PDHonline Course E467 (2 PDH)

Electrical Instruments and Meters

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Electrical Power Instruments and Meters

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COURSE CONTENT

1.0 Instruments and Meters

This course treats electrical instruments and meters used in the electric power industry. Instruments commonly used in the measurements of circuits containing active electronic components are not considered.

The term "meter" is commonly applied to instruments that are used to measure electrical properties. For example there are voltmeters, ammeters as well as numerous other types of electric meters. Although most of these devices are truly instruments of some description, the suffix "meter" is often applied. By common usage an electrical "meter" is a device that measures and sometimes records an electrical quantity as current, voltage, energy, power or resistance.

Electrical meters with a wide variety of capabilities are needed for installing, analyzing and maintaining electrical systems. For example, megohmmeters are needed to confirm that the insulation of a newly installed electrical system is adequate before an electrical source can be safely applied. Phase sequence meters are used to determine the phase sequence of a three phase electrical source and thereby help ensure proper connections to electrical gear as motors, transformers and generators. After installation of an electrical system ammeters may be required to measure system currents in various conductors. Often measurements are needed to confirm that potential levels are within acceptable limits. For that purpose hand held multimeters, permanently installed power quality meters or panel mounted voltmeters could be used. Watt-hour meters, which commonly go by the shortened title of "wattmeter," are a special kind of meters that allows a provider of electricity to charge for an electrical service.

Electrical instruments and meters are available in a variety of forms. Mostly the forms are: hand held, bench mounted and panel mounted. A few, as the common utility watt-hour meter, are generally designed for surface mounting on the side of a customer's building. The hand held and bench mounted devices are considered as portable whereas panel mounted surface mounted types are not intended for moving from one spot to another. All of these different forms are mentioned and illustrated below.

2.0 Voltmeters, Ammeters, Frequency Meters

Some of the more commonly recognized electrical meters are the voltmeters, ammeters and frequency meters. These meters are used to determine the most elementary properties of an electrical circuit.

In truth, modern electrical power generating plants no longer use separate voltmeters, ammeters and frequency meters all that much. These parameters are generally available by other means in the control room of a utility's generating plant. More specifically the monitor of the plant's distributed control system (DCS) could be used to determine the values of these parameters. Generally there are no separate voltmeters, ammeters and frequency meters in modern control rooms. That is not to say that voltmeters, ammeters and frequency meters are no longer found in the electrical industry. Most utilities have designated areas where separate, bench mounted voltmeters, ammeters and perhaps frequency meters would be used for testing and calibrations. Industrial facilities sometimes have central electrical rooms where these parameters might be continually displayed on panel mounted meters.

Today, some of the more common usages of voltmeters, ammeters and frequency meters are in the form of the panel mounted models. A panel mounted meter is one that is mounted on, or more exactly, in a panel. More often than not, the "panel" in which the instrument is mounted is the front door of an enclosure or the front door of a cabinet. A knockout opening is required to mount the device. When positioned in the knockout, part of the panel mounted device extends forward of the panel and part is behind the panel. The portion with the display is forward of the panel face. Wiring to the device is entirely contained within the enclosure where fingers of personnel cannot readily come in contact with electrically live parts. A typical panel mounted instrument is represented in Fig. 1. The meter represented in Fig. 1 is shown mounted in the front door of an enclosure.

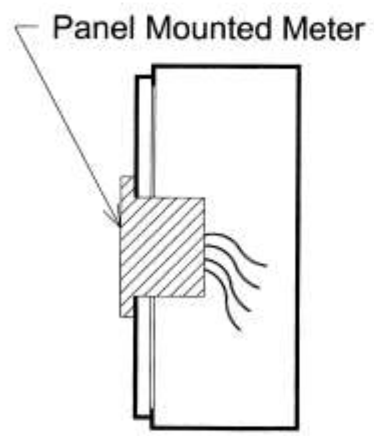

Fig. 1 - Panel Mounted Meter

Parameters can be displayed in a variety of forms on panel mounted instruments. The displays can be analog or digital. Some analog displays use a dial and others a bar graph type of indicator. Digital meters with LED displays have become especially popular in recent years. Character heights of the displays are typically are available in heights from 0.25 inch (6.35 mm) to 2.00 inches (50.8 mm). The size of characters is determined by the expected distance between a viewer and the display. Two typical LED type panel mounted displays are shown in Fig. 2 (Photo courtesy of Martel.)

