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Introduction

Welcome to another course in the STEP 2000 series, **S**iemens **T**echnical **E**ducation **P**rogram, designed to prepare our sales personnel and distributors to sell Siemens Energy & Automation products more effectively. This course covers **Power Monitoring and Management with ACCESS** and related products.

Upon completion of **Power Monitoring and Management with ACCESS** you should be able to:

- Identify five benefits of using the ACCESS system

- Explain the difference between peak, peak-to-peak, instantaneous, average, and effective values of AC current and voltage

- Identify linear and nonlinear loads

- Explain various industry terms for voltage conditions

- Describe a CBEMA curve

- Explain the effects of harmonics on a distribution system and associated equipment

- Explain the difference between true power, reactive power, and apparent power

- Identify solutions for various power supply problems

- Select appropriate power meters for use in a distribution system

- Explain various communication standards and network protocols

- Explain the use of various components in an ACCESS controlled distribution system

This knowledge will help you better understand customer applications. In addition, you will be able to describe products to customers and determine important differences between products. You should complete **Basics of Electricity** before attempting **Power Monitoring and Management with ACCESS**. An understanding of many of the concepts covered in **Basics of Electricity** is required for **Power Monitoring and Management with ACCESS**.

If you are an employee of a Siemens Energy & Automation authorized distributor, fill out the final exam tear-out card and mail in the card. We will mail you a certificate of completion if you score a passing grade. Good luck with your efforts.

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Monitoring and Managing Electrical Power with ACCESS

Siemens ACCESS™ is more than just power meters, trip units, and other hardware. The ACCESS power management and control system is a networked system comprised of a variety of devices that monitor and control an electrical distribution system. The ACCESS system provides electrical data necessary for troubleshooting, power quality studies, preventative maintenance, and cost allocation. A power monitoring and management system, such as Siemens ACCESS, can identify potential problems before they cause costly breakdowns.

There are five benefits to using the ACCESS system.

• Reduce or eliminate unplanned outages

• Proactively manage power systems to minimize utility bills

• Automate sub-billing of utility power bills

• Optimize capital equipment used in power systems

• Measure and analyze power quality

Electrical Power Distribution

Before discussing the Siemens ACCESS system an understanding of the production, distribution, and use of electric power is necessary.

Electric power is produced by converting potential energy into electricity. There are several sources used to produce electric power. Coal, oil, and uranium are fuels used to convert water into steam which in turn drives a turbine. Some utilities also use gas or a combination of gas and steam turbines. There are other forms of electric power generation such as hydroelectric and solar energy plants.
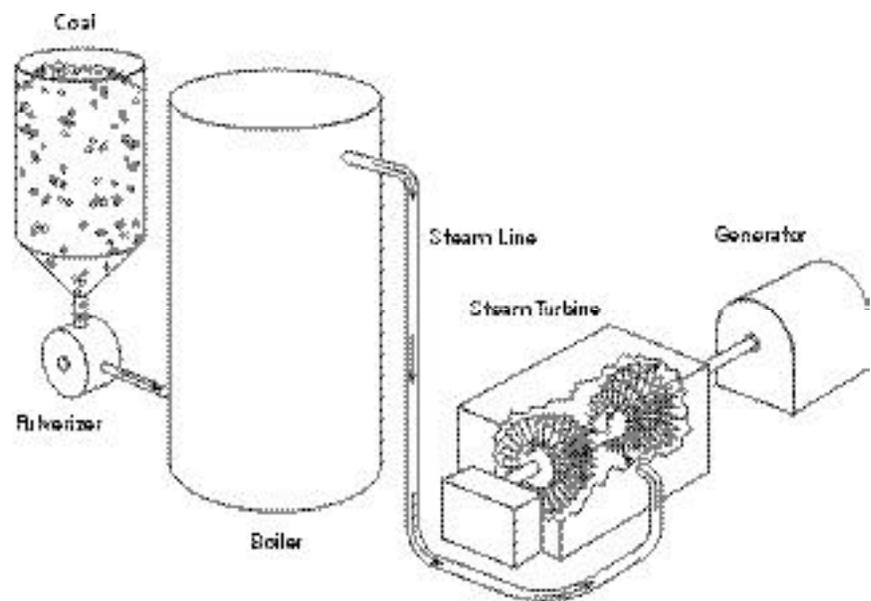
Distribution

In order for generated power to be useful it must be transmitted from the generating plant to residential, commercial, and industrial customers. Typically, commercial and industrial applications have higher demands for electric power than residential applications. Regardless of the size of the electric system, electric power must be supplied that allows the intended loads to operate properly.

