but also automated and manual modes of operation are thoroughly documented to enable the operator to have a detailed procedure in place for the operation of the DER for loss of communication. As such, the loss of communication should not affect the DER's ability to avoid overload.

The safety of operators and the well-being of the generator are major concerns as well. This chapter will outline the procedures that have been set in place to perform periodic testing of the generator. It also describes the alarms on the generator that ensure the safety of the operator and the integrity of the generator and distribution circuit.

In essence, the DER should act like fans on a transformer that come on and off automatically when needed. When the load on a circuit reaches its day-to-day rating, the DER senses this and turns on to maintain this level of load on the circuit. Furthermore, DTE Energy developed a load-following strategy to provide freedom from the transfer trip scheme and at the same time to minimize fuel expenses.

Cost effective integration of distributed resources into the utility can create challenges. How much information and at what cost? How far do you go with functionality? Do you have enough redundancy to ensure safe operation? This chapter outlines the desired control (manual, semi-automatic and fully automatic) and operation (island mode or grid support). The functionality of the mobile generator is gaining acceptance and its integration is evolving.

Control – Required Data/Status

Safe integration of the distributed generator is the highest priority. Is it practical to install hardwire controls for a mobile generator that is two miles from the substation? When one can't have hardwired controls, how much redundancy is needed to prove a status or control point? Allowing remote control or having automatic control requires the exchange of valuable data and having the safeguards to prevent injury or damage to the equipment.

Automated control (the preferred method of operation) requires remote communications. Traditionally, hardwire has been required for DER control and SCADA via phone line or internal radio network for communication. Today, the DTE Energy DER Group uses phone, cable, radio, cell phone or satellite communications to link the meter data to the SCADA controller. In addition to SCADA, DTE Energy uses a separate communication path. The data transmitted on the second communication path is available for viewing on an internet-based website.

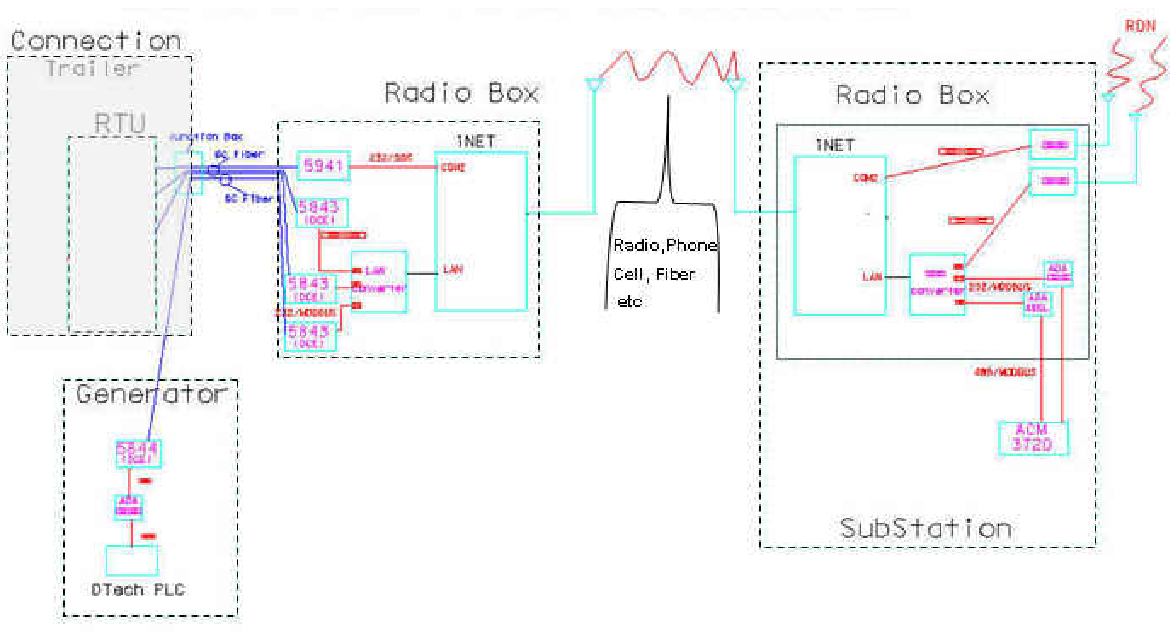


Figure 7-1
Communication Paths

Many of the packaged mobile generators have alarming built in. Most have an audible and visual alarm to indicate a fault. Faults are mainly categorized by severity to the operation of the genset. The genset manufacture pre-determines what is classified as a minor and major fault. Having a multi-path indication of a fault is valuable. System operations can receive a minor or major alarm, while the details of the alarm can be researched by the use of an internet-based website. The internet-based link offers a remote means to see all of the genset variables available.

Distributed generators located on or adjacent to substation properties have the ability to cost effectively receive a hardwire transfer trip signal from the feeding distribution circuit breaker. When the substation breaker opens (changes state), the generator is signaled to get off-line. The generator is prohibited from getting back on-line until the substation distribution breaker is closed for greater than 30 minutes. Special attention must be paid to the ground mat configuration. Fiber provides a means to send the signal from one ground mat to the other. Circuit loading information is easily passed from the portable electric power meter to the mobile generator by a parallel fiber link.

Distributed generators located on the distribution circuit elsewhere rely on radio or cell phone technology to communicate the same data. The question at hand is, are the radios or cell phone working properly?

This question requires additional data to show the health of the equipment and health of the data being transmitted. Distributed generators located remotely from substations must not contribute greater than one-third of the circuit supply (IEEE Standard 1547). As an added measure Detroit Edison distributed generators do not contribute greater than one-fourth of the circuit ampacity. In the absence of transfer trip technology, this is the operating philosophy. It is imperative to monitor the circuit amps on the substation distribution breaker and the generator output breaker to maintain this ratio of ampacity to allow exportation of power from the distributed generator site. The status point associated with this ratio is a permissive on/off signal. Two additional signals are added to the mix to ensure that the permissive signals are operating. Permissive on/off alarm indicates that the generator failed to keep the circuit loading between thresholds.

Theory of Operation—Permissive Signals

Methods of Operation

"Step by step and the thing is done."

—Charles Atlas

Most utility-installed distributed generator installations are designed to peak shave. They take care of the extra demand placed on the distribution system on back-to-back 90-degree days. During these times of high demand, manpower and resources are stretched to their limits. Ideally, distributed generators should act as seamless as "fans on a transformer." They should start as demands increase and stop when demands decrease and alarm systems operations when they don't work properly. Otherwise, no human intervention is required when the distributed generator is operating within defined limits. The functionality referred to is automatic operation.

Installation time constraints may limit the mode of operation to manual. Typically the order of installation and verification is manual operation, remote manual operation and automatic operation.

Automatic Generator Operation

As the load exceeds its normal rating on any phase of the circuit, the generator will turn on automatically at a minimum output. If for some reason the generator does not turn on automatically, the Regional System Supervisor will receive the ***Generator Permissive On*** (**PERMISSIVE ON)** alarm when the load reaches a predetermined level above the Normal rating. When this alarm is received, the Regional System Supervisor should immediately contact the DER Group to determine what prevented the generator from starting. Once the problem has been identified, the generator may be operated in "non-automatic" mode at the discretion of the Regional System Supervisor.

The **PERMISSIVE ON** alarm is dependent on load level only. Therefore the Regional System Supervisor will receive this alarm each time the load on the circuit exceeds the predetermined set point above the Normal rating. This alarm will occur even when the generator is running if the circuit loading is above the normal rating plus the maximum output of the DER.

Once the generator is operating in automatic mode, the generator controller will evaluate the circuit load every 30 seconds and automatically increase or decrease its output to maintain a ***Total Circuit Load*** at the normal rating. (The Total Circuit Load, or "true load", is the sum of the metered flow on the circuit plus the generator output. This value will be calculated and linked to the Distribution Management System (distribution SCADA) Display for reference by the Regional System Supervisor.) This process will continue until either of the following conditions occurs:

- The generator maximum output is reached. At this point, the Total Circuit Load will begin to exceed its normal rating. If the load continues to increase such that the emergency rating of the circuit is in danger of being reached, the Regional System Supervisor will need to take all necessary action to protect equipment.
- The generator minimum output is reached and the circuit load is less than 95% of its normal rating less the generator minimum (Circuit loading = .95*Circuit Normal – Generator Min). At this point, the generator will automatically shut down and be taken off-line. If for some reason the generator does not turn off automatically, the Regional System Supervisor will receive the ***Generator Permissive Off*** (**PERMISSIVE OFF)** alarm when the load falls to another 5% below the circuit rating. Following this alarm, the Regional System Supervisor should take the unit off-line unless the unit is being tested or operated for other special circumstances not related to circuit loading.

The generator should only be run when the under/over frequency relays and under/over voltage relays are operational and the Total Circuit Load is at least four times the output of the generator.

The generator requires a fifteen-minute cool-off period after shutdown before it can be restarted.

There is an ***Emergency Trip*** control point available in the Distribution Management System (DMS). This point will enable the Regional System Supervisor to trip the generator breaker remotely via SCADA in an emergency situation. However, it is not the preferred method of shutting down the unit.

The generator must remain off-line whenever the circuit is in an abnormal configuration.

Non-Automatic Generator Operation

The generator can be run in non-automatic mode on site by the Operating Agent, a Substation Operator or remotely by Internet-based operation center (DER SOC).

The generator may be operated in non-automatic mode as long as the Total Circuit Load exceeds the generator output by a factor of four. The under/over frequency and under/over voltage relays must also be operational. This will ensure that adequate relay protection is provided and guarantee sufficient protection to prevent the generator from serving an unintentional island of load. To maintain this protection, it will be necessary to continuously monitor the generator output and Total Circuit Load to ensure that the 4 to 1 ratio is maintained.

The generator requires a 15-minute cool-off period after shutdown before it can be restarted. The generator ***must remain off-line*** whenever DC 1770 Shores circuit is in an abnormal configuration.

Manual Operation

"More firm and sure the hand of courage strikes, when it obeys the watchful eye of caution."

—James Thomson

System Operations are equipped with a maintained list of connected generation to the utility grid. This spreadsheet identifies generator location, connected distribution circuit, configuration (sell-back, non-sell-back), generator capacity, site contact information and electric rate identifier (firm, interruptible, etc.). Based on distribution circuit need, Systems Operations contact the site instructing the site operator to start or stop the distributed generator. The burden of monitoring the generator is placed on the site personnel as well as the system operations to ensure that the generator operates at no more than one fourth of the distribution circuit load. For ease of operation the generator would operate in a baseload configuration or non-sell-back mode.

Loss of Communication

During the summer season, the Regional System Supervisor should periodically monitor the circuit RTU for potential communication failure. It is also recommended that the Regional System Supervisor check this at the start of days the unit is expected to be operating. Regular communication between the Regional System Supervisors and DER SOC is essential during the summer months to maintain a high availability of the unit for peak periods and to prevent load shedding.

Other Alarms for Control and Operation

Descriptions of additional alarms that require a detailed explanation are as follows:

The ***Generator Major Alarm*** **(MAJOR GEN ALARM)** in DMS will alert the Regional System Supervisor that the generator will be taken off-line and the unit will be prohibited from restarting. This alarm is a collective output taken from the generator.

The ***Generator Minor Alarm*** **(MINOR GEN ALARM)** in DMS will alert the Regional System Supervisor that the generator will NOT be shut down, but the unit will be prohibited from restarting. This alarm is a collective output taken from the generator.

The ***BE1-81 Alarm*** **(BE1-81)** in DMS will alert the Regional System Supervisor that there is no DC power to the under/over frequency relays. If this alarm is received, the supervisor should direct DER SOC or the Operating Agent to take the generator off-line. The generator should not be started unless there is DC power to the under/over frequency relays.

Periodic Testing of the Distributed Generator

"And with the new testing and research that's going on, I see a cure on the horizon."
—Geraldine Ferraro

The generator should be run periodically to perform operational tests and to ensure a high level of performance throughout the year. Such periodic tests should be arranged through the Regional System Supervisor.

Monitoring and Control

The Amp, MW, MVAR and Voltage values on the generator should be available in the Energy Management System (EMS) and the DMS. A website such as the DER SOC website can be used for an alternate way to view these values for the generator.