Fig. 2 - Panel Mounted Meters

While voltmeters, ammeters and frequency meters are available in panel mounted models, there are many other types of panel meters and instruments available. There are meters for: VARS, power, watt-hours, apparent power, power factor, temperature, liquid height in a vessel as well as numerous other process variables.

Portable multimeters, which are discussed below, are useful for the measurement of potentials as well as some other parameters.

3.0 Power Measurements

Power is commonly measured with a wattmeter of some type. Wattmeters come in a variety of types and styles that are designed to meet a variety of needs. Amongst the classifications of portable types there are the hand held wattmeters and the bench mounted wattmeters. Some portable meters are capable of only measuring single phase power whereas others are capable of measuring either single phase power or three phase power. Portable meters might be used, say, for energy audits to determine the various sources of energy consumption within a facility.

Electrical energy measurements are made with watt-hour meters. Permanently installed watt-hour meters are used for purposes other than those common to portable meters. A well-known, permanent watt-hour meter is the commonly installed meter outside a facility that measures the electrical energy delivered by a public utility. The purpose of a utility's watt-hour meter is to measure a customer's net energy consumption within a billing period so that a bill may be sent at a later date.

Aside from a utility's meter, permanent power and watt-hour meters may also be installed within a facility by the owner for a variety of purposes. These types of meters are called “submeters.” Internal accounting could be one purpose for the use of a submeter. Another reason could be to allow a facility to bill its sub-customers. For example, marinas often have permanently installed meters to bill the owners of boats that might dock at slips at a marina.

Throughout the 20^{th} Century most watt-hour meters were built with a mixture of coils and mechanical parts combined in ingenious manners to measure energy usage over time. These meters were capable of a surprising accuracy that was typically better than 1%. To this day a large number of installed wattmeters still are of this electromechanical design. More recently wattmeters available from manufacturers are based on a digital design. Besides measuring energy consumption many of these newer meters offer a wide range of novel and useful capabilities. Well into the future these new types of meters will become the means whereby utilities can offer to their customers a wide range of options. These new capabilities promise to benefit both the utility as well as their customers.

The measurement of either the current or potential of a single phase circuit can be accomplished with meters by an easily understood procedure. Power measurements can be a little more challenging. Whereas single phase power and energy measurement can be conducted in a straightforward manner, the use of meters on three phase systems requires greater knowledge and training. Three phase meters have more connections than single phase meters and correct readings can be obtained only if the connections are made in the proper configuration.

3.1 Single Phase Power Measurements

Power in a single phase circuit can be measured with a wattmeter. By one means or another, a single phase wattmeter measures current, voltage and the lead or lag of the current with respect to the measured voltage. For linear circuits, the wattmeter essentially performs a calculation in accordance with the algorithm,

$P = VI \cos \theta_P$, where

V = potential (voltage)

I = current (amps)

θ_P = phase lead/lag angle between phase current and phase voltage (degrees or radians) for a lagging current, $\theta_P < 0$ and for a leading current, $\theta_P > 0$

In a single phase circuit it is always true that $\theta_P > -90^\circ$ and $\theta_P < +90^\circ$

(A linear electrical circuit is one in which both the voltage and the current can be described as a sine function. A nonlinear circuit is one that cannot be so described. Some, but not all, power meters can be used to accurately measure power in nonlinear circuits.)

A type of meter that has proved convenient for measuring the power of single phase circuits is the hand held clamp-on type. A typical single phase, hand held clamp-on power meter is shown in Fig. 3. The feature of a clamp-on meter is that it does not require that a conductor be disconnected, re-connected, disconnected and finally re-connected to facilitate a reading. Proper orientation of the meter on the cable and correct connections of the potential leads are needed for valid power readings. (Note: The required potential leads are not shown in photograph of Fig. 3.) (Photograph provided courtesy of Amprobe.)

Fig. 3 – Clamp-on Single Phase Power Meter

There are meters other than the clamp-on type that are available to read single phase power. The bench meters are one type that can be used. Permanently installed submeters are likewise available for the purpose. Toroidal shaped current transformers are used with the more permanent types of meters. A toroid-shaped CT is represented in Fig. 4. In the CT, the conductor containing the current that is to be measured becomes the primary of the CT. The secondary of the CT provides a measurement of the current in the conductor.