The most efficient way to transfer energy from the generating plant to the customer is to increase voltage while reducing current. This is necessary to minimize the energy lost in heat on the transmission lines. These losses are referred to as I^2R (I-squared-R) losses since they are equal to the square of the current times the resistance of the power lines. Once the electrical energy gets near the end user the utility will need to step down the voltage to the level needed by the user.
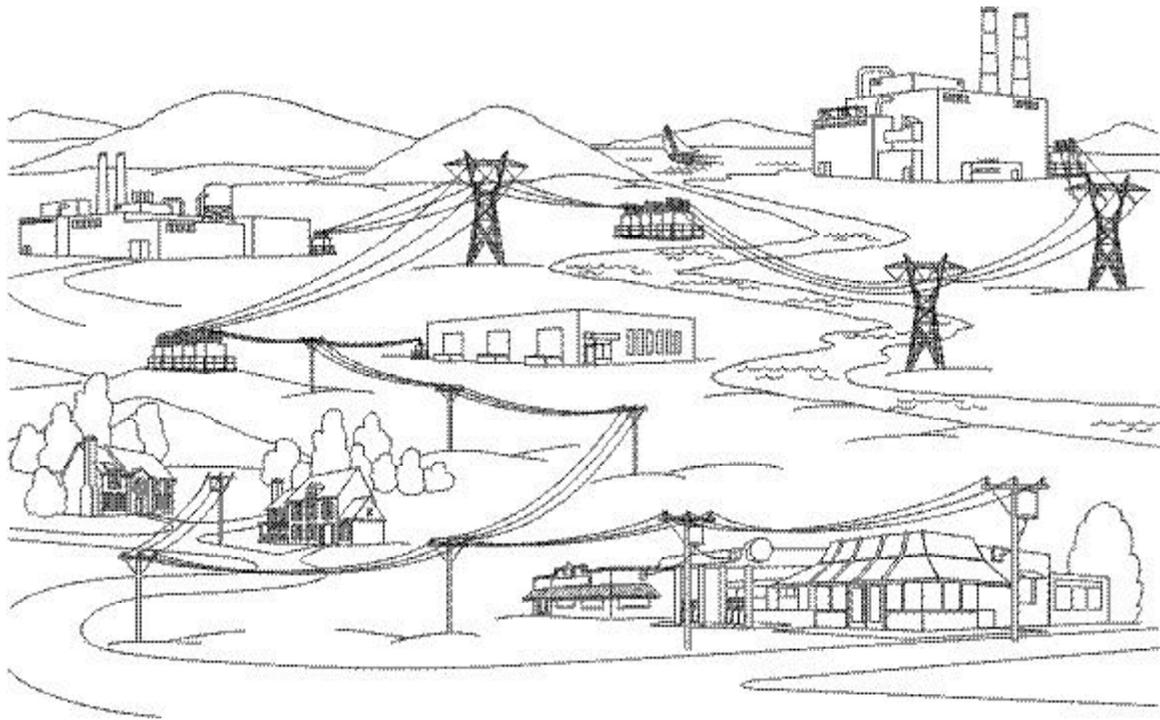

Power Quality

Electrical equipment is designed to operate on power that is a specific voltage and frequency. This power should also be free from quality problems, such as voltage spikes and harmonics. Unfortunately, power quality problems can occur from various sources. Power quality problems can affect the performance and shorten the life of electrical equipment. Power quality problems can significantly increase the operating cost of an electrical system.

