Welcome to Module 15, which discusses the importance of Power Management.

Power Management is important to our customers because it 1) Saves money, 2) Helps them produce a quality product, 3) Protects equipment and personnel while reducing downtime caused by electrical outages, and 4) Allows them to share best practices among facilities.

To accomplish these goals, we will focus on four areas within power management: Energy Management, Power Quality, System Reliability & Uptime and Information & Integration.

After completing this module, you should understand what power management is, why power management is important, and be able to offer various solutions to help a customer develop an effective power management plan.

Like the other modules in this series, this one presents small, manageable sections of new material followed by a series of questions about that material. Study the material carefully, then answer the questions without referring back to what you’ve just read. You are the best judge of how well you grasp the material. Review the material as often as you think necessary. The most important thing is establishing a solid foundation on which to build as you move from topic to topic and module to module.

**A Note on Font Styles**

Key points are in bold.

*Glossary items are italicized the first time they appear.*
# POWER MANAGEMENT

## WHAT YOU WILL LEARN

We will step through each of these topics in detail:

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For nearly a century, the reasons for monitoring electricity and the tools used by industrial, commercial and institutional facilities remained relatively unchanged. But in the last several years, important changes have occurred in the way electricity is used, the electrical utility regulations and the technology available to meter this resource.

Users of electricity have always had the need to meter basic electrical parameters — voltage and current. The earliest needs to monitor voltage were to ensure the electrical supply had the capacity and stability to power the load. Monitoring amperage (current) ensured conductors were appropriately sized and that the load was not being damaged by excessive current. As centralized power generation grew and power distribution systems within industrial and commercial buildings became more sophisticated, the reasons for metering also grew. Electricity customers were becoming interested in the amount of electricity they were using (watts) and how efficiently they were using electricity (power factor).

Until the early 1980s, electrical meters were all electromechanical devices. They took advantage of basic electromagnetic principles to cause a pointer or needle to move (ammeter and voltmeter) or a disc or rotor to rotate (wattmeter), proportional to the parameter being measured. Although there were advances in the quality, cost and capability of the meters manufactured, the basic design and operation remained unchanged.

Advances in the microprocessor industry changed the way we all live and work. The term “personal computer” went from science fiction to commonplace. Microprocessors became common components of just about everything. Everybody was going “digital.”

The earliest usage of microprocessors in the electrical power distribution market was in circuit protection and metering equipment. One digital meter could take the place of several electromechanical (analog) meters. An electronic switchboard meter could save the switchboard OEM or the end user time, money and space. When comparisons between analog and digital meters included mounting, wiring, layout and stocking expenses, the cost savings became even more apparent.

However, the recent high growth in the electronic metering business is no longer being fueled by simple analog to digital conversions. Electricity users now need better, more timely data to make decisions and take actions that will increase overall productivity and profitability. They need to develop power management programs.

The first factor in an effective power management program is energy management.
Energy management is the ability to optimize energy consumption. The first step is to understand the amount of energy consumed within a typical facility. The second step is finding out where the energy is being used. The third step is learning to use this information to take action to reduce costs. Energy data can be used to determine which energy supplier to choose, which practices are most cost-effective, highlight processes and machinery which require rework to become more energy-efficient, and encourage tenants or departments to reduce energy consumption by making them accountable.

Energy costs can be a substantial portion of a user’s operational expenditures. In some industries, energy costs exceed labor costs, which are generally a company’s second highest overall cost. From a financial standpoint, energy is typically treated as overhead with little effort made to identify how, when, why and by whom the energy is being used. Strategies exist for just about every other type of commodity (such as material or labor) to measure, account for and recoup costs. Development of an energy management plan will help identify energy cost and its effect on the facility’s operating budget and the unit cost of their product. This awareness, and the steps taken to decrease energy usage, can increase profitability.

One of the most effective ways to begin the development of an energy management plan is to measure and verify energy usage. In most facilities, the only energy measurement tends to be the meter supplied by the power utility. This meter is there for one purpose — to know how much to charge the facility for power usage. This meter does not provide the details (the when and where) to be of value in an energy management effort.

So, the first task in energy management is to measure energy usage and develop a facility load profile. A facility load profile is a chart that shows the quantity of energy used over time (day, week, etc.). Knowing this information is the first step to becoming a smarter consumer and negotiator for energy-related services (called supply-side management). It is also the first step in using energy more efficiently (called demand-side management). In a typical facility, many loads consume energy, however, before one can implement an energy management plan, one has to be able to determine what is consuming that energy and when. Once consumption patterns and trends are known, energy management programs can be developed.
Knowing energy consumption patterns is even more critical today because of Electric Utility Deregulation. The Energy Policy Act of 1992 is dramatically changing the utility industry. It removes the geographical restrictions of where a utility can sell its products. The act also allows for retail competition, which will enable educated customers to negotiate for better energy rates.

In a deregulated marketplace, electricity will be sold based upon power blocks, real-time pricing and power quality levels. Power Brokers will emerge offering bundled energy products of electricity, natural gas, steam and other energy-related products. These combined purchasing options may allow the customer to negotiate a lower rate.

Energy Service Companies (ESCOs) will offer a broad array of services, including power system management, energy auditing, consulting services and performance-based contracting. Developing a power profile will provide users with the critical information needed to effectively negotiate the best utility rate structure for their needs.

To not only survive power deregulation, but also take advantage of its benefits, energy users must carefully analyze their current energy usage. They will need to identify available discount rate structures from various suppliers and note any penalties a supplier may impose based on certain consumption or quality parameters. Energy users will need concise data to determine their power profile and avoid those penalties.

Once the user installs a permanent measurement and verification system, all of this data is available. If you can’t measure it, you can’t manage it.
Energy Charges Explained

An important factor in developing an energy management plan is understanding how utilities charge for the power consumed. As part of federal and state energy conservation plans, utilities are being required to service their customer’s demand for power, without building additional generating plants. Many utilities are focusing on managing their load demands by promoting conservation, shifting loads to lower usage periods and leveling demand spikes. To encourage their customers to assist them in the process, utility bills typically have different rates for usage at different times of the day.