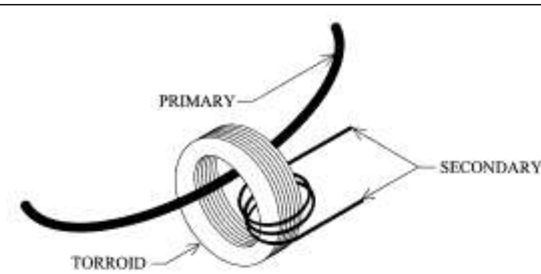

Fig. 4 - Toroid CT

3.2 Three Phase Power Measurements

A number of parameters are required to obtain valid three phase power values. If a portable meter is being used for the purpose, proper positioning of the current transformers and potential leads will be necessary. Otherwise meaningful reading cannot be obtained.

A customer of a three phase electrical service, three wire or four wire, will have a permanently installed meter that measures and records at least energy (watt-hour) consumption. The meter will be owned by the utility and provided for billing purposes. Depending on the area and the utility's policies, the meter may also measure other parameters for billing purposes. Larger users of electrical power are often billed for a reactive power factor and "demand."

Although single phase wattmeters may be used to measure three phase power, the preferred method is with the use of a three phase meter. (Course E344, *Calculating and Measuring Power in Three Phase Circuits*, explains in detail the various procedures that can be used to measure power in three phase circuits with single phase power meters.) The current transformers used with three phase meters are relatively expensive. For this reason, it is advisable to use no more CT's than what is required for the application. A single CT will suffice if the load is balanced and two will suffice for all other three wire applications provided there is no need to monitor currents in the three phase conductors.

Digital, three phase power meters function by making separate, single phase measurements of currents and potentials. Depending on the application and the capability of the instrument, the measurements are then combined by algorithms contained within the envelope of the instrument to produce a variety of values.

For many years instruments known as "power analyzers" have been the traditional means of examining the characteristics of a three phase circuit. Power analyzers come in a wide variety of shapes, sizes, prices and with a wide variety of features. In general, power analyzers can provide numerous details characteristic of a circuit including parameters as currents, voltages, power factors, power, VARS, VA, frequency, phase sequence, lead/lag angles and nonlinear current characteristics. Some power analyzers can display a circuit's phasor diagrams. Additional information measured by a power analyzer is generally available on a display on the instrument. Some power analyzers can transmit data serially over a cable to a remote location. Many models allow a print-out of measured parameters. Although more costly than conventional wattmeters, in many instances the greater cost of a power analyzer is justified by the greater amount of information that it provides. More or less by custom the term "power analyzer" is applicable to either portable hand held or bench mounted instruments that are also portable but less so. Most power analyzers measure currents by means of clamp-on CT's that avoid the need to disconnect and then to re-connect conductors. In general power analyzers are relatively expensive instruments. A power quality analyzer typical of the new generation of meters is shown in Fig. 5. The instrument of Fig. 5 can simultaneously display the traces of five voltages and two currents. (Photo courtesy of AEMC Instruments.)

Fig. 5 – Power Quality Analyzer

In recent years digital "power quality" meters have become available for the continuous monitoring of three phase power sources. Many of the new generations of digital power quality meters or submeters are intended for permanent mounting in a panel. Unlike traditional, portable power analyzers, current measurements for the panel mounted power quality meters are made with permanently installed toroidal CT's. The newer power quality meters can provide data comparable to that obtained with power analyzers. And the digital power quality meters are generally much less expensive than the traditional power analyzers.

4.0 Watt-hour Meters

Most watt-hour meters are used to measure electrical energy supplied by a utility to a customer. Traditionally watt-hour meters are mounted outside a customer's building where a meter reader from the utility may visit the meters and take periodic readings. Meters of past years were generally mounted in a conspicuous location that could easily be found by the meter reader and where the theft of electricity could be detected more easily. Meters must be weatherproof and have a cover that has a utility seal that, if broken, might suggest tampering. A traditional, electromechanical watt-hour meter of the type used by utilities for many years is shown in Fig. 6. (Photograph provided courtesy of Fry Electric Inc., Indianapolis.) To determine a customer's energy usage since the last reading, a meter reader would note the positions of the dials and manually record the energy usage. The utility would subsequently send a bill to the customer for energy usage since the last billing. The procedure whereby a meter reader must regularly visit every one of a utility's customers is labor intense.