8
CASE STUDIES: DISTRIBUTION SOLUTIONS

Chapter Organization

This chapter presents five examples of DTE Energy's application of DER for distribution relief. Each example includes a description of the DER installation, the approval process, planning and protection issues, economic evaluation, operation and conclusions.

Each of these installations is listed below, and then described in greater detail.

Collins **–** DTE Energy's first installation; internal to a distribution circuit to resolve an emergency

Adair – Temporary installation on substation property to resolve emergency overload

Quail **–** Temporary islanding of a radial fed substation for emergency & maintenance

Grosse Ile **–** Temporary installation internal to a distribution circuit at a school

Wayne – Emergency installation internal to a distribution circuit on commercial lot

Collins Emergency Installation

Collins was first installation of DER at DTE Energy. The project took only four days to construct. This installation caused several concerns such as safety because the lack of detailed design, union jurisdiction and issues of commissioning. Future installations addressed all of the concerns and lessons learned that came about from our first emergency DER installation.

This emergency application of a leased 2 MW generator on the tag end of an overloaded distribution circuit ended daily circuit outages. These outages to 3500 customers on a 13.2 kV multi-grounded Y circuit were caused by a delay in completing a new substation. The $500K spent on an emergency generator and other circuit work was roughly equivalent to annual charges for a one-year delay of the $6.4M Collins substation project. If planned, this emergency alternative including the DER installation would have been more economical.

Figure 8-1
Collins Emergency Installation

Approval Process

The new Collins Substation Expansion Project approval process was slowed because of concerns for EMF effects on area children as they visited the new library. It should be noted that the new substation was several hundred yards across the road from this new township development, which included a library. Further, they had chosen to build the new library a couple hundred feet from an existing 120 kV double circuit tower line that ran along the entire length of the library property.

The summer heat started early, higher than expected load growth and the additional year delay in substation approval led to daily outages to the area. Once these daily outages began, the community thought it in their best interest to allow DTE Energy to put in an emergency generator as well as granting permission to proceed with the new substation. There were 27 days of 90 plus degree weather that year (average is 12-15 days). Many more outages would have occurred if the generator, as well as other emergency items, were not done. The other items included installation of a portable substation and building a temporary line and many load transfers. The generator was an important mitigating element to the emergency condition but was not the only element.

Planning and Protection Issues

One single-phase operating device was found in the feed forward path from the substation to the generator. This single-phase recloser was jumpered during generator operation avoiding potential single phasing of the generator. This was done until the single-phase recloser could be replaced with a ganged three-phase device.

The generator was operated in parallel with the distribution system. Relaying was installed to protect the distribution system from the generator and the generator had its own protection. Over/under voltage and frequency relays were installed on the high side of the generator step up transformer, a 480 volt to 13.2kV Y to delta. Transfer trip was not installed since there was much more load than the necessary 3 to 1 ratio of circuit load to DER output, which assumes that the under voltage relay would trip the DER within two seconds as defined by IEEE 1547.

Economic Evaluation

Project	Total Cost	Annual Cost
T&D Collins New Substation installation	$6,400K	$640K
	Emergency Cost	**Annual Cost**
T&D Emergency Capital Cost	$250K	$25K
T&D Emergency Total Cost	$250K	$25K
DER Capital Installation	$135K	$14K *
O&M Lease & Operating	180K	$180K **
DER Installation Total Cost	$315K	$194K
Total Emergency Cost	$565K	$219K

*Several parts were reused as part of the connection (transformers, relays, SCADA, etc). Some of the site preparation was consistent with site preparation of the new substation site.
** The lease cost was nearly 40% of the direct purchase of the generator, which was purchased by year-end.

Notwithstanding the emergency nature of this installation, the economics appeared to be nearly breakeven when comparing the total emergency cost and the one-year deferral of the substation project ($565K vs. $640K). If the emergency installation had been planned and the generation purchased as is now typical in such situations, this becomes a more definite case for the *DER-and-Defer* strategy.

Operation

The generator was monitored, started and stopped remotely. The regional system supervisor ordered the generator run whenever the forecast was above 85ºF. This translated to the generator being run approximately 300 hours.

Conclusions

Overall, the DTE Energy DER group managed to make its first DER installation a success. Additionally, this project was done in only a few months after the DER group was formed. It was also apparent that the lease, which cost nearly 40% of the purchase price of a new 2 MW DER, was not the most economical way to do this in the future. After learning from this experience, the group decided to purchase two generators to reduce future costs.

The generator was run much more than necessary to relieve the overload. This situation convinced the DER group to begin work on an automatic load-following strategy.

Adair Temporary Installation

The Adair project utilized a 1-MW natural gas DER unit to support an overloaded 2.5 MVA, 41.57/4.8 kV substation transformer that was connected to an overhead circuit (at substation) and operated in parallel.

This temporary installation of a purchased 1 MW natural gas generator resolved emergency transformer overloads to a small radial fed 2.5 MVA 41.57 to 4.8kV substation transformer located between Port Huron and Detroit, where a number of manufactured home parks installed in less than one year had caused the overload. The installation ended emergency overloads caused by increased load and high temperatures to 1,200 customers on two small 4.8 kV delta circuits.

Before the DER solution was agreed upon, other solutions to the problems at Adair were explored and some were initially implemented. For example, a portable transformer oil cooler was used to manage the heat of the overloaded transformer for a while but loading exceeded two times the nameplate of the transformer.

The best temporary fix was a two-year project to install a 1-MW natural gas generator on substation property to manage loading on a 2.5 MVA transformer. A traditional 4.8kV delta substation expansion solution could not be completed in time to relieve the transformer emergency overload. Costs were approximately breakeven. The substation budget cost was $870k and DER project was $895k. However, all the components associated with the DER were returned to stock and later reused at DTE Energy’s Milford DER installation. The installation allowed for the deferral of the substation project an additional year.

Figure 8-2
Adair Temporary Installation

Approval Process

The community was contacted to obtain permission for the temporary installation of the generator. The township planning board's legal advisors drafted a position letter to the board. In this letter, they contended that the township board had the authority to grant permission for this temporary installation that was required to maintain electric service to the area residences. The key point here was that electric service was considered an essential service. During the petitioning, the board wanted to know if this was a merchant plant with power primarily for the benefit of another area. The DER team assured them that it was only for local area use. In fact, back feeding of the grid would not be allowed by the protection system. The board granted us a two-year waiver and asked for assurance that the permanent substation project would be undertaken. So, in reality, this generator project not only helped manage the load for the two years that it was there, it also helped gain community acceptance for our future substation expansion.

Planning and Protection Issues

The generator was attached to the smaller of the two 4.8kV circuits. Islanding was a concern because of the generator size compared to the load. Transfer trip was installed using fiber because the generator was installed just outside the substation. A reverse power relay was also installed on the substation transformer to protect for backfeed and faults. The substation transformer was a fixed tap transformer and an older 3-phase bus regulator was used. A simple control device was used to protect the line regulator from regulating incorrectly if back fed from the DER. No single-phase operating devices were found in the feed forward path from the substation to the generator.

A rudimentary load following scheme feeding directly from a temporary power meter to the generator programmable logic controller was developed. This scheme became the group's template for later automatic load following techniques. The generator had its own protection. Over and under voltage and frequency relays were installed to protect the system from the generator on the high side of the generator step up transformer, a 480 volt to 4.8kV Y to delta. The existing capacitors were not seen as presenting a voltage problem due to their electrical location on the circuit.

Relaying was installed to protect the electrical system from the generator. Additional protection, which consisted of transfer trip and back feed protection, was installed to prevent islanding of circuit. The DER was remotely monitored from a Systems Operation Center. The generator automatically started when transformer load was above its normal rating. It turned off when the transformer loading decreased sufficiently below the normal rating to allow the DER to turn off without going over the rating again. This approach prevented hunting and continual start/stop actions.

Economic Evaluation

Project	Total Cost	Annual Cost
T&D Adair Substation Expansion	$870K	$87K
DER Capital Cost	$880K	$88K*
O&M over 2 years	$15K	$8K
DER Total Cost	$895K	$96K
DER Capital Installation	$150K	$15K**
O&M over 2 years	$15K	$8K
DER Installation Total Cost	$165K	$23K

*Includes generator purchase
**Generator already purchased

Note that the substation project could not have been completed, so this comparison is just for demonstration purposes.

Operation

The generator was started and stopped remotely whenever the hours of operation deemed necessary to offset overload on the transformer.

Conclusions

The DER group's second installation utilized designed and standard parts. These first two installations led to designing and building a universal connection skid to accompany the generators for the next installations. This installation also included fixing the problem with less regard for the economics. Although analysis showed the DER alternative as about a breakeven with the T&D alternative, the T&D solution was impossible to accomplish in the same time.

Quail Emergency/Temporary Islanding Installation

The DER group believes that the most important aspect of this DER application was that the idea came from the field work force.

The DTE Energy field workforce was aware of the DER installed in the summer at Collins. Knowing that the DER was still available for use after the heat ended in September, field forces asked if they could use it in island mode to facilitate some emergency repairs.

This project installed a 2-MW diesel generator to support a maintenance shutdown for a 4.8kV delta substation fed by a long 40 kV radial feed that had been damaged by a tornado. Before the generator was used, temporary repairs were made to the tornado damaged area of the 10 mile radial 41.57kV feed line to the substation. The customers were out of service for several days while these temporary repairs were made. The generator project saved 600 customers served from this substation from having additional 2-10 hour outages and the importing of additional crews to repair the tornado damaged radial feed. The project also negated the need to install a portable substation for substation maintenance due the following year. Cost was similar to the installation of the portable substation, but customers were not outaged and repairs were made by the local work force on straight time.

Figure 8-3
Quail Substation: 2 MW Diesel Installation to Support Maintenance Shutdown

Approval Process

No approvals were deemed necessary. It is the utility's belief that it has the right to temporarily bring in equipment (portable substation, oil filtering units etc) to do maintenance and/or make emergency repairs. DTE Energy did, however, send out letters to affected area customers advising them of the plans, which now would only consist of two momentary outages. One to cutover the substation to the DER and one on the go back after repairs were made. The DER group took credit for trying this new means of repair to stave off multiple day lengthy outages. A local radio announcement was also made.

Planning and Protection Issues

The loading pattern at the substation was examined to determine if the anticipated peak would be within the DER's capability, which it was. Power flow analysis for this time of the year suggested that running the DER at 124 meter volts in voltage control load following would be sufficient to provide adequate voltage to all area customers without a boost in the step up transformer at the anticipated peak load. The generator and connection parts were installed within the substation on the portable substation ground mat. The connection parts were delivered from Collins and put together on mud mats for ease of handling.

The switch over began by first jumpering the two circuits together on the overhead. The generator was started and rotation checked. Then, with two operators present, one opened the feed circuit recloser at the substation and the second operator closed the breaker on the generator. The outage was less than two minutes—the generator spewed a brief belch of dark smoke and the lights were on. On the "go back", the process was reversed, the generator breaker was opened. The utility circuit recloser was closed restoring service from the substation. The "go back" also took less than two minutes.

Economic Evaluation

The generator had already been paid for on the Collins Project, so the only cost was the relocation and installation of the generator and connection parts (switch, transformer, etc). However, the repairs to the tornado damaged sub-transmission feed line were made without customer outage. These repairs, as well as the substation maintenance, were done by a single service center work load complement at a cost not much more than that involved with the installation of a portable substation.

Operation

The generator was operated in island mode with voltage controlled load following. An operator was standing by during the entire event. The customer, on the switch to and from the generator, saw momentary outages. The project team felt this was advisable on the first installation rather than attempting switching between operating modes on the fly (parallel to grid generator output equal to load) then switching to voltage control load following when the substation was outaged.

Conclusions

Avoiding the use of two other service centers' personnel, their lost productivity to their own service centers, and not paying travel and overtime for two days more than made up for the modest additional cost associated with the relocation and installation of the generator and its parts. Not to mention the customer service aspect of not giving customers two long intentional outages.

Moreover, these first installations demonstrated the need to design and build a connection skid or trailer to lower both cost and installation time involved with future installations.