![SP & L

SOMEBODY’S POWER & LIGHT

<table>
<thead>
<tr>
<th>METER NUMBER</th>
<th>READING DATE</th>
<th>READING PRESENT PREVIOUS</th>
<th>METER CONSTANT</th>
<th>USAGE</th>
<th>ACCOUNT NUMBER</th>
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<tr>
<td>T3874</td>
<td>SEP 8</td>
<td>6912</td>
<td>6420</td>
<td>1400</td>
<td>688800 kWh</td>
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RATE SCHEDULE LGS AUG 6 – SEP 8 33 DAYS METERED SERVICE

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<tr>
<th>BASIC CONNECTION CHARGE</th>
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<tr>
<td>ENERGY CHARGE</td>
<td>$25,444.272</td>
</tr>
<tr>
<td>DEMAND CHARGE</td>
<td>$16,728.750</td>
</tr>
<tr>
<td>PEAK kvar 1,426 – (1,487 X 62%)</td>
<td>$201,524</td>
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<tr>
<td>TAX &amp; SPECIAL CHARGES</td>
<td>$1,336.06</td>
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TOTAL DUE $44,181.61

FIGURE 4: “UTILITY BILL” OF A SMALL-SIZED ASSEMBLY PLANT

The Basic Connection Charge is typically based on the voltage of the service and the overall magnitude of the energy used. If the building uses the power as it is supplied by the utility, called the transmission voltage, the cost is often lower. If the utility has to use transformers to supply power at lower voltages than the transmission voltage, it will cost more. Some large facilities will use the transmission voltage and supply their own transformers to reduce the voltage to suit their needs throughout the facility.

The Energy Charge is shown in kWh (Kilowatt-hours) and reflects the raw energy used. If we look at the present and previous meter readings, we see 492 units used, with a meter constant of 1400, giving us our usage of 688800 kWh.
The Demand Charge (shown in KW) represents the utility’s way of passing on the cost of maintaining the generating capacity required to service their entire customer base. The utility defines a time window, and measures the amount of energy demand (kW) within the interval. They may measure the demand in 15-, 30- or 60-minute increments. The charge is based upon a peak demand (the highest average in any window).

Peak demand is the largest energy reading detected within the period for a month. To meet higher demand values, the utility may require additional capacity equipment or may need to buy the extra power from another utility.

The relatively costly demand charge ($11.25 per kW in this case) is designed to encourage demand leveling by the customer to save money. However, since this bill is for the entire facility, the customer does not know where the higher demands are consumed, or which loads may be consuming large amounts of energy at the same time. With an energy management program, the customer could very possibly identify high-demand loads and implement programs to reduce the overall demand within a facility. Once a plan is in place, a company could consume many more kWhs of energy and still have a lower overall energy bill by leveling out the demand.

The kvar, or power factor charge, is implemented by the utility to compensate for the power required to “energize” the system, but is not measured in the kWh or kW charges.

Supply-side management involves rate negotiation, on-site supply sharing to reduce energy costs and verification of the utility bill. If users were to shift loads to other times of the day, the peak demand would naturally fall. For that reason, many utilities offer seasonal, weekday/weekend, holiday and off-peak rate schedules. Careful energy management allows a customer to take advantage of the best rates and avoid the penalties of the higher rates.

Many utilities offer interruptible rate plans. These plans allow the utility to interrupt a block of power to the customer when overall demand exceeds the utility’s capacity. Another supplier-based technique involves paralleling the customer’s genset with the utility. When the utility is running low in capacity, instead of interrupting a facility, they may ask the facility to power on their gensets and supply the utility’s grid for an amount of time. This could benefit the customer one of two ways: (1) the utility actually purchases the power provided by the on-site generator or (2) the customer receives better rates from the utility. This is a form of distributed generation, a term used to describe locating the generation source near the load.
Another procedure, which takes advantage of an on-site generator, is peak shaving. **Peak shaving** is helpful when the customer’s peak demand is approaching the threshold demand value where cost increases considerably. An **on-site generator could supply part or all of a facility, thereby leveling utility demand.** The important question for the customer is whether the cost to run the generator is more or less than the price of the utility’s power at that point in time.

**Demand-side management** is when the user takes action to lower the energy consumption within their facility. Methods that customers can use to lower energy consumption include:

- Shifting loads to off-peak periods. Non-critical processes that can be run overnight or on weekends rather than during the normal business day.
- Scheduling large loads to start at different times. By delaying the start of a large load for as little as 15 minutes, peak values will be reduced.
- Installing adjustable frequency drives on variable torque loads such as **HVAC** compressors. (See Distance Learning Module 20 for information on Drives).
- Using specially designed motors and transformers for higher efficiency.
- Retrofitting ballasts and lighting for lower cost and higher efficiency.
- Installing lighting control systems.
- Peak shaving.

The key to implementing a successful energy management plan is measuring and verifying the consumption data.
This silicon chip manufacturer instituted demand leveling by shifting the start times of his 12 machines.

The 4-step process of each machine requires high energy during the initial melt process, less in the next cycle, still less in the third cycle, and very little during the final cooling cycle.

By shifting each of the machines to start later in the cycle than the previous machine, they were able to reduce their peak demand from 3300 kW to 1800 kW. This reduction resulted in a saving of $18,000 per month, or almost $200,000 per year.
As we have discussed, before an energy management program can be developed, an evaluation of the current usage must be made. A permanently installed measurement and verification system will provide detailed information on a continuous basis.