Fig. 6 - Conventional Watt-hour Meter

Watt-hour meters have been in use practically since the availability of electricity. For at least the first 100 years of their use, watt-hour meters have been of an electro-mechanical design of one sort or another. The most popular design has been based on the use of what is essentially a miniature motor that drives a disc. The rate of rotation of the disc is proportional to the power being used. Rotations of the disc are proportional to watt-hours of energy consumed and the disc in turn drives a register that logs watt-hours (or, more exactly, kilowatt-hours) consumed. In the past, the registers of the type shown in Fig. 6 had to be read and recorded by a meter reader. Many existing watt-hour meters are still of this design. The newer meters of today are offering improved alternatives to the older types of meters.

Watt-hour meters are subject to governmental regulations that specify minimal accuracy properties. In the United States each state determines its unique accuracy requirements. Many states require that new meters meet the accuracy requirements of ANSI Standard 12.1. Some states have very stringent accuracy requirements and most states require an accuracy much better than 1%. Some states also require periodic in-service testing or sampling program to confirm that the type of meter used by a utility maintains sufficient accuracy after years of use.

Because many utilities have developing needs for innovative ways of billing customers, the traditional and mechanical watt-hour meters of the past have been found lacking. Smart meters, which are of a digital design, are gradually replacing the older conventional electro-mechanical designs in many parts of the world. Smart meters are permitting utilities to do away with meter readers while also allowing the introduction of programs that will assist in reducing peak loads.

5.0 Demand Meters

A demand charge is typically a large part of the bill sent by utilities to larger commercial and industrial customers that have a three phase service. Traditional demand meters of the type used in past years have been of an electromechanical design and were designed to measure either a customer's peak usage of current or power (kW - not kWh). The choice of current or power of course would be determined by the respective utility as every utility has the right to formulate its method of billing. A typical electromechanical meter with both a kilowatt-hour reading and a demand reading is shown in Fig. 7. (Photograph courtesy of the Archman Corporation.) The selected parameter, current or power, is measured throughout a predetermined period of time. A duration of 15 minutes has been the most popular time period although some utilities use a 30 minutes sampling period. A meter with a 15 minute sampling period would take over 2800 readings within an average billing period. The highest reading determines the demand charge for the billing period.

Fig. 7 - Watt-hour Meter with Demand

Despite its title a demand meter does not actually measure maximum power or current "demand." Rather, the value indicated by the pointer on the meter is in fact an integrated value. For example, if the energy usage during the first period of measurement (for a new billing period) was constant at, say, 20 kW, the red pointer would show 20 kW at the end of the period. Of course, subsequent measurements might move the red pointer higher. The highest reading during a billing period determines the demand charge. If the power level was at 40 kW for half the measurement period but 0 kW during the other half, the red pointer would still indicate 20 kW. Although the true peak usage in this example was 40 kW within the measurement period, the integrated value during the time period would be recorded as only 20 kW.

Traditional electromechanical demand meters are still in use but many utilities are gradually replacing these older, electro-mechanical meters with the new, more capable smart meters which are digital-based.

6.0 Smart Meters

6.1 Definitions

One of the forerunners of the present day smart meters was the AMI metering system. The term "Advanced Metering Infrastructure" (AMI) first appeared in the 1990's and it was used in reference to a series of meters that contained what at the time were new capabilities. Mostly, the AMI meters would electronically record and store electric consumption by hour of the day which data could be retrieved at a later date. This type of data was especially useful for those utilities that offered the TOU (Time of Use) programs. Those early AMI meters did not have real time, two way communications capabilities. The term “Advanced Metering Infrastructure” was still used (primarily by the US Federal Government) in reference to what many began to call smart meters. Yet the later versions of the AMI meters began to incorporate features not found in the earlier AMI meters.

Another family of innovative meters that offered a number of improved features was the ARM (Automatic Reading Meters). The ARM’s were available in a variety of models. Some of these models allowed a meter reader to record data at meters but the instruments did not require a meter reader to first interpret the displayed numbers and then record the noted numbers. Rather, the data was downloaded to a handheld data recorder. Some advanced ARM models did in fact offer radio transmission of data to a central gathering server.

The term “smart meter” describes a more recent family of meters that have two-way communications capability. Nevertheless, some utilities have purposely avoided use of the term, “smart meter.” Public Service of Oklahoma, for example, use the term “advanced digital meter.” Philadelphia Electric Company used the term “smart meter” for a time but eventually reverted to “Advanced Metering Infrastructure” when referring to the meters. Unlike the electromechanical registers used in the older meters the smart meters have LED type read-outs. A typical smart meter is shown in Fig. 8. (Photograph provided courtesy of Itron.)