Grosse Ile Temporary Installation

This was a five-year project that involved installing a 1MW natural gas distributed generator on high school property, deferring eventual T&D expansion on the island of Grosse Ile. Grosse Ile is an island in the Detroit River near its entrance to Lake Erie. A $3.8M Grosse Ile 4.8 kV substation expansion project is planned which will require bringing in another marine cable feed to the island. The DER installation cost was $880K.

Figure 8-4
Grosse Ile 1 MW Natural Gas Generator to Defer T&D Expansion

Approval Process

By looking at aerial photographs, it appeared that school property was the only place a DER could be placed in this primarily residential area. The DER group contacted the school system with the idea of placing the DER on their property. The school was receptive and even helped find an acceptable site that was located in an area that was out of sight and sound of all neighbors. The DER group hand-delivered letters to each of the 10 closest neighbors explaining the situation to those at home and inviting all to a meeting hosted by the school board. The DER group created a video and sound test for this meeting. During the meeting DER group members answered all questions, played the video, which used Adair as an example of what the site might look like; explained that the anticipated hours of operation were typically less than 100 hours and were not late at night, did a site walk over and conducted a sound test for the neighbors. The neighbors' primary concerns included the sound, environmental impact and that the installation not become permanent. They wanted language in the lease limiting the term of the lease and a clause that gave them review of any extension of that lease. The city manager, also a school board member, was also very supportive and, like the Adair community leaders, waived site permitting.

Planning and Protection Issues

No single-phase devices or regulator were in the feed forward path between the substation and the DER. The newly designed and built connection skid was used to connect the DER to the circuit.

Economics

Project	Total Cost	Annual Cost
T&D Grosse Ile Substation Expansion	$3,800K	$380K
DER Capital Installation	$150K	$15K
O&M	$15K	$15K
DER Installation Total Cost	$165K	$30K

The installation of the DER is a more economic alternative for the initial deferral of the substation because of having already purchased the DER.

Operation

The loading is managed by having the DER start automatically and load follow when the portable meter located on the circuit head at the substation reaches the circuit normal rating. The signal is communicated using the utility 900 MHZ radio system.

Wayne Emergency Installation

This was a four-month installation to provide 13.2 kV circuit relief due to R/W delay in a new $5.2M Zebra Substation Project. No other cost-effective solution (1 mile of new overhead = $180k) was available to prevent rotating blackouts to 2100 customers. It was doubtful that the new overhead line could be designed, permitted and built before the summer peak.

This emergency installation of a previously purchased 2MW diesel generator prevented daily circuit outages caused by an overload situation to 2100 customers on a 13.2 kV multi-grounded Y. The $125K spent on the installation and removal of this previously purchased emergency generator and connection trailer was more economic, faster and less of a drain on already taxed line designers and construction work force than the emergency T&D alternative priced at $180K.

(The other alternative involved designing and constructing portion of a mile of new line. Not to mention potential R/W delays involved with obtaining new R/W.)

A modest lease payment for the 4-month installation was negotiated with the commercial property owner/developer. Some of the site preparation work was left for the benefit of the developer. The project was completed using a contractor work force before summer and was removed October 1.

Figure 8-5
Wayne Emergency Installation

Approval Process

The community was aware of the R/W problems and obtaining exist paths for the newly built substation. In fact, the community was helping to define new routes by using community property, dedicating new road R/W, etc. This fact, added to the previous summer's outages and some input from Grosse Ile and Shores community leaders, led the city manager and planning committee board to waive all formal approvals and granted permission to proceed. They also helped decide which one of the three researched sites for the new DER location was the easiest solution. The property owner, a developer, was planning on a new commercial development on this vacant lot.

Here again, the understanding that this installation was temporary and that the utility was an essential service led the planning community to elect to grant permission with just board review and approval, negating the need for full planning review and public comment.

Planning and Protection Issues

No single-phase operating devices were found in the feed forward path from the substation to the generator. The generator had its own protection. Over and under voltage and frequency relays were installed to protect the system from the generator on the high side of the generator step up transformer, a 480 volt to 13.2kV Y to delta. Two capacitors were present within the circuit. One of these capacitors caused voltage excursions above the standard 132 meter volts for the overvoltage relay. A modest reset was initiated to avoid a possible over voltage trip due to capacitor switching.

Economic Evaluation

Project	Total Cost	Annual Cost
T&D Wayne Substation Expansion	$5,200K	$520K
DER Capital Installation	$150K	$15K
O&M	$15K	$15K
DER Installation Total Cost	$165K	$30K

As in the preceding example, the installation of the DER is a more economical alternative for the initial deferral of the substation, here again because of having already purchased the DER.

Operation

The loading is managed by having the DER start automatically and load follow when the portable meter located on the circuit head at the substation reaches the circuit normal rating. The signal is communicated using the utility 900 MHZ radio system.

A
REFERENCE INFORMATION FOR PLANNING AND PROTECTION ENGINEERS

Introduction

Appendix A provides additional reference material to supplement the information in chapter 4, Planning and Protection. This material addresses the following topics:

Basic Relaying Principles

1. **Loadability:** Equipment must carry load

2. **Sensitivity:** The protection equipment must sense fault conditions.

3. **electivity:** Isolate the fault with the minimum amount of load loss—the device closest to the fault operates

4. **Islanding:** The DER is normally not permitted to operate isolated or islanded with other customers

Issues: Single phasing, interrupting ratings, high-speed reclosing

Protective relay engineers are paid to focus on sensing faults and properly clearing them. However, one must remember that if the equipment and protective relays cannot carry the load one must re-evaluate the study. Therefore, "Loadability" is placed first in the sequence above.

Typical margins for sensitivity are described with respect to bolted fault currents. Protective elements are installed and selected such that they will sense faults that are 50% or less in the calculated bolted fault currents. A typical value used as the margin for tripping times is 30 cycles. A protective device such as a relay or another fuse that is upstream of a fuse will have a clearing time that is 30 cycles slower than the clearing time for the fuse.

Also, the first three terms are commonly mentioned when discussing protective relaying, but they all are elements of providing a reliable system.

The 29 Issues for Connecting DER

"The issues of my performances vary, but most of the questions buried in the work remain the same."

—Joey Skaggs

DTE Energy's Murray Davis and Dave Costyk have identified 29 key issues for connecting DER, as shown in the following table (which also appears in chapter 3). Of these 29 issues, more than half are protection issues, shown in bold, that would be of primary concern to a protection engineer.

Key Issues for Connecting DER (Bold are Protection Issues)

Key Issues for Connecting DER	
1. mproper Coordination	**16. Isolate DER for Upstream Fault**
2. Nuisance Fuse Blowing	**17. Close-in fault Causes Voltage Dip, Trips DER**
3. Reclosing out of Synchronism	**18. Switchgear Ratings**
4. Transfer Trip	19. Self Excited Induction Generator
5. Islanding	20. Long Feeder Steady State Stability
6. Equipment Overvoltage	21. Stability During Faults
7. Resonant Overvoltage	22. Loss of Exciters Causes Low Voltage
8. Harmonics	23. Inrush of Induction Machines Can Cause Voltage Dips
9. Sectionalizer Miscount	24. Voltage Cancelled by Forced Commutated Inverters
10. Reverse Power Relay Malfunctions	25. Capacitor Switching Causes Inverter Trips
11. Voltage Regulation Malfunctions	26. Flicker from Windmill Blades
12. Line Drop Compensator Fooled by DR's	**27. Upstream Single Phase Fault Causes Fuse Blowing**
13. LTC Regulation Affected by DR's	**28. Underfrequency Relaying**
14a Substation Load Monitoring Errors	**29. Distribution Automation Studies**
14b Cold Load Pickup with & without DER	
15. Faults within a DER zone	

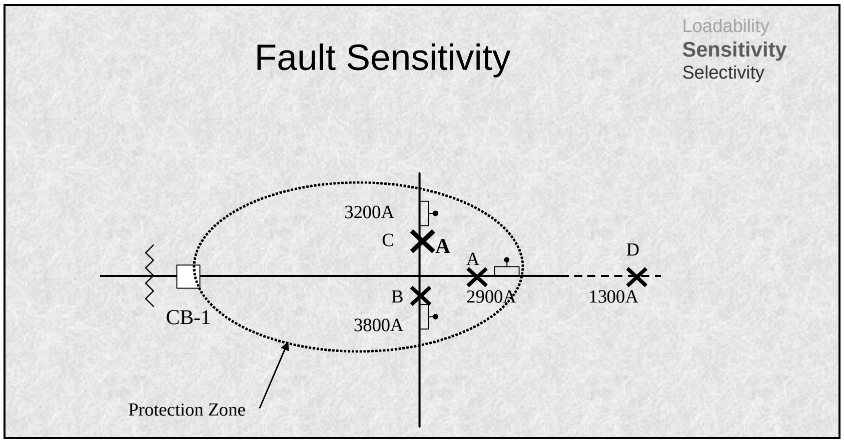
Parameters Affecting Protective Device Performance

The following parameters affect the performance of protective devices:

- The fault current available at the substation bus
- The fault current available from each DER
- Circuit configuration (wye or delta, grounded or ungrounded)
- Circuit topology (radial or ring)
- Impedance of wire or cable between protective devices
- Location of protective devices and DERs on the circuit
- Location of any type of fault
- The time current characteristic of each protective device.

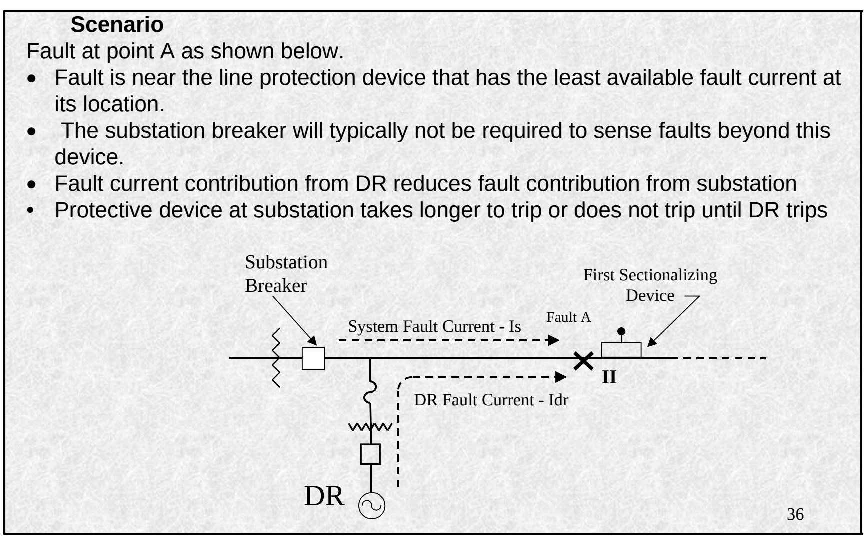
Fault Sensitivity

The addition of DER devices on the distribution circuit will reduce the fault detection sensitivity of the substation protective relays. This is a key issue for determining the maximum penetration limits of DER on a distribution circuit.



Fault Sensitivity

In the figure above, referring to the relay protection of the substation breaker CB-1, the breaker must sense the lowest fault current of the three fault locations (A, B, or C). Reclosers sense faults beyond that zone (i.e., location D). The following figure presents a fault detection sensitivity scenario. The DER is located near the substation breaker because this represents the worse case in-feed condition.