One way to do this is to install a revenue class meter that can provide information on usage trends, peak demands and power quality. This data can allow the user to verify utility bill accuracy, determine historical consumption for rate negotiation and investigate the distributed generation and/or peak shaving potential. **Money is saved when action is taken based on the evaluation of that data.**

A user can take this metering approach further by integrating submetering, a low cost system of energy meters strategically located throughout the facility. **By using submeters, energy consumption can be measured in greater detail,** down to even the smallest loads. Submeters also **allow for accurate allocation of energy costs to the departments or tenants using the energy.**

Software tools are available to assist in creating an effective energy management program:

- Energy trending software can graphically identify usage trends by meter or energy user over specified time periods.
- Energy billing software verifies utility bills and enables allocation of energy costs to tenants or departments.
- Energy tracking software can be used to establish an “energy cost per piece” by tracking production costs on a per unit basis.
- System monitoring software can provide real-time monitoring of the entire distribution system. It can provide early warning if demand values are about to be exceeded. It can provide proactive management of power consumption and compliance with the energy management plan.
1. Utility metering is not an effective tool for establishing an energy management plan.
   
   TRUE  FALSE

2. Peak Demand represents the amount of generation capacity a utility must have to service their customers.
   
   TRUE  FALSE

3. _________ management involves rate negotiation, on-site supply sharing to reduce energy costs and verification of the utility bill.

4. One type of supply-side program is when the utility asks a user to power on their generators and supply the utility’s grid for an amount of time.
   
   TRUE  FALSE

5. Peak shaving is: ____________________________

6. When a user takes action to lower energy consumption, it is called _________ management.

7. Submetering can provide a method for accurate allocation of energy costs.
   
   TRUE  FALSE
Power quality is a sweeping term used to cover a variety of disturbances and distortions to a power signal. Poor power quality may have a negative effect on both the power distribution system in a facility, and on the loads being powered. The Institute of Electrical and Electronic Engineers (IEEE) defines power quality as “The concept of powering and grounding sensitive equipment in a manner that is suitable to the operation of that equipment.”

Poor power quality can cause expensive downtime costs. If equipment is damaged by the disturbance, it must be repaired or replaced, and production is halted. In addition, there is potential for an entire assembly of equipment to require restarting. Electronic equipment is especially sensitive to variations in power quality. Automatic controls may lose their memory, requiring reprogramming and creating process or facility downtime.

Outages of even less than 1/10 of a second can result in hundreds of hours of data being lost. Imagine a power “blip” to an office building with one hundred people using computers. Poof! All of that data, gone in a blink! Some people might have been saving their files often, but you can figure everyone is going to lose an average of at least five minutes worth of work. That works out to over 8 hours of lost data and productivity.

The powering of sensitive equipment with protective devices and proper grounding can save you inconveniences from power distortions. It can be as simple as applying surge suppression devices into the electrical distribution panel and at sensitive loads. It can also be a facility-wide, sophisticated monitoring system to warn of imminent power quality disturbances. Before we discuss some of these monitoring tools and options, let’s take a closer look at the types and causes of these disturbances and distortions.

A power quality disturbance can range from a microsecond to constant steady state. A microsecond may not seem like a long time to you and I, but to a delicate piece of electronic equipment, it is a lifetime! Power quality disturbances can be caused by forces of nature, equipment START/STOP cycles or distortion inducing devices.

There are some very common disturbances which can affect a system. These include:

- Transients or surges
- Multi-cycle voltage variations
- Noise Distortion
- Harmonics

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1 IEEE 1100-1992
Transient or surges are usually sub-cycle increases in voltage. A common usage term for transient is voltage impulse. There are several sources for these transients:

- Lightning
- Switching loads (capacitive and inductive)
- Short circuits
- Variable speed drive operation
- Imaging equipment operation (photocopiers and scanners)
- Arc welders
- Light dimmers

Transients are of short duration (.5 – 200 microseconds). They can be impulse, (single surge) or oscillatory (ringing) in nature. They make circuit breakers trip, solid-state items fail (or become damaged), and they corrupt data in microprocessors. The use of lightning arrestors, surge arrestors and voltage surge suppressors help alleviate some of the problems caused by transient surges.

A curve has been designed by members of CBEMA, the Computer and Business Equipment Manufacturers Association, to provide a guideline giving a range of voltage levels versus time in which equipment will operate satisfactorily. The presence of voltage variations in a power line, such as transients, could greatly affect the operation and life of equipment.
After a violent thunderstorm, the facility manager at Eaton Corporation’s Westerville, OH facility was greeted by several firefighters with their axes drawn. The automatic fire alarm system sent out a false signal when induced lightning entered the building through the HVAC system. In that split second, tens of thousands of dollars in electrical and electronic equipment were destroyed.

The facility manager decided that surge suppression needed to be installed as part of a complete facility-wide power protection plan. A small investment to prevent future expensive damage.

**FIGURE 10: FACILITY-WIDE PROTECTION AN INVESTMENT**

Undervoltage and overvoltage conditions can be caused by large loads turning on or off at one time. A sag in voltage can be caused when several large motors start at once. Faults in distribution systems or utility equipment malfunctions may also cause sags. Swells are often caused when there is a sudden load decrease. Single line-to-ground faults or switching on large capacitor banks may result in swells or overvoltage conditions.

The duration of sags and swells is generally between 1/2 and 120 cycles. They can cause computers and PLCs to shut down or lock up in a program, motors to stall, contactors and relays to open, voltage arcing and component failures. Sags affect operating coils of motor starters which are designed to drop off-line at less than 85% voltage. The use of voltage regulators, power line conditioners and uninterruptable power supplies (UPS) can solve these problems. Custom power products which utilize power electronics are becoming viable solutions to mitigate voltage sags and interruptions.

**Noise distortion is unwanted electrical signals** on the steady-state voltage waveform. Radio frequency interference (RFI), produced by communication system components, can contribute to system noise. Have you ever experienced static on your TV caused by a CB radio right outside your house? That is an example of RFI. Single filters or combinations of multiple filters can decrease noise in a line to increase the quality of your power.

Another form of noise is brought about by the differences in ground potentials throughout an electrical system. The surge suppression, wiring, shielding and grounding of the building’s electrical system, including communication cabling, can have a pronounced effect on the levels of noise to which electronic equipment is exposed.
Power Quality Disturbances (continued)

Grounding represents the foundation of a reliable power distribution system. **The primary purpose of grounding is personnel safety and equipment protection.** Without good facility grounding, the other power quality solutions cannot achieve their intended results. **The secondary purpose of grounding is to reduce noise disturbances for better electronic equipment performance.** Because of the increased use of network and data communication equipment, proper grounding procedures have become even more important.