Fig. 8 - Smart Meter

Following is a typical definition of a smart meter provided by a utility.

<u>By the New York Public Service Commission:</u>

> “Smart Metering – a concept embracing two distinct elements:
>
> Meters that use new technology to capture complex energy use information and communication systems that can capture and transmit energy use information as it happens, or almost as it happens.”

The New York Public Services Commission further explains that the "Reasons for Using Smart Meters" are to:

- "Identify and implement operational strategies to control load factor and peak-load requirements and reduce energy waste
- Expand the capacity to manage operations in response to potential price volatility
- Understand and improve consumption patterns to secure better pricing from the retail electricity market
- Participate in demand response programs that pay end users to manage loads as needed to improve grid reliability during peak demand periods
- Measure and verify anticipated energy savings from energy-efficiency modifications, and
- Help monitor and address complex issues such as power quality"

6.2 Operation

It is worth noting that the term "smart meter" is commonly applied to not only electric meters but also to water meters and gas meters. As used here the term "smart meter" refers solely to electric meters.

Smart meters are electronic digital instruments with a wider range of capabilities than what was available with the electromechanical designs of the past, the AMI meters or the AMR meters. Smart meters monitor electricity usage at a facility and that data is stored internally in the meter. Periodically a smart meter sends recorded data by radio signal to a receiver that is mounted nearby. A single receiver may gather data from dozens or hundreds of smart meters. Received data in turn is subsequently retransmitted to one of the utility's servers where it will be retrieved later for billing purposes.

The terms "smart meter" and "smart grid" are distinctly different concepts. Each refers to different types of instruments that are used for different purposes and which have different functions. Nevertheless, the two terms are often used in conjunction with one another. Smart grids are fitted with a variety of sensing devices that are intended to provide real time information descriptive of the condition of an electrical distribution system. Smart meters on the other hand are intended to offer utilities information and a tool that can be used to shift some customers' peak loads to off-peak times.

It appears that the variances in the names applied to smart meters are a result of early, adverse press. That bad press in turn was largely traceable to two issues raised by consumers. The most frequently raised objection to smart meters was due to the fact that the meters periodically emit a radio signal for the purpose of transmitting recorded data. Some persons feared the adverse health effects of being near transmitted radio signals. Another expressed concern related to the fact that the smart meters monitor customers' power usage and, therefore, customers' living habits. Some argue that for that reason the meters constitute an invasion of privacy.

Although smart meters present a means whereby a utility can induce customers to shift usage to off-peak times, the meters alone cannot accomplish this end. The shifts in usage will take place only if a utility combines a program of incentives in combination with the measurement capabilities of the smart meters. The most common method used by utilities to reduce peak load is to offer reduced rates for electric consumption during off-peak times. This feature of the smart meters simulates to some extent the earlier TOU (time-of-use) programs offered by utilities. The TOU programs were used by utilities to provide reduced energy rates during off-peak periods.

Aside from the TOU initiatives, utilities have since devised a variety of programs with the intention of shifting energy usage away from peak times. In most instances financial incentives are offered to encourage the shifting of loads away from peak times. It can be expected that some utilities' customers will take advantage of these programs whereas others will find it too inconvenient or impractical to reschedule many if not most electrical loads.

In the event of an outage, an installed system of smart meters will immediately alert the respective utility to the condition. The smart meters will allow a utility to quickly determine the extent of a problem. As a result the improved real-time intelligence, a utility will be better prepared to organize and more quickly dispatch line crews to restore electrical service.

6.3 Implementation Examples

Programs in at least 25 USA states called for deployment of some extent of smart meters. Many of these programs were extensive whereas others could best be classified as trials. Following are typical examples of programs that have been implemented through the use of smart meters and which assist to explain the usefulness of the meters.

Ontario Power Authority, Canada

In conjunction with the installation of smart meters the Ontario Power Authority introduced a policy of "time of use" for home owners and small business. Customers shifting electricity use to off-peak can bring as much as a 46% rate reduction in energy costs for use during those periods. A reduction of 16% is offered for use during mid-peak times. The Authority also offers incentives to commercial and industrial customers for reducing use during peak periods. The installation of the smart meters facilitated implementation of the peak reduction program.