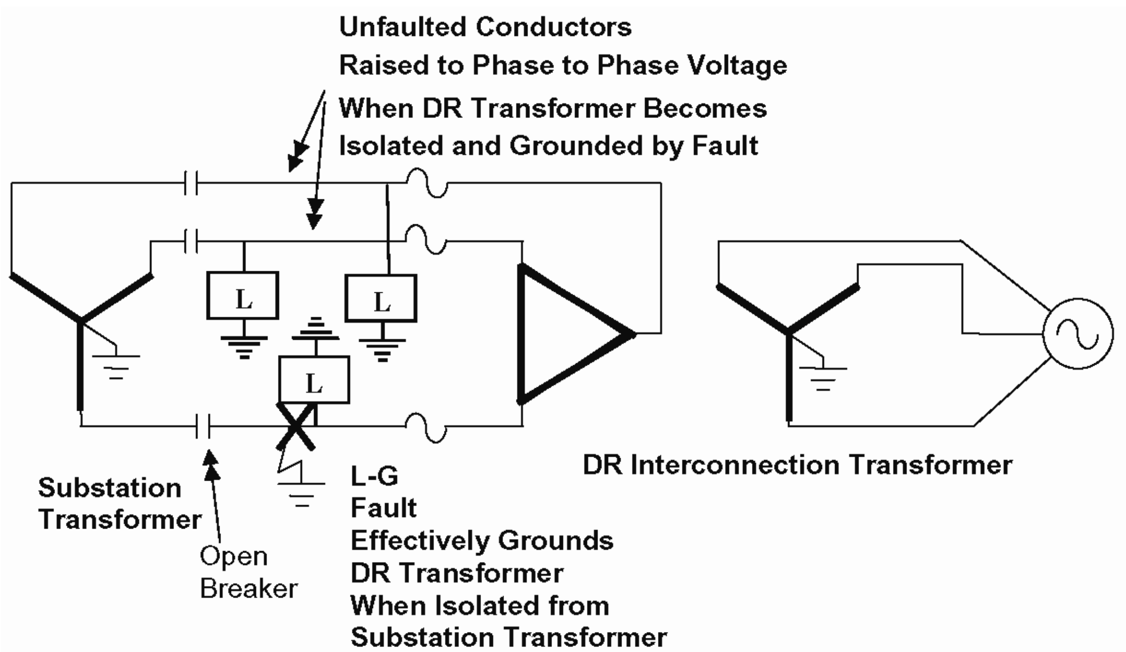
Fault Detection Sensitivity: One Line

The protection engineer must decide if the reduced sensitivity of the substation relays is significant enough to require additional protection or possibly reject the connection of the DER at this location. Sequential tripping of the DER will assist in the substation breaker sensing the fault and clearing it. Low voltage during the fault conditions may be significant enough for the undervoltage relays to trip the generator prior to the substation breaker opening.

Note that IEEE Standard 1547 for low voltage requires tripping in 0.16 seconds for voltages less than 50% of nominal. Note that 0.16 sec x 60 cycles/second = 9.6 cycles, a relatively short time for protective relays on distribution systems. Adhering to this standard will help ensure that the DER is tripped during a fault and also help ensure the current provided by the system is adequate to operate existing protective devices.

Overvoltage

The three line diagram below shows indicates the line to ground fault, substation breaker operation and DER delta connection that can created a high voltage condition.

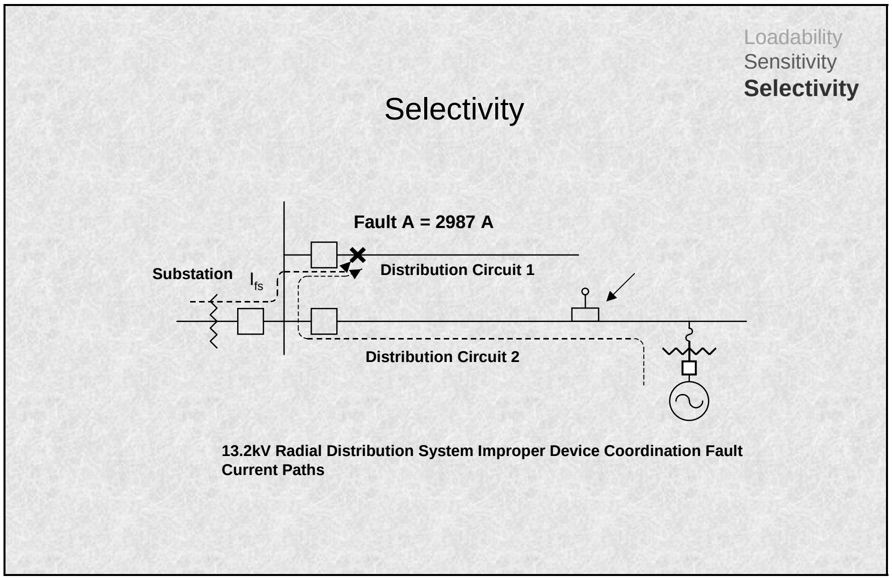


Selectivity

"It is or should be a significant document, a penetrating statement, which can be described in a very simple term—selectivity."

—Berenice Abbott

One of the basic relaying principles, selectivity means isolating the fault with minimal loss of load. This means operating the protective device closest to the fault.



Selectivity

In the scenario depicted in the preceding figure, faults on Distribution Circuit 1 (DC 1) may cause protective devices to operate on DC 2. Typically, this is undesirable because it interrupts service to customers who would have otherwise remained in service.

- Fault occurs on DC 1
- Fault current contributions are from the substation transformer (I_{fs}) and the DR (I_{fDR}).
- The circuit breakers CB-1, CB-2, the recloser and the fuse sense the fault current.
- If the circuit breaker CB-1 does not trip soon enough, the fuse, recloser or both may also trip.

If sufficient current flows for enough time through the recloser on Distribution Circuit 2 (DC 2), it will operate. This result is undesirable since the fault is not on DC 2.

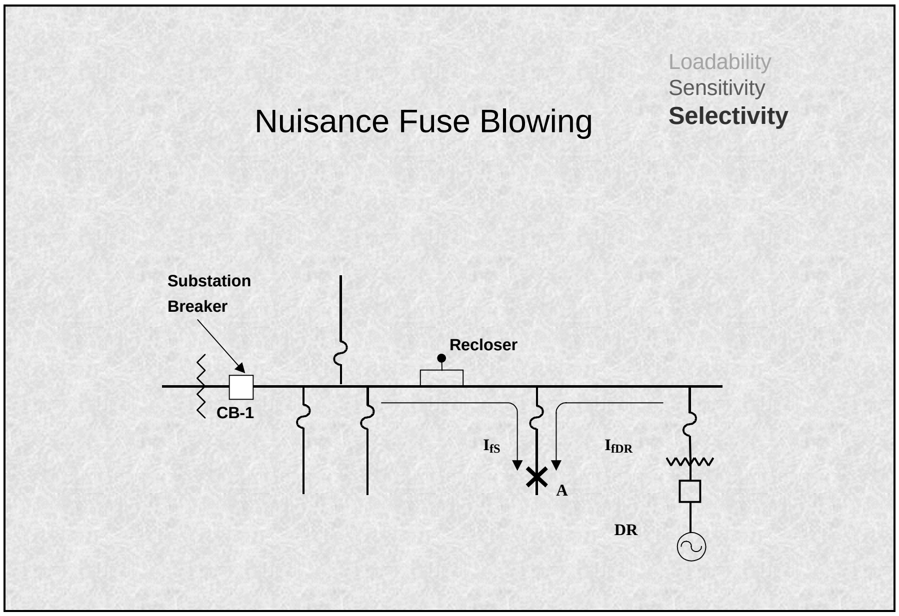
The circuit breaker (CB-1) on Distribution Circuit 1 will be in the process of tripping based on the relay setting applied to the protective relays on the breaker.

If CB-1 trips before the recloser operates, then the DER and other load downstream of the recloser remain in service. If the recloser operates first, the load downstream of the recloser will be interrupted and if the fuse blows first, the DER will be interrupted.

Nuisance Fuse Blowing

"What we call progress is the exchange of one nuisance for another nuisance."
—Henry Ellis Faults

Faults on the lateral may cause the sectionalizing fuse to operate without being saved by the "fast" curve of the recloser. Typically, this is undesirable because many faults that are temporary in nature can be cleared by momentarily de-energizing the system with the recloser and then immediately reclosing the line.

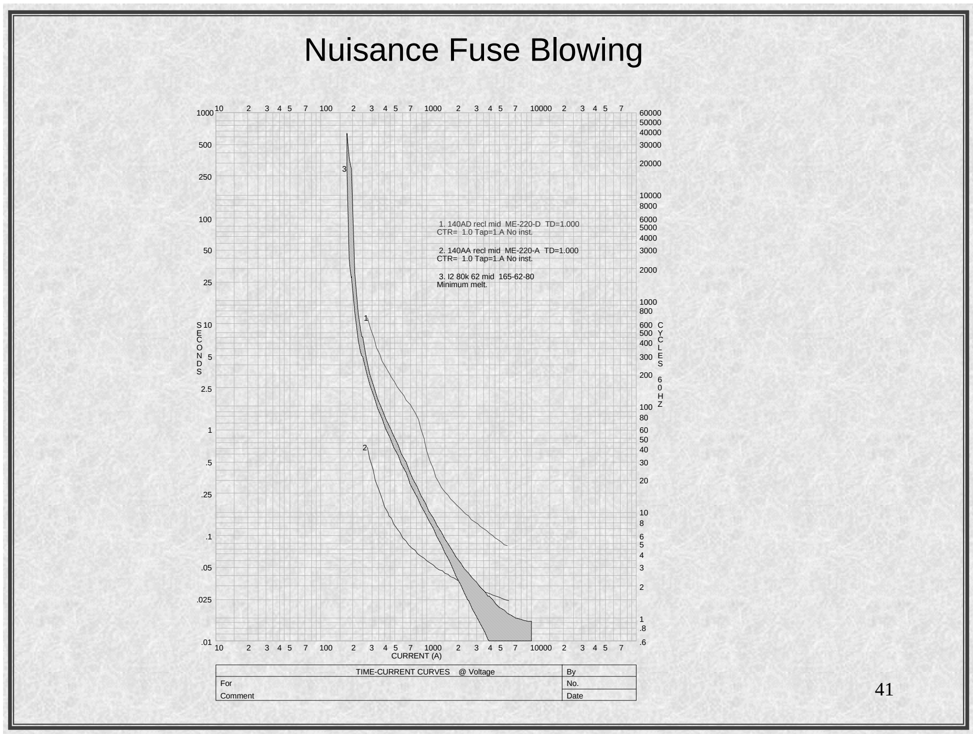


Nuisance Fuse Blowing

In the scenario depicted in the figure above, the fault occurs on lateral at location A.

- Current flows from the substation transformer (I_{fs}) and from the DER (I_{fDR}) to the fault A.
- The fuse senses the fault current through the recloser plus the fault current from the DER.
- Under normal operating conditions (without DER), when a temporary fault occurs at A, the recloser will open for about 100 cycles to allow the temporary fault to clear. The recloser and fuse operating times are normally coordinated such that the recloser will open first to prevent the fuse from blowing and avoid unnecessary loss of load down stream from the fuse.
- The added current from the DR may cause the fuse to blow, whereas if the DR were not present, the current through the fuse would have been only supplied through the recloser.

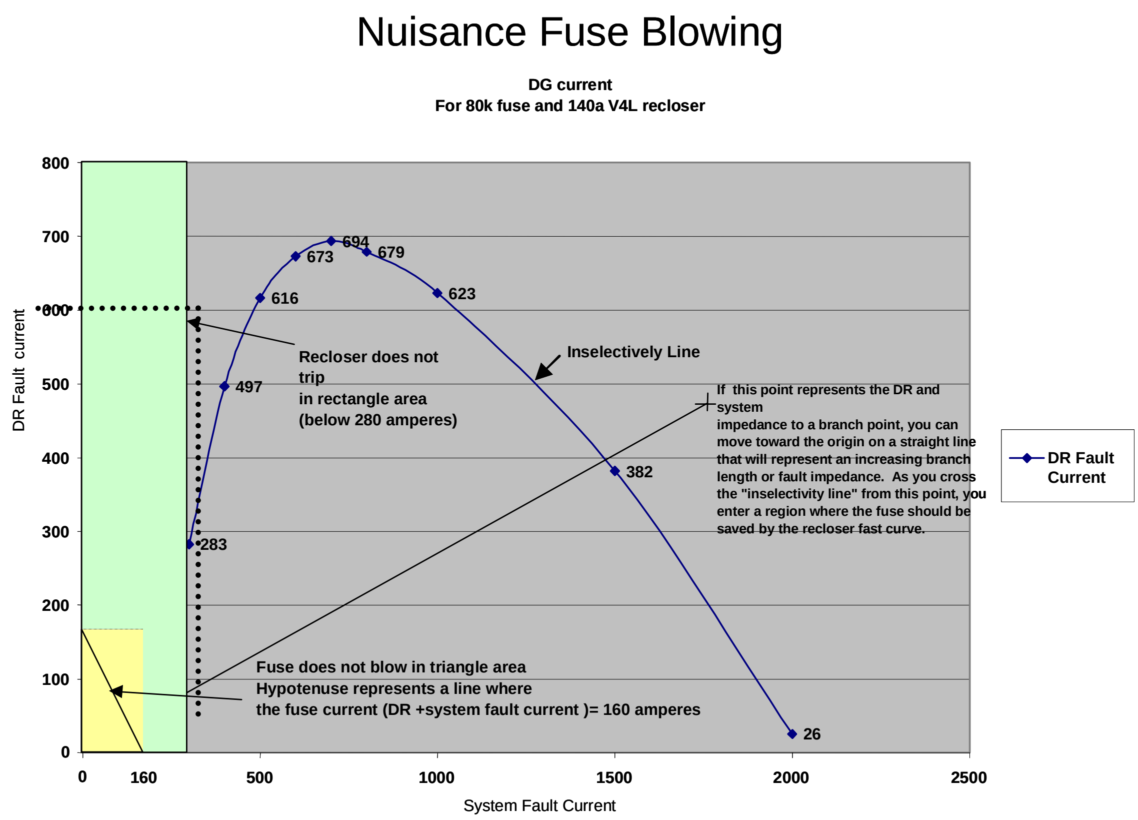
- If the recloser does not trip soon enough due to the temporary fault, the fuse will blow, causing the loss of load beyond the fuse.