Loads

Electricity is used to produce motion, light, sound, and heat. AC motors, which account for about 60% of all electricity used, are widely used in residential, commercial, and industrial applications. In today's modern commercial and industrial facilities there is increased reliance on electronics and sensitive computer-controlled systems. Electronic and computer systems are often their own worst enemy. Not only are they susceptible to power quality problems, but they are often the source of the problem.
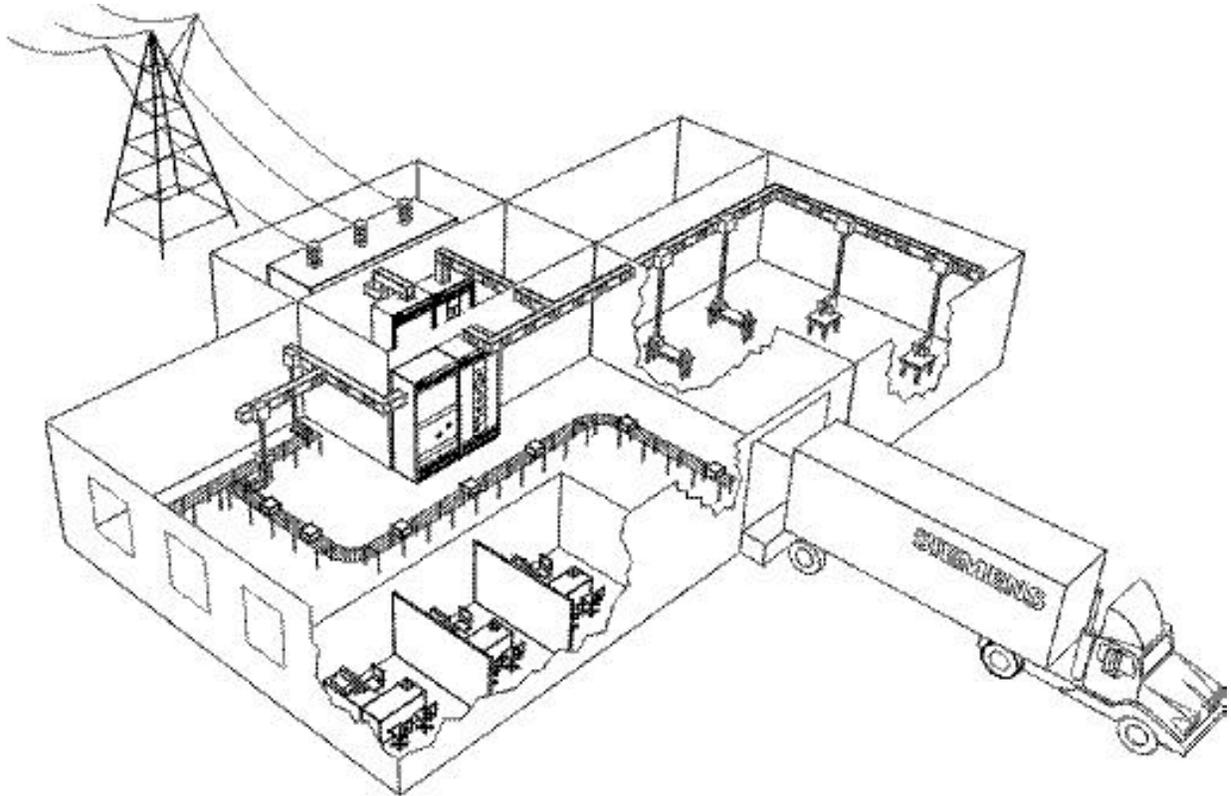
Review 1

1. Which of the following is a benefit to using the Siemens ACCESS system?

    a. Reduce or eliminate unplanned outages
    b. Proactively manage power systems
    c. Automate sub-billing of utility power bills
    d. Optimize capital equipment used in power systems
    e. Measure and analyze power quality
    f. All of the above

2. AC motors account for about _____ % of all electricity used.

3. The most efficient way to transfer energy from the generating plant to the customer is to increase voltage while reducing _____ .

4. Power quality problems can significantly _____ the operating cost of an electrical system.

    a. increase
    b. decrease

Voltage and Current Values

An accurate measurement of voltage supplied by the utility and the current produced by the connected load is necessary in identifying power usage and power quality problems.