State of Pennsylvania

In 2008 the Pennsylvania State passed a bill that mandated installation of smart meters throughout the state by the year 2018. Equipped with the new meters the various utilities within the Commonwealth will be positioned to devise and offer a variety of programs all of which, it is anticipated, will benefit both the utilities as well as their millions of customers.

7.0 Submeters

Submeters are commonly used at marinas, condominiums, mobile home parks, RV parks, apartments, home owners associations and the like. In a typical installation that uses submeters, the local utility would have a single meter at a facility that records net electrical consumption by that facility. A single party would be responsible for paying the utility for the electricity recorded by the utility's meter. In turn, submeters measure the electrical usage of the various tenants or parties using electricity recorded by that utility's single meter. The party that pays the utility's bill each month would be responsible for the submeters as well as collecting payments from the variety of electricity users. Some states have rules that determine which of their customers will be allowed to resell electricity.

Submeters might be used, for example, to track usage by internal departments or division within an industrial facility. A charge for electricity usage can then be levied against that user for accounting or internal billing purposes. Submetering can serve as an aid to conservation efforts. History has proven that if electrical consumption is charged to an identifiable individual or department, conservation efforts almost always follow.

Submeters are similar to conventional watt-hour meters in function; both types of meters must accurately record energy use. Many submeters are not mounted outdoors and therefore do not have weatherproof cases typical of utility meters. Submeters often need not be tamper-proof to the degree required of utility meters as the meters can be located in a secured area. Submeters are available in a large number of models. Designs are available for panel mounting, surface mounting or DIN rail mounting. Today, new submeters are invariably the digital type with remote CT's for measuring current. Accordingly, a large number of submeters can be grouped together to facilitate the convenient reading of the respective registers. A typical, modern, digital submeter is shown in Fig. 9 (Photograph provided courtesy of Simpson Electric).

Fig. 9 - Submeter

In some regions of the United States the accuracies of submeters are regulated much as the accuracies of watt-hour meters. The State of California has rigid requirements for submeter accuracies. The State of Maryland publishes a list of approved submeters. The use of meters not on Maryland's list is disallowed in the State.

8.0 Phase Sequence Meters

A phase sequence meter is a hand held instrument that allows a person to determine the phase sequence of a three phase electrical source. A correct determination of the sequence is frequently important for a number of reasons. For example, the correct sequence is needed to properly connect a three phase electrical source to a power distribution center or a motor control center. Both of these types of electrical gear are normally marked for the incoming electrical conductors to be connected in the sequence A to T1, B to T2 and C to T3. If this sequence is followed throughout to branch circuits, motors connected to those branch circuits will rotate in the anticipated direction and in accordance with the direction of rotation shown on the motor housing. On the other hand, if the sequence of connection were A to T1, C to T2 and B to T3, the rotation of motors will be reversed and incorrect. Incorrect rotation of a motor can result in severe damage to property as well as injury to personnel.

Fig. 10 - Phase Sequence Meter

It is true that color coding of cables will often indicate the sequence of phase rotation. Frequently in the United States the sequence “brown-orange (or violet)-yellow” is followed for three phase circuit 480-3-60 conductors. Color coding is also often followed for lower voltages. However, color coding practices around the world vary greatly. Above 480 VAC, black conductors are usually used and not color coded. Color coded conductors, where found, may not accurately reflect the true phase sequence. When there is doubt a phase sequence should be confirmed.

A typical phase sequence meter is shown in Fig. 10. The photograph is of a non-contact type of instrument. Phase sequence is determined with the meter merely by clamping the probes over the insulation of the conductors being analyzed. (Photograph provided courtesy of Extech Instruments.)

9.0 Earth Ground Meters

Fig. 11 - Ground Meter

The grounding of electrical systems and gear is critically important for several reasons. Inadequate grounds can be the cause of damage to electrical gear should a fault occur. An inadequate ground can also introduce conditions potentially hazardous to personnel. Errors can occur in grounding systems. Sometimes a connection can be faulty from the day of installation and sometimes a ground connection that was initially adequate might become inadequate over time. Poor soil conditions are often the cause of an inadequate ground. The best means to confirm that an electrical ground is viable is with an earth ground meter. After an initial installation, grounds should be tested periodically to confirm continuity. A suitable type of clamp-on type earth ground meter is shown in Fig. 11. (Photograph provided courtesy of Reed Instruments.) To take a reading of resistance to ground with a clamp-on type meter, the meter's jaws are merely clamped around the grounding connection and a reading is taken. Both NEC and OSHA prescribe minimal values for ground resistance. If the resistance to ground is found to be unacceptably high, measures will be required to ensure a low resistance path is present. In the extreme it may become necessary to excavate unsuitable soil and replace it with a more conductive soil. At some sites a small but continuous flow of water is applied to soil to maintain adequate conductivity in the soil at the ground connection.