All grounding bonds should be inspected and tested annually to ensure a low impedance grounding system. Up to 80% of all power quality problems can be exacerbated by grounding and wiring problems. Loose or corroded connections, improper installations, or high impedance will cause power quality problems.

**Harmonics are becoming more prevalent in distribution systems, due to the increase of harmonic-producing equipment in factory floor and institutional operations.** Traditional loads such as incandescent lamps, motors, resistors and heating elements draw an even 60 Hz current. They are sometimes referred to as linear loads. But, non-linear loads are being applied more often. These include adjustable frequency drives, inverters/converters and electronic lighting ballasts. One very large grouping of non-linear loads are personal computers, fax machines, scanners and photocopiers.

Linear loads draw a pure current sine wave, composed of a 60 Hz component only.

The word “nonlinear” refers to systems that draw non-sinusoidal current, even though the voltage may be sinusoidal. Current harmonics are induced onto the power line by non-linear electronic equipment and systems which operate using switch-mode power supplies that “gulp” current, distorting its waveshape. Voltage distortion typically results from current distortion reacting with system impedance.
Power Quality Disturbances (continued)

Non-linear devices connected to the power system produce signals which may be transmitted at a multiple of the fundamental frequency. For example, if the fundamental frequency is 60 Hz, a multiple is \((7 \times 60 \text{ Hz})\) or 420 Hz.

Harmonics are multiples of the fundamental frequency that, when added together, result in a distorted waveform.

Harmonics operate at the lowest frequency of all the disturbances.

Harmonic distortion can cause electronic control malfunction, nuisance tripping of circuit breakers, inconsistent meter readings and data corruption. It can also lead to overheating of motors, transformers and conductors. Some common ways to mitigate harmonics include the use of harmonic filters and zero sequence traps. Shifting the phases of harmonic currents with phase-shifting transformers can also solve the problem through harmonic cancellation.

We can see the impact that poor power quality can have on a facility. Power quality problems can be overcome with careful system design and distribution products designed to overcome or withstand distortions. Just as we needed to monitor our power consumption in order to develop an energy management plan, we need to monitor power quality to develop a system-wide power quality plan.
**Power Quality Monitoring (continued)**

Monitoring should be done continuously in various locations throughout the electrical distribution system. There will be different monitoring requirements at different locations throughout a facility. Monitoring at multiple locations will allow pinpointing sources of distortion, logging of events and event alarming for impending disruptions. By logging the time various power events occur, important clues about the nature of the power problem can be discerned. Comparing power event logs to equipment event logs may point to the source of the disturbance. Continuous monitoring can also alert you to any degrading performance of equipment within the system preventing unplanned downtime and loss of productivity.

**Products are available to monitor the incoming line power from the utility.** Monitors at the service entrance can measure harmonic contributions and record voltage disturbance events with time stamping. You can determine the overall power quality of the facility.

**Distribution monitoring can locate problems within the facility.** Devices can measure power quality including voltage/current levels and harmonic values. Additionally, they can set off alarms when systems are at voltage and current thresholds. Feeder protectors such as low voltage electronic trip units and protective relays may also offer power quality monitoring capabilities.

**Software is available to analyze the data gathered, determine the cause of power quality situations and display trends.** The software can tie together all of the data to help produce a fully integrated power quality and energy management system.

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**IN THE WORKPLACE**

A drilling operation in Northwest Texas used two variable speed drives (VSD), each protected with separate surge protection devices. One afternoon, the 12.47 kV aerial line feeding the site took a direct lightning strike. While the lightning arrestors took the brunt of the energy, enough energy was diverted downstream to the VSDs. VSD#1 was destroyed, yet VSD#2 continued to operate.

A physical investigation later showed that the grounding conductor between the VSD#1 cabinet and the ground rod was missing. This oversight caused a day’s loss of production and $15,000 in equipment damages. The grounding connection of VSD#2 was fine and there was no loss of production.

**FIGURE 16: GROUNDING IS KEY TO EQUIPMENT RELIABILITY**
1. Electronic equipment is especially sensitive to variations in power quality.
   
   TRUE  FALSE

Match the distortion term to the correct statement:

2. Transient or Surge  _____ Frequency multiples of current or voltage added together
3. Sag  _____ Short duration decrease in RMS voltage
4. Swell  _____ Unwanted electrical signals on line
5. Noise  _____ Short duration increase in RMS voltage
6. Harmonics  _____ Voltage impulse
System reliability and uptime can mean different things to different users. It may differ by industry requirements, corporate profitability goals or servicing client needs. We will take a brief look at the importance of reliability and uptime from several aspects. We will discuss the key contributing factors and some ideas to help customers achieve high system reliability and reduce their downtime costs.

These important contributing factors include:

- Costs associated with reliability, such as ownership and downtime.
- Power availability, including system design and power providers.
- System reliability and coordination for safety and damage avoidance.
- Need for predictive diagnostics and ease of maintenance.

One of the major costs involved in providing reliability to a system is defined by the term: **total cost of ownership.** It examines the aspects of overall cost versus return on investment in developing system reliability. These aspects include:

- How much will it cost to design the system?
- What tradeoffs are acceptable in the evaluation process? Do you rule out a redundancy system because of high cost or does an outage cost you more?
- What does the necessary equipment cost?
- What does it cost for installation?
- What is the maintenance cost, how often will it be necessary, and can it be planned for on a regular basis to reduce that cost?
- What is the expected lifetime of the system and how soon will it pay for itself (therefore producing the return on the investment)?

In an effort to begin to answer these questions, a user needs to define why uptime is important and how much downtime can cost them.