Time Current Characteristic (TCC) for a 140A Single-Phase Recloser and 80k Fuse

The figure above shows the time current characteristic (TCC) for the fast or "A" curve for a 140A single-phase recloser and an 80k fuse. If the total fault current is below about 2000 amperes, the recloser will interrupt fault current at the same time the fuse will blow (i.e., at 2000 amperes of fault current the "A" curve of the recloser and the minimum melt time curve of the 80k fuse intersect). If the tripping time of the recloser is held to 75% of the time it takes to blow the fuse, then a current maximum of about 1600 amperes would be permitted in this case. The fuse can be expected to blow if the current is greater than 1600 A. Within a certain current range both the fuse and recloser will open. Fault current that flows from a DER through the fuse will tend to cause the fuse to blow before the recloser operates.

The above figure also shows the "D" curve for the recloser as Curve 1. As previously noted, the slower "D" curve will permit permanent faults to be cleared by the fuse without any additional operations of the recloser.



Maximum DER Fault Current That Can be Added Through an 80k Fuse

The figure above shows a plot of the maximum DR (I_{fDR}) fault current that can be added through an 80k fuse. Maximum DR fault current is plotted for a range of system fault current (I_{fS}).

Note that as the system fault current approaches 2000 amperes, the amount of permissible DR fault current approaches zero. The curve is plotted for the system shown in the previous one-line diagram using the following steps.

- An initial current value is selected on the recloser "fast" curve and the trip time noted.
- A point is found on the fuse minimum trip curve that has the same trip time as the recloser "fast" curve.
- The difference between these two currents is the added current from the DR that will cause the fuse to "nuisance" blow. Note that no selectivity margin has been used
- A point is plotted using the recloser current as the x coordinate and the calculated DR current as the y coordinate, e.g., (500, 616)
- Continue plotting points until a curve is developed.

For this curve a spreadsheet was developed that accepted data points from the recloser and fuse curve data. Considerable manual intervention was required to produce the curve however. A more automated procedure is being reviewed.

Interrupting Ratings

Approximate Values

Universal Link Fuse	8000
Boric Acid Fuse	17,000
Current Limiting Fuse	50,000
Hydraulic Recloser	4000
Vacuum Hydraulic	6000
3 ph Vacuum Recloser	12,000

Must Check the equipment being used

Interrupting Ratings

Islanding

"Isolation is the sum total of wretchedness."

—Thomas Carlyle

A DER device is normally not permitted to operate isolated or islanded with other customers. The following figures include islanding information and definitions from the IEEE 1547 Standard for Interconnecting DER With Electric Power Systems.

Island Detection

- P1547 section

  4.4.1 Unintentional Islanding

  For an unintentional island in which the DR energizes a portion of the Area EPS through the PCC, the DR interconnection system shall detect the island and cease to energize the Area EPS within two seconds of the formation of an island.[7]

  7 Some examples by which this requirement may be met are:

  1. The DR aggregate capacity is less than one-third of the minimum load of the Local EPS.
  2. The DR is certified to pass an applicable non-islanding test.

- Transfer tripping
- Transfer Tripping pilot

Island Detection

P1547 Island Definitions

3.1.13 island: a condition in which a portion of an Area EPS is energized solely by one or more Local EPSs through the associated PCCs while that portion of the Area EPS is electrically separated from the rest of the Area EPS.

3.1.14 island, intentional: a planned island.

3.1.15 island, unintentional: an unplanned island.

3.1.16 non-islanding: intended to prevent the continued existence of an island.

P1547 Island Requirements

4.4 Islanding

4.4.1 Unintentional Islanding

For an unintentional island in which the DR energizes a portion of the Area EPS through the PCC, the DR interconnection system shall detect the island and cease to energize the Area EPS within two seconds of the formation of an island.[7]

[7] Some examples by which this requirement may be met are:
1. The DR aggregate capacity is less than one-third of the minimum load of the Local EPS.
2. The DR is certified to pass an applicable non-islanding test.

Installation of Transfer Trip Relaying

For systems where DER's are not permitted to operate as an island, transfer tripping from the utility's breaker or recloser to the DER may be needed. The DER generation is automatically removed from the utility's system when the utility's breaker or recloser opens.

Circuit Configuration: 13.2kV "Y" Multiground

Size of DR: Typically:

	Medium Range:	100kVA - 1 MVA
	Large Range:	1 MVA - 5 MVA
Number of DERs:		One or many
Type of DR's		Three phase synchronous machines
		Self excited induction machines
		Self comutated inverters
Circuit Protection:	I	Substation Breaker
	II	Three Single Phase Reclosers
	III	Three Phase Primary Lateral - Fuses (3- 100k)
	IV	Transformer Primary Fuse (3) at DR Cable Pole
	V	DR Transformer Secondary Breaker
	VI	DR Generator Breaker
Generator Protection:	Synchronism Check	(not shown)
	Over/Under Voltage	(not shown)
	Over/Under Frequency	(not shown)
	Overcurrent	(not shown)
	Neutral Overcurrent	(not shown)

Steady-State Stability

"There is nothing so stable as change."
—Bob Dylan

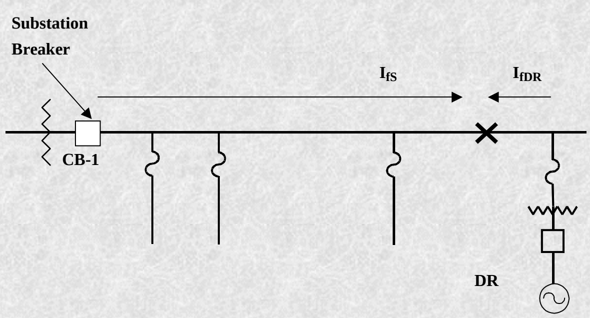
Steady-state stability is associated with the ability of a synchronous machine to remain stable while delivering power into an interconnected ac system. For a simple radial connection between a single generator and a relatively stiff power system, simple formulas are available to determine the maximum power that may be transmitted. For a multi-machine system with distributed loads, this calculation may produce unrealistically pessimistic results and needs to be evaluated by more rigorous methods.

The real power output of synchronous machines can be controlled independently of the reactive power. It is determined by the applied mechanical power, which produces a change in the power angle δ. The machine's real power output is given as,

$$P = VE/Xs \sin \delta \quad \text{Equation (6)}$$

where V is the terminal voltage, E the internal generated voltage and X_S is the machine's synchronous reactance. As the value of δ is increased, due to increasing mechanical power input, the power output of the generator increases. Maximum power is produced when δ = 90°. Any further increase in the value of δ results in a reduction of the power produced. The value of the power angle for which maximum power is produced is called the steady-state stability limit of the generator. If the power angle is increased beyond the stability limit the generator loses synchronism with the power system to which it is connected. For round rotor generators, the theoretical stability limit occurs for a power angle equal to 90°. For salient pole machines, the stability limit occurs at values of δ slightly less than 90º.

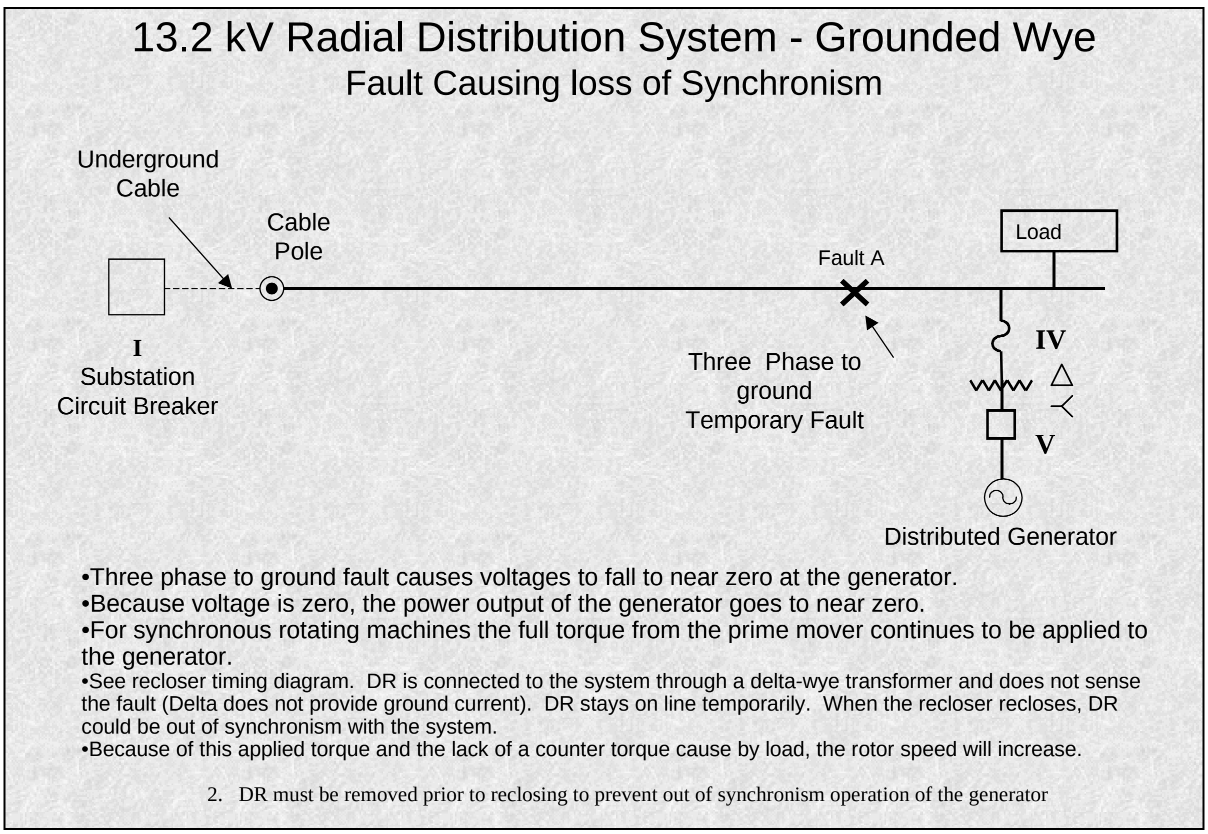
Stability During Faults



For a three phase fault shown:
- **Assume voltage at the fault is zero**
- **Load on DR will be reduced**
- **Torque applied to generator will remain the same for some short period**
- **Relative phase angle of the rotor of the generator will increase with respect to the system phase angle**
- **When the fault is cleared the angle of the generator and the system may be such that the generator will lose synchronism**
- **If that happens, generator damage can result and unacceptable voltage flicker may occur at nearby customers**

In normal operation, a generator must be operated with a power angle much below the stability limit. During a system fault, the terminal voltage is reduced and so the electrical power demand on the machine is greatly reduced. However, the prime mover cannot respond as rapidly to reduce the applied mechanical power. So in the initial moments after fault occurrence, the excess mechanical power input over the electrical power output causes the rotor to accelerate. As a result, the power angle increases, possibly beyond the point where synchronism is lost.