10.0 Megohmmeters

Megohmmeters are used to determine the integrity of a system's insulation. Energization of an electrical system with inadequate or deteriorated insulation is highly inadvisable. Testing of a system's insulation is recommended if electrical gear has been out of service for an extended period of time. Testing of insulation is especially recommended if equipment has been inactive for an extended period of time in a high humidity environment. Testing of the insulation of a high voltage system is especially important. A megohmmeter measures the impedance of insulation by the application of a voltage that might be in the range of 500 to 1,000 volts. An insulation impedance of 100 megohm would generally be considered as satisfactory. Lower readings would be questionable. Megohmmeters are often called "meggers." A typical megohmmeter is shown in Fig. 12. (Photograph courtesy of the Megger Corporation.)

Fig. 12 - Megger Instrument

11.0 Hi Potential Testers

A high potential test is most commonly called the, "hi pot test." It is also known as the, "dielectric withstand test." A hi pot test is performed much for the same reason as a megohm test which is to verify the integrity of an insulation system. A hi pot test is performed by the application of a relatively high voltage and the resulting leakage current is noted. Some instruments are intended solely for the purpose of performing a hi pot test although some can perform either a hi pot test or a megohm test. Under some circumstances a hi pot test can result in the destruction of a system's insulation. So, care must be taken in the application of a hi pot test.

Test should be conducted only by trained personnel using appropriate protective gear and in compliance with the manufacturer's guidelines.

12.0 Multimeters

A review of electrical instruments would not be complete without mention of the multimeter. A multimeter is an instrument that has the capability of measuring more than one parameter. Thus, the "multi" in "multimeter." Most multimeters have the capability of measuring, at a minimum, DC voltage, (rms) AC voltage and resistance. Many are also capable of measuring a number of other parameters as temperature, peak voltage, small DC currents, small AC current, AC frequency, capacitance and reluctance. Multimeters are available in the hand held design whereas others are a design intended for positioning on a bench or for panel mounting. Years ago multimeters all had analog needles that pointed to the value of the measured parameter. Today, most multimeters, but not all, have digital readouts. For some types of measurements, as when the measured variable is constantly changing value, the analog meters are still preferred. For power applications, the input impedance of the meter generally is immaterial. For electronic measurements, however, a very high input impedance is needed for some parameters. Otherwise the current draw of the meter will cause a false reading. Probably the most common use of a hand-held multimeter is on troubleshooting missions. Most multimeters are capable of measuring potentials up to 1000 VDC or 1000 VAC. Some multimeters are capable of potentials up to 40,000 volts with the use of high voltage probes. A typical hand held multimeter of the type that might be preferred for taking measurements of an electrical power circuit is shown in Fig. 13. (Photograph courtesy of Triplett.)

Fig. 13 - Multimeter

13.0 Oscilloscopes

The behavior of an electrical circuit can be observed in detail with an oscilloscope. Oscilloscopes measure electric properties as potentials or currents and display those properties on a screen with a calibrated grid. Power quality instruments to some extent duplicate some of the capabilities of oscilloscopes but oscilloscopes generally offer a wider range of capabilities. Older oscilloscopes used a cathode ray tube (CRT) to display the measured properties. To obtain a permanent record, it was common to take a photograph of the display on the CRT. It was a relatively inconvenient and inaccurate procedure for recording data. Traditionally oscilloscopes were used to measure only repetitive occurrences.

Oscilloscopes have greatly improved over the years. Today oscilloscopes no longer use CRT displays and, instead, use various types of display screens. Conditions and events can be stored digitally for subsequent retrieval, printing or analysis. Some modern oscilloscopes can be used to record not only repetitive events but single events as well. This capability is especially useful in the analysis of power circuits. The newer oscilloscopes are useful for displaying and recording harmonics and current inrush. An oscilloscope can be triggered to start recording when a contact is either opened or closed. The oscilloscope can then record the resultant circuit response as well as voltage spikes. Most oscilloscopes are the bench mounted type. A modern oscilloscope is shown in Fig. 14. (Photo courtesy of Rigor.)

Fig. 14 - Oscilloscope