Some large users in differing industries have reported what uptime means to them:

- Paper Industry — Maximizing output per working hour.
- Automotive Industry — Up and running, all the time, no excuses.
- Steel Industry — Maximizing return on investment.
- Petrochemical Industry — Measurement of actual operational time.
Downtime costs can be measured by:

- Lost revenue — measured in $$$ per day, could be in millions per day.
- Lost profitability — incremental production per-piece-costs.
- Unexpected repair expenses — could preventive maintenance have helped?
- Lost opportunities — inability to perform now = future business lost.

The magnitude and impact on the business needs to be determined so a plan to decrease downtime/increase uptime can be cost-effectively designed.

Two essential influences on whether power will be available, at any given time, are the design of the electrical system and the provider of the power. We will look at system design first.

One distribution system design is referred to as a **simple radial system** because a single primary feeder supplies a single transformer, protected by an overcurrent device, which supplies all of the loads. Most electrical services are of the simple radial design, including residential service. These systems can be of high ampacity such as 5000 amperes, down to 100 amperes. **The loss of the primary feeder or transformer causes an outage to the entire facility.** In some cases, a fault downstream of the main protective device can also shut off power to the whole facility.

The radial system is the least expensive distribution design. If the magnitude and impact of the downtime costs are not severe, then it may be a good choice for a given facility.

**To add reliability to this system, a standby on-site method of power generation can be used.** A diesel generator and automatic transfer switch is the most common approach.
A closed transition automatic transfer switch (ATS) can be used to eliminate power outages during planned transfer of load to the generator. Adding an uninterruptable power supply (UPS) can prevent outages when utility power is lost and before the generator is up and running.

The backup system can be sized to handle the full load of the facility or just the critical loads.

This can be determined upon the user’s needs and the cost-of-ownership tradeoff decision. To counterbalance downtime costs, an energy management plan could include “interruptible” plan or peak shaving involvement to lower energy cost.

Another popular system design is a dual utility, secondary selective service. It is often known as “Double-ended Substations”. In this system, two primary services and two transformers serve loads on a common bus. They are separated by a normally open TIE breaker. If a primary feeder or transformer fails, the main breaker opens, the TIE is closed, and the loads are re-energized. There is only a momentary power outage. Closed transition switching (paralleling sources temporarily) can prevent dropping loads.

In order to accomplish closed transition switching, the devices need to be adequately rated. This can affect future additions to the system to remain within the rating.

Temporarily paralleling transformers is sometimes desired by hospitals and medical facilities. These systems cost more than simple radial systems, but offer better assurance that loads will stay on-line.
Power Availability
(continued)

The addition of a standby, on-site source of power can be added to this system to further improve power reliability. As before, it can be sized to handle the total facility, selected areas or only critical loads. The use of a closed transition ATS will help minimize downtime during planned transfers. A ride-through system can be developed using a UPS.

Another variation on the dual utility, selective system allows for automatic switching from the primary source to a continuously available alternate source whenever there is a system disturbance. Sub-cycle transfer switches with programmable logic detect momentary interruptions, outages, sags and swells. The transfer between sources is accomplished in 4 milliseconds or less.

Typical applications might be data centers, hospitals, semiconductor plants and others where economic need for higher level power quality and reliability exists.
Power Availability (continued)

Spot Network Systems represent the pinnacle of performance, operating at a reliability level rivaling Utility Grid systems from which their primary source comes.

Two or more networkable, in-phase primary circuits of same voltage and phase angle are connected through network transformers to a common low-voltage assembly. Transformer redundancy is usually 50-100% of the total connected load kVA. For example, (3) 1000 kVA units serving a 2000 kVA demand load. If TIE breakers are used, they are normally closed.

Network protectors ensure that transformer secondaries are connected to the load bus only when power flows into the network load bus. Overcurrent protection may be added to use protectors as service mains. Fault current values are comparatively high; therefore, high interrupting breakers are usually needed for feeder breakers in the switchgear. Maintenance of the system is possible without extended outages.

This system provides automatic operation, even when primary cable faults or transformer faults occur. No power outages occur for any load so long as only one event occurs at one time. This is commonly called a “single contingency outage”. Multiple events occur only rarely. The obvious tradeoff for this level of reliability is high cost. However, if you were one of those facilities that must be “up-and-running, all the time, no excuses” this system would be one to look at seriously.

Power Provider

The second key influence to power availability is how it can be affected by the provider of the power. The changing environment brought on by utility deregulation may impact the availability and cost of power in a given area. However, it also offers some new opportunities, especially those involving on-site generation.

On-site generation might be used as the prime power source for a facility in an area that has relatively no electrical distribution. Access to natural gas with an on-site generator would provide a more reliable and less expensive means than installing a new radial distribution line. As discussed earlier, standby generation can be used in utility interruptible programs, distributed generation and peak shaving.

Deregulation has also brought about “performance based energy contracts.” Users and providers negotiate contracts that promise power delivery and a share in the cost savings for implementation of energy saving programs.
When looking at system reliability and availability, concern for personnel safety and minimizing damage to the electrical equipment play an important part. Throughout any electrical system, there are many protective devices of varying size and capability. Devices, such as HMCPs, molded case circuit breakers and fusible switches, protect branch and motor circuits. Power circuit breakers and insulated case breakers are used to protect power distribution circuits.

A system’s reliability is affected by the coordination or selectivity of all of these breakers. Selectivity involves choosing protective settings to ensure that the breaker closest to a fault responds first, before others can nuisance trip. Breakers also impact reliability by their withstand and continuous current ratings, their speed of operation and their ease of maintenance.

Proper coordination between upstream and downstream breakers means devices are able to clear faults and isolate problems without blackout effects reaching the rest of the site. (See Modules 6, 7, 7+ and 8 for more information.)

Preventive maintenance is a planned activity that uses visual inspection, manual testing and corrective action to prevent equipment damage and future unscheduled outages. It generally means taking a system off-line during the entire process. Since it is planned, it does not cause any “nasty surprises”, but it is still an inconvenience to shut down the system.