The actual operating angle will depend on the specific machine design. For typical machine synchronous reactances of 1 to 2 p.u., the operating angle ranges over 30 to 40 degrees for rated output. Within this range of power angle and with constant field voltage (manual excitation control), steady-state stability is generally not an issue since there is sufficient inherent synchronizing torque to maintain steady-state stability. With automatic voltage regulator control with fast exciter (high gain feed back system) can reduce synchronizing torque, potentially causing oscillatory instability. Such problems can be avoided with proper design and are not considered as an issue in this study.



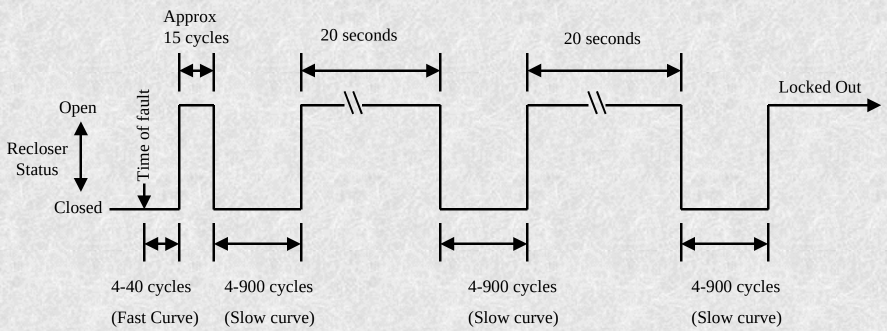
Fault Causing Loss of Synchronism

Transient Stability

To determine whether a power system is stable after a disturbance, one can plot and inspect the swing curves. If these curves show that the angle between any two machines tends to increase without limit, the system is unstable. If, on the other hand, after all the disturbances including switching have occurred, the angles between the two machines of every possible pair reach maximum values and thereafter decrease, it is probable, although not certain, that the system is stable. Occasionally in a multi-machine system one of the machines may stay in step on the first swing and yet go out of step on the second swing because the other machines are in different positions and react differently than the first machine.

In a two-machine system, under the usual assumptions of constant input and constant voltage behind transient reactance, the angle between the machines either increases indefinitely or else, after all disturbances have occurred, oscillates with constant amplitude. In other words, the two machines either fall out of step on first swing or never. Under these conditions the observation that the machines come to rest with respect to each other may be taken as the proof that the system is stable.

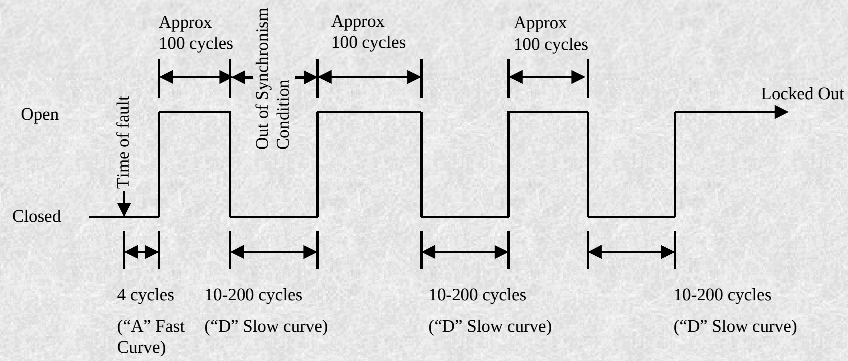
Issue #3 Three Phase Recloser Timing Diagram



3 Phase Recloser Sequence:

1. Fault occurs
2. Recloser opens on "Fast" time delay curve
3. Recloser recloses with no intentional time delay (approximately 15 cycles)
4. Recloser opens on "Slow" time delay curve
5. Recloser recloses after set time delay. (20 seconds in this case)
6. Recloser opens again on "Slow" time delay curve.
7. Recloser recloses the final time after set time delay. (20 seconds in this case)
8. Recloser opens the final time on the "Slow" time delay curve.
9. Recloser locks out and stays open until manually closed.

Issue #3 Single Phase Recloser Timing Diagram

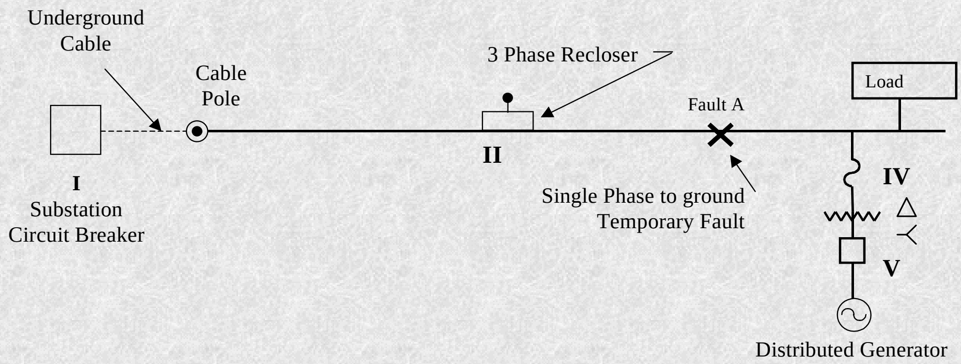


Single Phase Recloser Sequence:

1. Single phase to ground fault occurs at A.
2. Recloser opens on "Fast" time delay curve
3. Recloser recloses with no intentional time delay (approximately 100 cycles)
4. Recloser opens on "Slow" time delay curve
5. Recloser recloses with no intentional time delay (approximately 100 cycles)
6. Recloser opens again on "Slow" time delay curve.
7. Recloser recloses the final time with no intentional time delay (approximately 100 cycles)
8. Recloser opens the final time on the "Slow" time delay curve.
9. Recloser locks out and stays open until manually closed.

13.2 kV Radial Distribution System - Grounded Wye

Reclosing Out of Synchronism



Example 1: Three-Phase Recloser

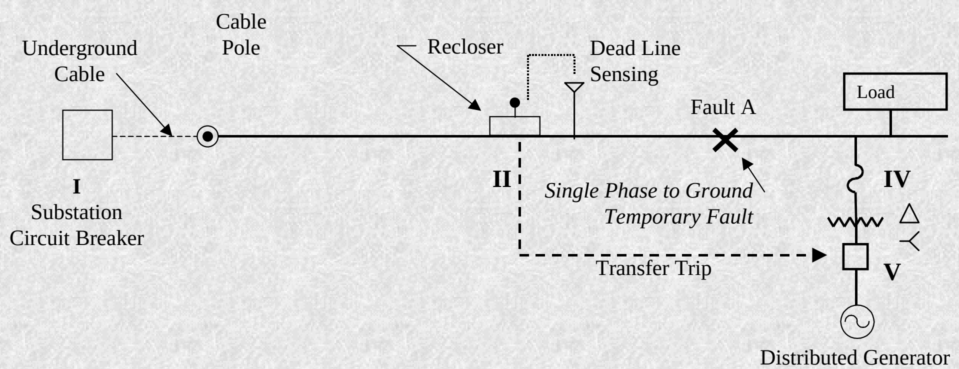
Problems:

1. Single phase to ground fault causes three-phase recloser to open. Fault is successfully cleared by recloser. See recloser timing diagram. DR is connected to the system through a delta-wyetransformer and does not sense the fault (Delta does not provide ground current). DR stays on line temporarily. When the recloser recloses, DR could be out of synchronism with the system.
2. DR must be removed prior to reclosing to prevent out of synchronism operation of the generator

13.2 kV Radial Distribution System - Grounded Wye

Reclosing Out of Synchronism

Solutions



Example 1: Three-Phase Recloser (continued)

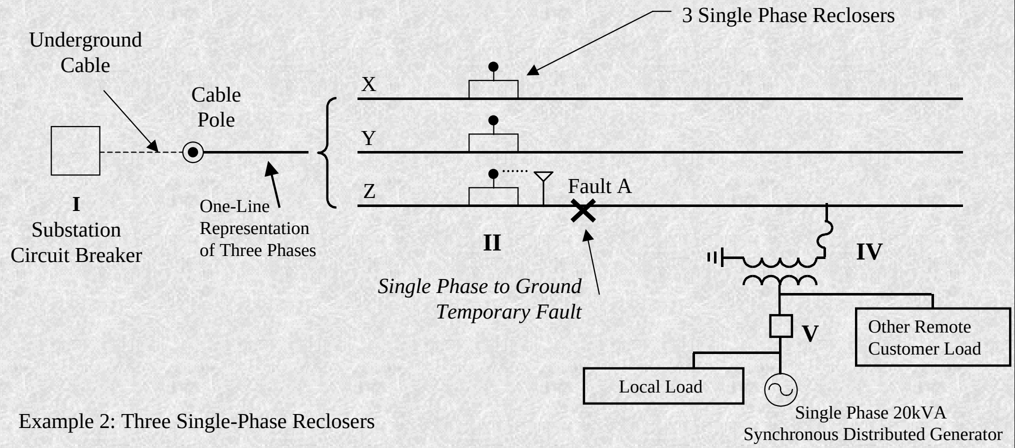
Solutions:

1. Install dead line sensing at the recloser, which consists of three voltage transformers (VTs) connected wye. If potential is present on any VT, automatic reclosing of the recloser is disabled. This will prevent reclosing of the recloser if the DR is operating.
2. Another solution is to install transfer-tripping from the recloser to the DR(s). See Issue #4.

N59 (neutral or zero overvoltage) relaying can be used to trip the generator to ensure that the generator is isolated prior to reclosing of the recloser.

13.2 kV Radial Distribution System - Grounded Wye

Reclosing Out of Synchronism



Example 2: Three Single-Phase Reclosers

Problems:
1. Recloser on Phase Z opens on fast curve "A" and may reclose before generator breaker opens. The generator is less likely to trip as the distance or impedance between the fault and generator increases.
2. Recloser recloses prior to generator breaker opening which could result in non-synchronous operation. See single phase recloser timing diagram.

Solution:
1. Install dead-line sensing at the recloser. This consists of 1 VT at the recloser. This prevents the recloser from closing if the generator is in operation.

Protective Parts: Breakers, Reclosers, Relays

"By irreducibly complex I mean a single system composed of several well-matched, interacting parts that contribute to the basic function, wherein the removal of any one of the parts causes the system to effectively cease functioning."

—Michael Behe

Protective relay engineers may need additional knowledge of how generators interact with utility systems. The interactions involve many subtle effects that are not evident when one draws a generator on an operating map of a circuit. This subsection reviews some of the principles of the devices that interact with DER. The intent is to provide readers who have not performed fault studies as a protective engineer with a basic understanding and an appreciation of the complexities involved with connecting DER devices to utility electric power systems.

Breakers and Reclosers. Circuit Breakers provide the capability to interrupt fault current and de-energize the circuit that it feeds. They are typically electrically opened or closed by a variety of control devices. Protective devices are connected to open or "trip" the breaker for abnormal system conditions.

Reclosers are intended to withstand a higher number of reclosings prior to maintenance or rebuilding. In some applications, a breakers and reclosers are interchangeable. Reclosers are typically outdoor devices. On medium voltage equipment, breakers are often indoor devices.

In the case of DER, the circuit breaker would be opened to isolate the generator from the system by the protective devices on the interconnection.

Circuit Breakers are typically equipped with current transformers that reduce the line current to levels that protective relays can utilize. The current transformers also isolate the protective relays from the relatively high line voltage. Properly applied current transformers divide the line current by a fixed value such as 20, 50, 120, 240, 400, or 500. Improperly applied CTs may not provide the expected current during fault conditions.

Breakers: Key Points for DER

- Interrupt and disconnect fault
- Disconnect generator
- Provide isolated low-level current to relays from CTs
- Utility substation breakers typically automatically reclose
- Note: load capability, interrupting rating, fault closing rating, momentary rating.