A Predictive Diagnostics program uses measuring and trending against known limits or specifications to detect, analyze and correct problems before failure occurs. This takes preventive maintenance a step further. Sensors and monitoring equipment are used to gather data on particular devices throughout the system. Knowing how many times a circuit breaker has tripped can be compared to its mechanical life rating. This will supply data immediately to know if the breaker will work in the immediate future. By trending how often a particular breaker trips, and combining this data with how many trips have occurred so far, the customer can predict when the breaker’s mechanical life will be exceeded. Replacement or maintenance can take place based on predictable need rather than arbitrary scheduling.

An example of predictive maintenance can be demonstrated with a car. It is wise to periodically check the level of oil in your car. The indicating stick tells you whether you should add more oil at this time. An organized person will check their oil on a scheduled basis. However, checking the level does nothing to advise you of the quality of your oil. Oil temperature, viscosity and metallic residue affect the quality to the point where the oil should be changed. Many people rely on a date or mileage parameter to make this decision (i.e. every three months or 3,000 miles).
Newer vehicles are equipped with sensors that log the temperature, pressure, viscosity and so forth. When the values for these exceed or go below a threshold value, a light on the dashboard alerts you to the need to get your oil changed, well before damage occurs. Unnecessary change outs based on an arbitrary parameter are eliminated. Predictive maintenance is based on data and need.

In a distribution system, many elements can be part of a predictive maintenance program. Transformers can be monitored for current flow and temperature changes, the insulation medium can be analyzed, and a spectrum analysis can be performed. Circuit breaker electrical and mechanical life can be monitored and analyzed based on number of interruptions, operations and operating conditions. Cable runs can be monitored for insulation breakdown, ground leakage current and other anomalies. Induction motor loads can be reviewed for voltage or current unbalance, speed/slip differentiation, temperature imbalance and total runtime. **Maintenance needs can be predicated, scheduled on need and implemented with a minimum amount of downtime.**

A cereal manufacturer needs to use a corn syrup coating to add fancy colors and flavors to its popular children’s product. However, their conveyors were becoming continually stuck due to this sticky confection.

That was wreaking havoc on the motors driving the conveyors. The lines would shut down on an overload condition, the batch scrapped, and everything would be cleaned off.

By monitoring the electrical parameters of the conveyor motors, overloads could be predicted. Conveyor cleanings could occur on a planned basis, before all that crunchy sticky delight could burn out a motor.
Ease of Maintenance

We have been looking at the issues involved in preventing downtime, especially unexpected downtime, equipment damage, and personal injury. Maintenance is necessary, no matter how the decision is reached as to the “when”. Nevertheless, there are ways of making it safer, easier, more accurate and less expensive.

Maintenancing a circuit breaker energized with 480V or greater can be a little nerve-wracking. If you are unsure whether the system is on-line or off-line, or you are worried about causing a lengthy outage, the pressure is on. Personal safety is always an issue when working on equipment.

Testing may be required for establishments who are funded or federally related. Hospitals must run emergency generator systems a minimum of 30 minutes every 30 days under normal load conditions. Results must be documented, and is often done manually leading to errors. The Environmental Protection Agency (EPA) has requirements for companies regarding environmental issues. Non-compliance could land an owner in jail or paying large fines.

A facility may encompass several buildings that each require monitoring. For example, a military facility has over 200 barracks. Two employees must travel to each barrack, each month, to check on the electrical equipment. The result is a two-day job for two employees — very costly and time consuming.

**One solution to all of these situations is to develop a power monitoring system.**

It can provide:

- Real-time continuous monitoring
- Analog alarming
- Remote data gathering
- Remote device set point adjustment
- Power system coordination
- Trip diagnostics and sequence of events
- Accurate documentation

A power monitoring system consisting of metering and protection devices, a PC as a master station, software and a communication network can be used in a single facility, multiple building complex or a remote location facility.

A performance profile for each piece of equipment can be created. When a change from the profile is noted by an alarm, real-time data can be documented and checked to determine the problem and cause. Maintenance can be scheduled as needed — before the problem causes system downtime.
Remote data gathering reduces labor costs, errors and dangerous situations. Diagnosing can be done from the convenience of the PC; testing setups can be on file for easy reference and duplication.

A graphical display of the data can be used to see at a glance any problem locations.

Another solution to making maintenance easier, safer and less costly is the distribution products themselves. Devices should have terminals that are easily accessible, visual indicators for wear and status, easy to install accessories. Devices that have through-the-door designs, side secondary wireways and communicating trip units can increase personnel safety.

We’ve seen how system reliability and uptime are of major impact on any facility:

- Costs of lost output, information, customer contract compliance or opportunities
- Costs of scrap, rework, an idled labor force, repair of damage equipment
- Costs of higher utility rates, non-compliance fines, wasted man-hours.

As we’ve discussed here, there are solutions available to minimize the risk, contain outages when they happen and ensure a rapid return to uptime.
Answer the following questions without referring to the material just presented. Begin the next section when you are confident that you understand what you’ve already read.

Match the power system term to the correct statement:

1. Simple Radial
   ____ Two or more networkable, in-phase primary circuits of same voltage and phase angle are connected through network transformers to a common low-voltage assembly

2. Double-Ended Substation
   ____ Automatic switching from the primary source to a continuously available alternate source whenever there is a system disturbance

3. Dual Utility, Primary Selective
   ____ If a primary feeder or transformer fails, the main breaker opens, the TIE is closed, and the loads are re-energized

4. Spot Network
   ____ A single primary feeder supplies a single transformer, protected by an overcurrent device, which supplies all of the loads

5. Proper coordination between upstream and downstream breakers means:
   ________________________________________________________________
   ________________________________________________________________
   ________________________________________________________________

6. Predictive Maintenance takes place based on predictable need rather than arbitrary schedule.
   TRUE    FALSE
In this section, we are going to look at some of the methods available for communicating information. A communication system can be as simple as connecting a monitoring device to a single computer. Or, it can be as complex as sending the information around the world on the Internet through a series of different communication devices and protocols. (Protocols are the communication rules between computers on a network.)

Networks

A network is a series of points or nodes interconnected by communication paths. Networks can interconnect with other networks and contain subnetworks.