Outdoor Reclosers

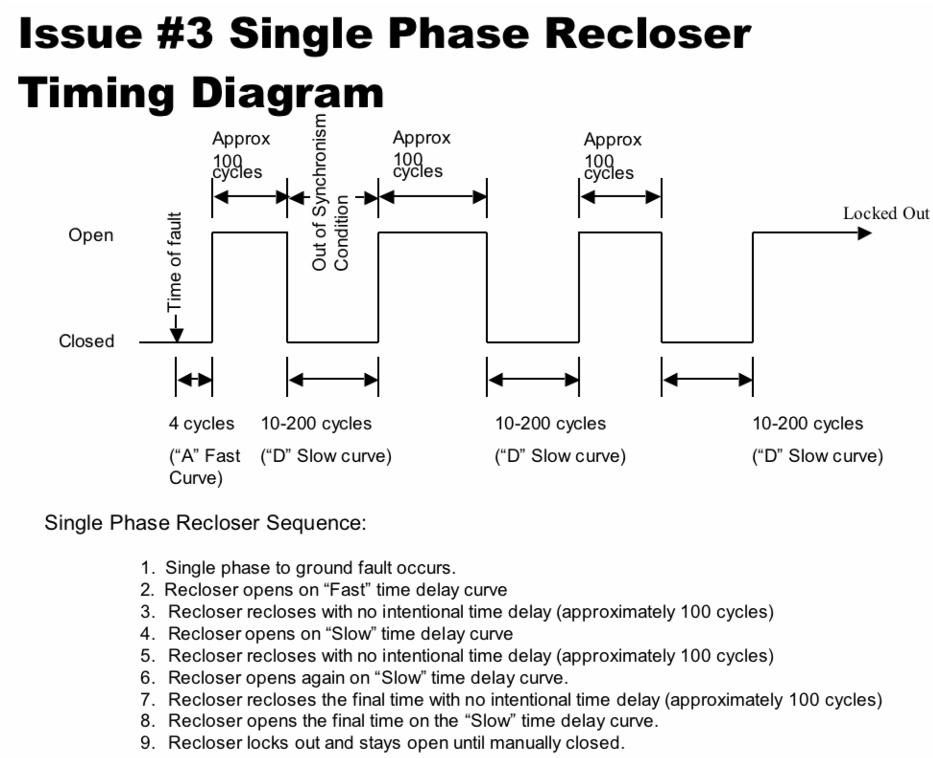
Circuit Breaker Enclosures

The following figure shows a circuit breaker rolled out of its compartment. Note the six points where the breaker makes contact with the bus at the back of the compartment: two for each phase.

Circuit Breaker Removed From Enclosure

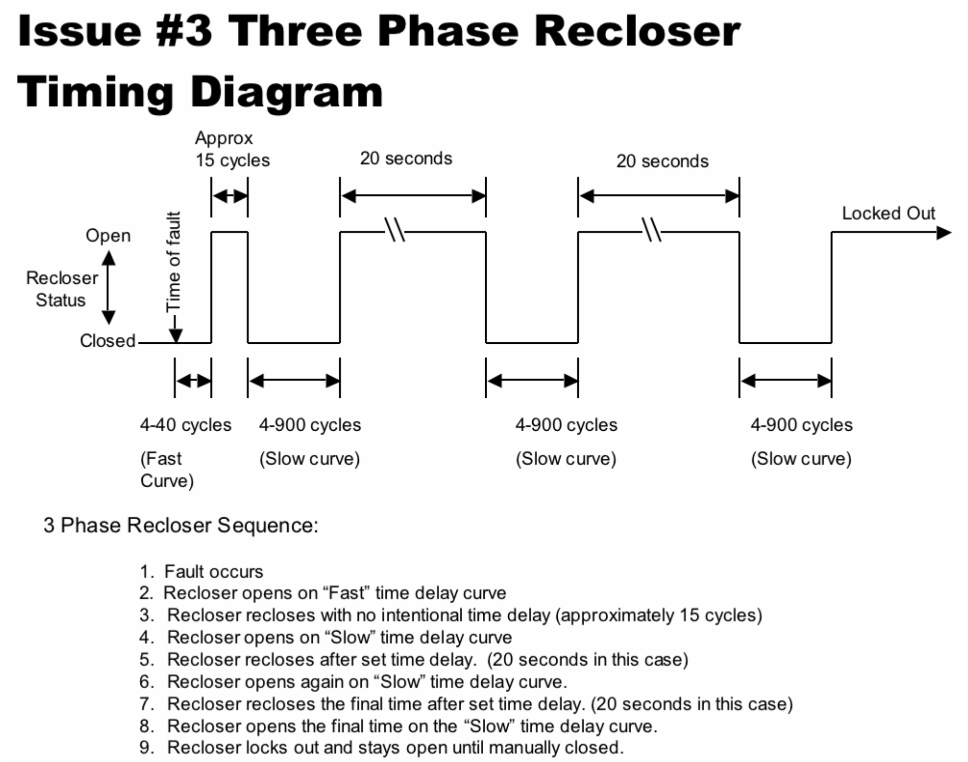
Reclosers: Key Points for DER

- Automatically reclose after fault
- Fast tripping curve saves fuses
- Slow tripping curve permits fuse to isolate fault
- Single-phase and three-phase types



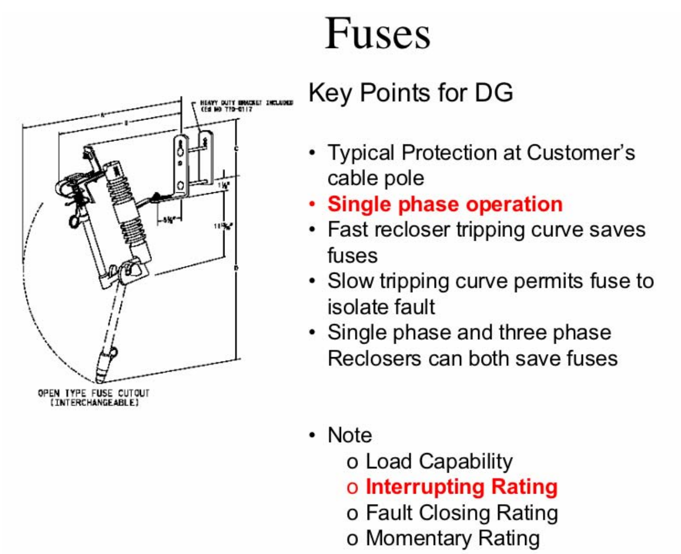
Single Phase Recloser Timing Diagram

The preceding figure shows a timing diagram for a single-phase recloser as it goes through a sequence of operations for a bolted fault. The following figure shows a timing diagram for a three-phase recloser.



Three-Phase Recloser Timing Diagram

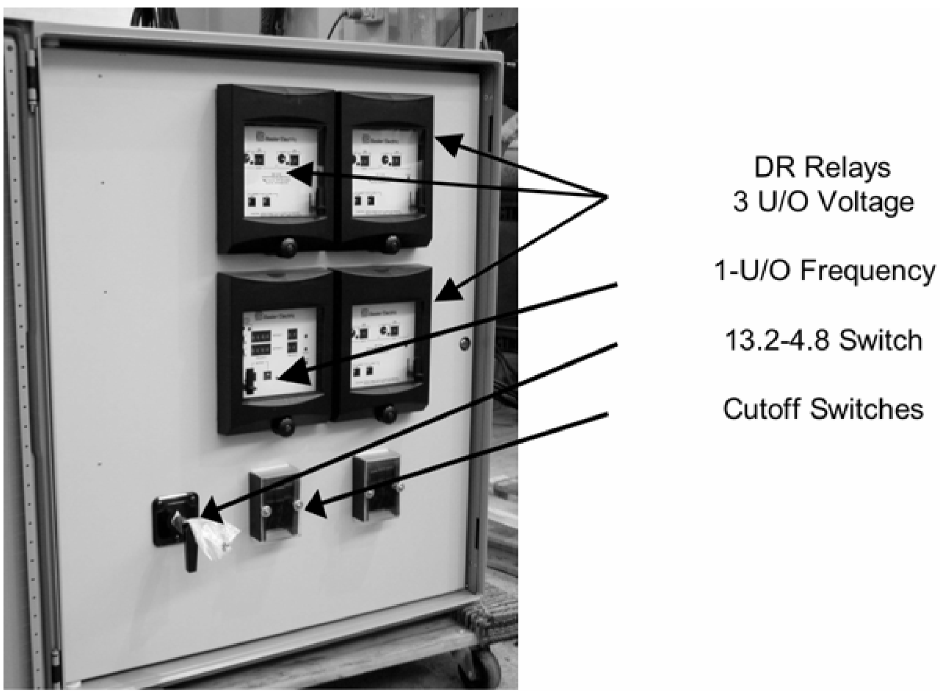
The following figure shows a typical expulsion fuse. The interrupting rating for this type fuse is typically 8000 amps. An electric utility will have thousands of these devices in service.



Fuses: Key Points for DER

Relays: Key Points for DER

- Accept voltage and/or current input
- Under/over voltage
- Under/over frequency
- Reverse power
- Overcurrent
- Directional overcurrent
- Timers
- Note: Load capability, adjustment range, power supply voltage

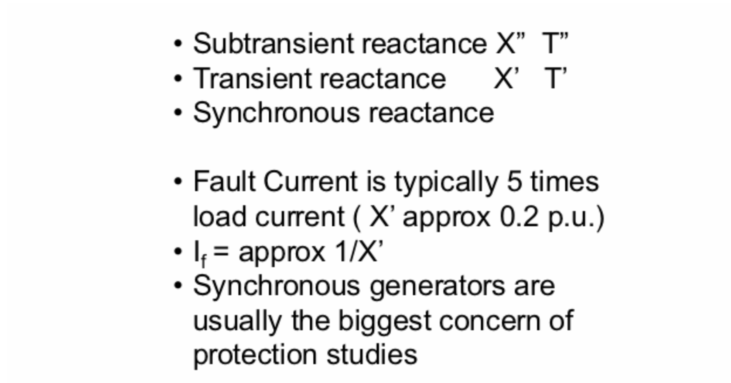


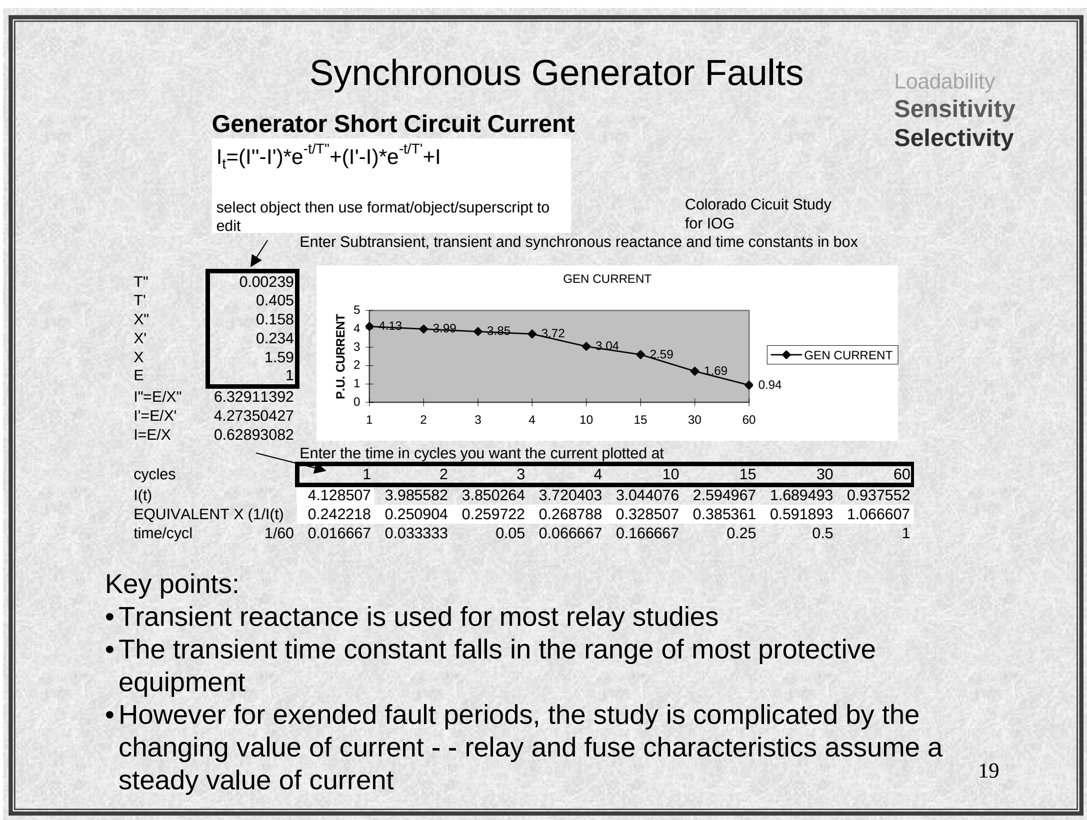
Relays

Field personnel must be familiar with devices being tested. There is limited manpower to develop and provide training as new devices become available. Maintaining a list of approved devices provides assurance that the devices operate as expected and that engineers can correctly specify a setting and the field personnel can apply the setting.