A given network can be characterized by:

- The type of data transmission technology in use (for example, a TCP/IP network).
- Whether it carries voice, data or both kinds of signals.
- Who can use the network (public or private).
- The usual nature of its connections (dial-up, dedicated line or virtual connections).
- The types of physical links (fiber optic, coaxial cable and copper wire).

Networks can also be characterized in terms of spatial distance as local area networks (LANs), metropolitan area networks (MANs) and wide area networks (WANs). Large telephone networks and networks using their infrastructure (such as the Internet) have sharing and exchange arrangements with other companies which create even larger networks.

When communication is between two items, such as a monitoring device and a single computer, it is called point-to-point. If the distance between devices is short (less than 50 feet), the connection can be made with RS-232. If the distance is less than 4000 feet, RS-422 or RS-485 can be used. RS-232 and RS-422 can only be used for one-to-one communications. Most personal computers have an RS-232 port for connecting a modem or mouse.
RS-485 allows you to daisy chain up to 32 devices on a single computer. The devices on the system are often referred to as drops or nodes. These three systems (RS-232, RS-422, RS-485) have only a single channel for communication across the cable. Only one device can transmit or receive at a time. If the wiring connection is broken at any point, the entire network fails.

An analogy to this is a single telephone line into your house: only one person can talk at a time. If there are more people on extension phones, each person has to take turns because there is only one line.

RS-485 networks are used in a half-duplex mode, where a single “master” in the system sends a command to one of several “slave” devices in the network. Typically, one device (node) is addressed by the host computer and a response is received from that device. The other slave nodes cannot “listen” to other nodes or respond at any other time.

Connections are generally made using twisted pair cables. Twisted pair cables are available in two configurations: shielded and unshielded. Unshielded Twisted Pair (UTP) is what is typically installed by telephone companies. Shielded Twisted Pair (STP) has an outer covering designed to function as a ground. Twisted Pair is graded according to its data carrying capabilities (Levels 1 through 5). A higher grade (4 or 5) is often used for networks because it is less expensive than coaxial cable. Coaxial cable provides a rugged, protective structure around the communicating signal. Coaxial cable is often used by cable TV and telephone companies to bring their signals to poles near users. It is also widely used on local area networks (LANs).

A LAN is a network of interconnected devices sharing the resources of a single processor or server within a relatively small geographic area, such as an office building or plant. Ethernet is one of the most widely installed LANs. Ethernet was originally developed by Xerox, and then further enhanced by DEC and Intel. The IEEE and ISO have now established standards for Ethernet cabling and signal transmissions.
Ethernet networks have become the worldwide standard for moving information. Industry has recognized Ethernet as a high speed, flexible, low-cost network that is not vendor dependent. Multiple vendors and users can share Ethernet backbone networks. The information can be sent across the plant, or around the world.

The IEEE has established names for the different physical types of Ethernet. The names also help describe characteristics of the network. For example:

- **10Base2** — 10 MHz speed transmission over thin, 50 ohm *baseband* coaxial cable.
- **10Base5** — 10 MHz over standard (thick) 50 ohm baseband coaxial cable.
- **10BaseT** — 10 MHz over unshielded twisted pair (and the most common).
- **10BaseF** — 10 MHz over fiber-optic cable.
- **10Broad36** — 10 MHz running through a *broadband* cable.

There are some limitations to each of these types of Ethernet: cable lengths, number of repeaters, hubs, servers and so forth. However, they are beyond the scope of what we want to cover here.

Ethernet uses a type of transmission called Carrier Sense Multiple Access/Collision Detect (CSMA/CD). Any device on the network can try to send a packet (unit of data) at any time. Since only one device can transmit at a time, they must first check whether the line is in use by another device. If the line is idle, the data can be transmitted.

The packet has a header field and a trailer field that “frame” the data. The destination address, source address and data checks are also included in the packet. If the packet is being sent over the Internet, the Transport Control Protocol/Internet Protocol (TCP/IP) is used.
TCP/IP is a two-layered program. The higher layer, TCP, manages the disassembling of a message, file or data into smaller packets. The receiving unit’s TCP reassembles the packets into the original file. The lower layer, IP, addresses each packet so that it gets to the right destination.

Another means of gathering data is using “smart” devices that communicate on a DeviceNet network. **DeviceNet is an open communication network that interfaces to factory floor automation products for machine control.** The devices can be controlled, configured and monitored by a PC.

You can also integrate power monitoring allowing you to determine energy cost-per-piece and the effects of power quality on the manufacturing process. (See Module 26 for more information on DeviceNet.)

Remote access is the ability to get access to a computer or a network from a remote location. In corporations, people at branch offices, telecommuters and people who are travelling may need access to the corporation network.

**Dial-up connection using a modem over regular telephone lines is a common method of remote access.** A laptop computer with a **PCMCIA card** can connect to the Ethernet network at headquarters from virtually anywhere in the world. Remote access can also be done with a dedicated line between a computer or remote LAN and the main corporate LAN. It is more expensive and less flexible, but it offers faster data rates. **ISDN** is a common method of remote access since it offers dial-up with faster data transfer.
Other means of remote connection include:

- Wireless — radio connection, spread spectrum, microwave and infrared light.
- Cable modem — uses a local cable TV line.
- **DSL** (Digital Subscriber Line) — uses telephone lines but is faster than ISDN.

**A Remote Access Server (RAS) is a computer and software set up to handle remote access to a network.** It usually includes a firewall to ensure security. It may also have a router to forward the remote request to another part of the corporate network. It may include or work with a modem pool manager so that a small group of modems can be shared among a large group of intermittent users.

As you can see, there are numerous ways to create and access a network. There are many more that we did not mention. The ability to access information is key to establishing a comprehensive energy management plan. Using a client/server suite of software products with monitoring devices, protective devices and communication devices allows for the rapid distribution of information and data. With the capability to analyze power quality, manage power costs, track and schedule maintenance, receive an early warning about potential problems, troubleshoot, and increase productivity, you can increase profitability.