Synchronous Generator Fault Characteristics

Synchronous generators are rotating machines whose rotor speed determines the frequency of the output voltage. Synchronous generators are usually the biggest concern of protection studies.





Synchronous Generator Faults

The chart and equation in the figure above show the time varying short circuit current output of a synchronous generator. The parameters in the equation are:

X” Subtransient reactance

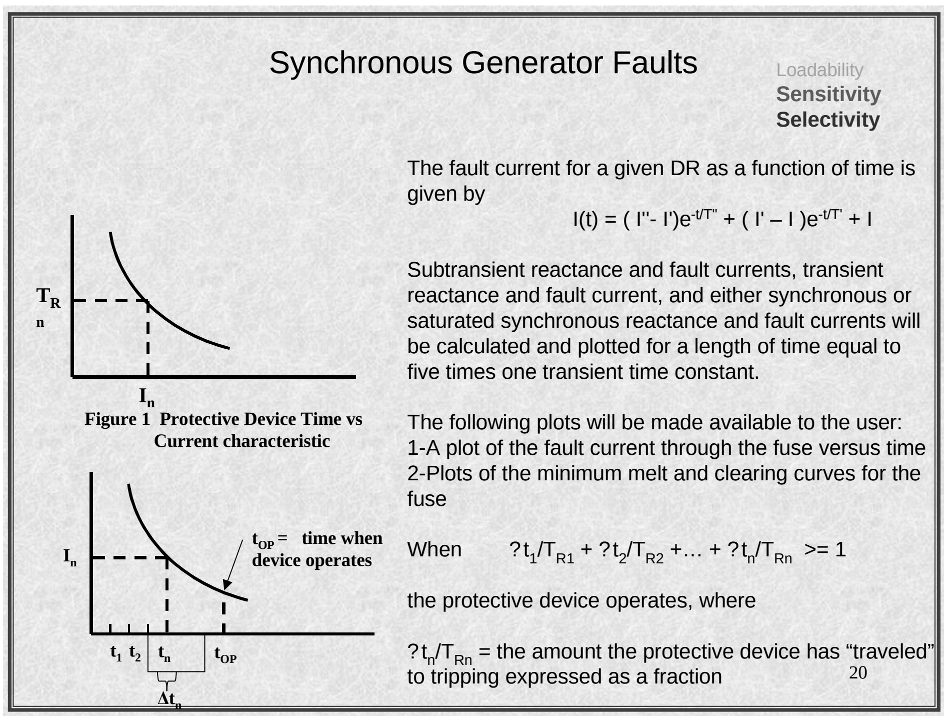
X’ Transient reactance

X synchronous reactance

T” Subtransient time constant

T’ Transient time constant

The reactances are per unit quantities based on the generator rating. The time constants are in seconds. Note that the current decreases to less than 1 pu in 60 cycles.

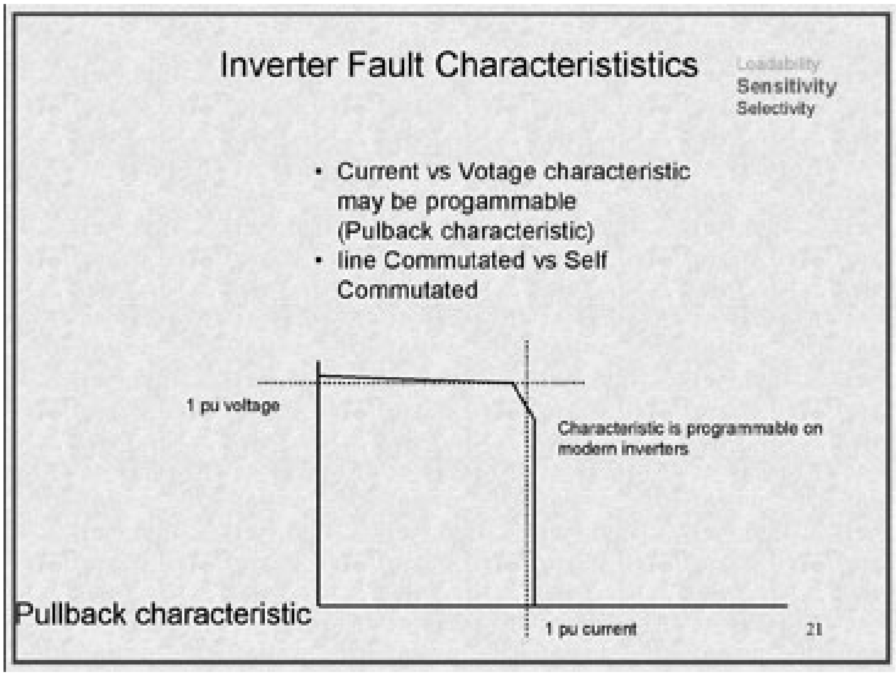


Synchronous Generator Faults: Determining Time Required to Blow a Fuse

Because the current from the generator is varying with time, determining the time required to blow a fuse is not a straightforward process of entering a fuse characteristic time curve at a single current and reading the associated operate time.

An integration process must be used. The decaying generator current is divided into time segments. The smaller the segments, the more accurate the calculation.

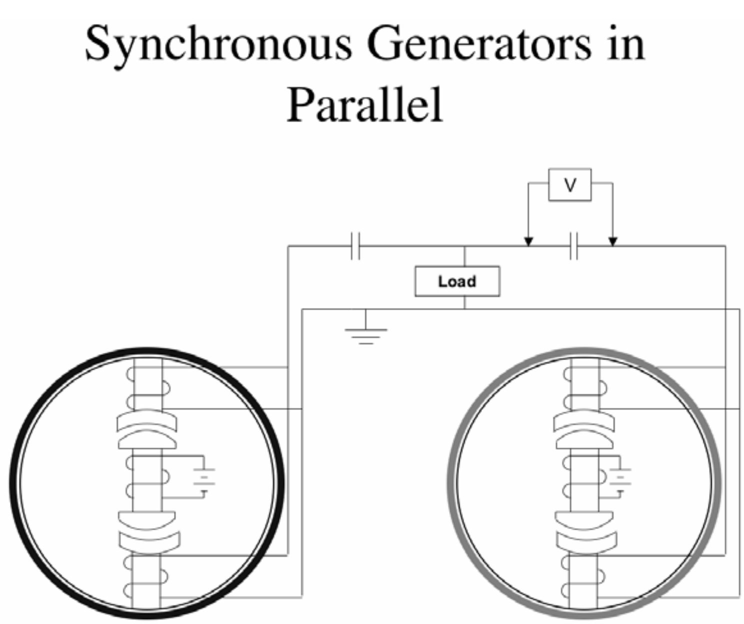
A current is determined for each of the time segments. For each time segment, the current and associated time is plotted on the fuse characteristic. The ratio of the time segment length to the time it takes to blow the fuse at that current is determined. This is the amount of “travel” that the fuse has made towards blowing. The ratios for all the segments are added to determine if the sum of the ratios totals 100%. If the ratio sum gets to 100%, the fuse blows. If it never gets to 100% then the fuse does not blow.



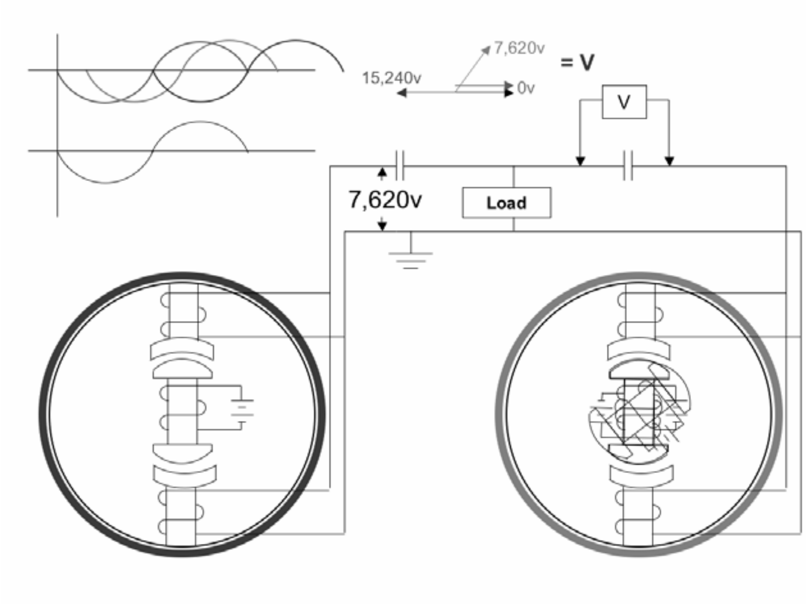
Inverter Fault Characteristics

Line commutated inverters rely on the source from the utility to provide var support and a frequency reference.

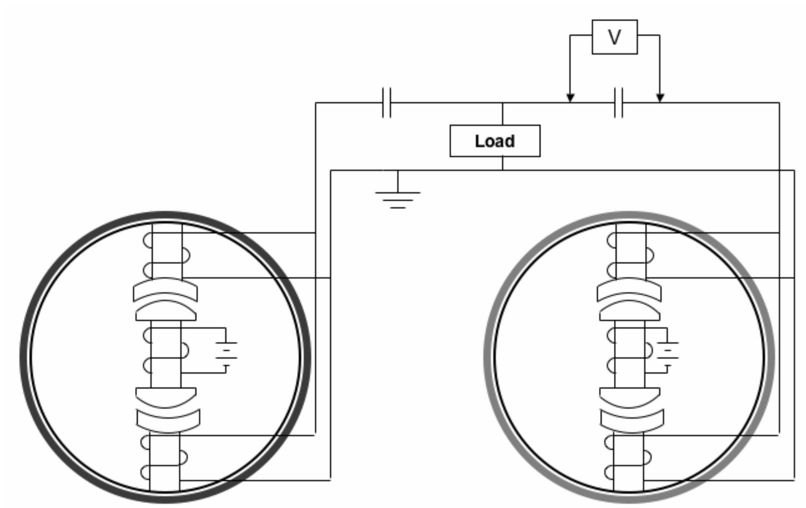
During fault conditions, inverters will typically provide about 1.1 times the full current rating of the unit. This maximum value is limited by the inverter's control circuitry or control software.



Synchronous Generators in Parallel



Synchronous Generators in Parallel



- Increase field current to increase output voltage
- Increase torque to increase power output

Synchronous Generators in Parallel

Synchronous Generator Loading Adjustments

- To increase load (generator power output), increase torque applied by prime mover
- To increase reactive output (generator var output), increase field current

After the generator is synchronized to the system, power output of the generator is increased by applying additional torque to the generator. In the case of a steam turbine, more steam is allowed into the turbine by opening a valve. The additional torque applied to the generator shaft will increase the relative phase angle of the generator's output. Because the impedance of the system between this local generator other generators on the system is largely inductive, power flowing from this generator increases as this relative phase angle increases.

In the case of an internal combustion engine, more fuel is permitted to flow to the engine. This is similar to what happens when one steps on the accelerator pedal in a car.

Reactive output of the generator is increased by increasing the field strength. This increases the voltage output of the generator and causes more reactive power to flow out of the generator. The higher voltage will cause increased var flow through the connecting impedance of the EPS, which is largely inductive.

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ELECTRIC POWER RESEARCH INSTITUTE
3420 Hillview Avenue, Palo Alto, California 94304-1395 • PO Box 10412, Palo Alto, California 94303-0813 USA
800.313.3774 • 650.855.2121 • askepri@epri.com • www.epri.com