![A Fully Integrated System Using Multiple Communication Methods](image)
Answer the following questions without referring to the material just presented.

Match the power system term to the correct statement:

1. Half-Duplex Mode  ____ Open communication network interfacing factory floor automation products for machine control.

2. Local Area Network (LAN)  ____ One device is addressed by the host computer and a response is received from that device.

3. DeviceNet  ____ Computer and software to handle access to a network remotely.

4. Remote Access Server  ____ Interconnected devices sharing the resources of a single server in a small geographic area.

5. The ability to access information is key to establishing a comprehensive energy management plan.

TRUE  FALSE
## GLOSSARY

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Backbone</td>
<td>A larger transmission line that carries data gathered from smaller lines that interconnect with it.</td>
</tr>
<tr>
<td>Baseband</td>
<td>A network that provides a single channel for communications across a physical medium (cable). Only one device at a time can transmit.</td>
</tr>
<tr>
<td>Broadband</td>
<td>A network using cabling that is divided into several different channels, each having a unique carrier frequency. Allows for multiple transmissions at a time (such as cable TV).</td>
</tr>
<tr>
<td>Client/Server</td>
<td>Client/Server describes the relationship between two computer programs in which one program, the client, makes a service request from another program, the server, which fulfills the request.</td>
</tr>
<tr>
<td>Demand Leveling</td>
<td>Shifting the operation of loads or processes to keep the demand level at a normal range, to avoid creating a demand spike.</td>
</tr>
<tr>
<td>Demand Spikes</td>
<td>When the demand for power exceeds the normal level of demand within the utility system.</td>
</tr>
<tr>
<td>Distributed Generation</td>
<td>Using a generator as a power source to supply a facility’s load during a utility requested energy reduction period. Also known as Load Sharing.</td>
</tr>
<tr>
<td>DSL</td>
<td>Digital Subscriber Line — Newer technology than ISDN allowing for faster transmission of data in a digital (rather than analog) format.</td>
</tr>
<tr>
<td>Genset</td>
<td>Industry term describing a facility’s entire generating equipment set.</td>
</tr>
<tr>
<td>HVAC</td>
<td>Heating, Ventilating and Air Conditioning.</td>
</tr>
<tr>
<td>IEEE</td>
<td>Institute of Electrical and Electronic Engineers.</td>
</tr>
<tr>
<td>Interruptible Rate</td>
<td>A lower rate for allowing the utility to interrupt a block of power to the customer during excessive demand.</td>
</tr>
<tr>
<td>ISDN</td>
<td>Integrated Services Digital Network — a dedicated line is used to access the network and transmit data at 128 Kbps (thousands bits per second).</td>
</tr>
<tr>
<td>ISO</td>
<td>International Standards Organization.</td>
</tr>
<tr>
<td>Load Profile</td>
<td>Chart showing the quantity of energy used over a certain time period (day, week, month, etc.).</td>
</tr>
<tr>
<td><strong>PCMCIA</strong></td>
<td>Personal Computer Memory Card Industry Association — an industry group promoting standards for credit card-size memory or I/O devices that fit into a personal computer, usually a notebook or laptop computer.</td>
</tr>
<tr>
<td><strong>Peak Demand</strong></td>
<td>The largest energy reading detected within a certain time period for a month. It represents the amount of generation capacity a utility must have to service their customers.</td>
</tr>
<tr>
<td><strong>RS-232</strong></td>
<td>Recommended Standard-232 is an interface for connecting serial devices usually with 9-pin or 25-pin standard connectors. Limited to 50-foot distances in most cases.</td>
</tr>
<tr>
<td><strong>RS-422</strong></td>
<td>Recommended Standard-422, like RS-232, only can handle faster data transmissions for up to 4000-foot distances.</td>
</tr>
<tr>
<td><strong>RS-485</strong></td>
<td>Recommended Standard-485, will support 32 drivers and receivers for bi-directional, half-duplex, multi-drop communication for up to 4000-foot distances.</td>
</tr>
<tr>
<td><strong>Sag</strong></td>
<td>A decrease in RMS voltage lasting from ½ cycles to a few seconds.</td>
</tr>
<tr>
<td><strong>Side Secondary Wireway</strong></td>
<td>Allows users to install control wire without having to remove the breaker from the cell, and isolates the user from live areas of the breaker itself.</td>
</tr>
<tr>
<td><strong>Swell</strong></td>
<td>An increase in RMS voltage lasting from ½ cycles to a few seconds.</td>
</tr>
<tr>
<td><strong>TCP/IP</strong></td>
<td>Transmission Control Protocol/Internet Protocol. Handles the sizing of data and proper addressing for transmission across the Internet.</td>
</tr>
<tr>
<td><strong>Transmission Voltage</strong></td>
<td>The voltage as supplied by the utility without transformers to lower the voltage for customer usage.</td>
</tr>
</tbody>
</table>
1. True
2. True
3. Supply-side
4. True
5. Using an on-site generator to supply part or all of a facility, leveling utility demand.
6. Demand-side
7. True

Match the distortion term to the correct statement:

2. Voltage impulse
3. Short duration decrease in RMS voltage
4. Short duration increase in RMS voltage
5. Unwanted electrical signals on line
6. Frequency multiples of current or voltage added together

Match the power system term to the correct statement:

1. A single primary feeder supplies a single transformer, protected by an overcurrent device, which supplies all of the loads
2. If a primary feeder or transformer fails, the main breaker opens, the TIE is closed, and the loads are re-energized
3. Automatic switching from the primary source to a continuously available alternate source whenever there is a system disturbance
4. Two or more networkable, in-phase primary circuits of same voltage and phase angle are connected through network transformers to a common low-voltage assembly
5. Devices are able to clear faults and isolate problems without blackout effects reaching the rest of the site.
6. True
Match the power system term to the correct statement:

1. One device is addressed by the host computer and a response is received from that device.

2. Interconnected devices sharing the resources of a single server in a small geographic area.

3. Open communication network interfacing factory floor automation products for machine control.

4. Computer and software to handle access to a network remotely.

5. True