DC

Voltage is either direct current (DC) or alternating current (AC). DC voltage produces current flow in one direction. DC voltage can be obtained directly from sources such as batteries and photocells, which produce a pure DC. DC voltage can also be produced by applying AC voltage to a rectifier.
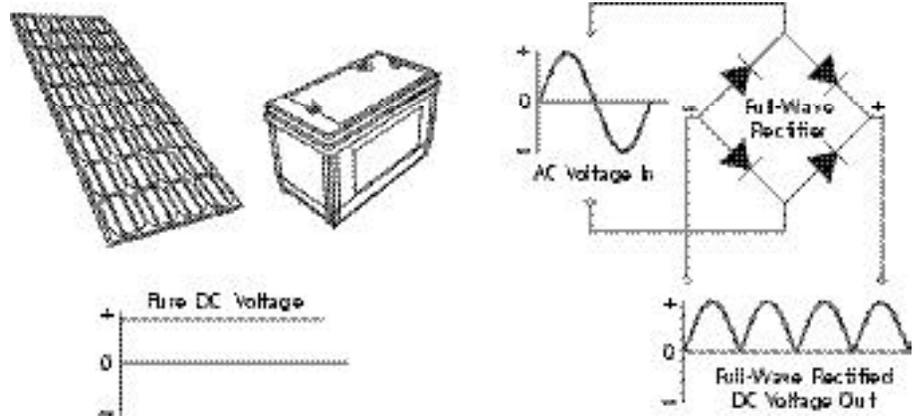
Measuring DC Voltage

The value of DC voltage varies. Low level DC voltages, such as 5 - 30 VDC, are commonly used in electronic circuits. Higher levels of DC voltage, such as 500 VDC, can be used in many industrial applications to control the speed of DC motors. A voltmeter is used to measure DC voltage.

AC Voltage, Current, and Frequency

Current flow in AC voltage reverses direction at regular intervals. AC voltage and current are represented by a sine wave. Sine waves are symmetrical, 360° waveforms which represent the voltage, current, and frequency produced by an AC generator.

If the rotation of an AC generator were tracked through a complete revolution of 360°, it could be seen that during the first 90° of rotation voltage increases until it reaches a maximum positive value. As the generator rotated from 90° to 180°, voltage would decrease to zero. Voltage increases in the opposite direction between 180° and 270°, reaching a maximum negative value at 270°. Voltage decreases to zero between 270° and 360°. This is one complete cycle or one complete alternation.

Frequency is a measurement of the number of alternations or cylces that occur in a measured amount of time. If the armature of an AC generator were rotated 3600 times per minute (RPM) we would get 60 cycles of voltage per second, or 60 hertz.
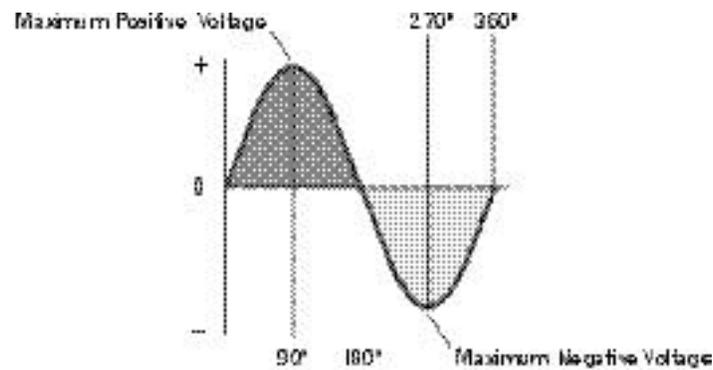
AC voltage can either be single- or three-phase. While single-phase power is needed for many applications, such as lighting, utility companies generate and transmit three-phase power. Three-phase power is used extensively in industrial applications to supply power to three-phase motors. In a three-phase system the generator produces three voltages. Each voltage phase rises and falls at the same frequency (60 Hz in the U.S., 50 Hz in many other countries); however, the phases are offset from each other by 120°.


Single-Phase   Three-Phase
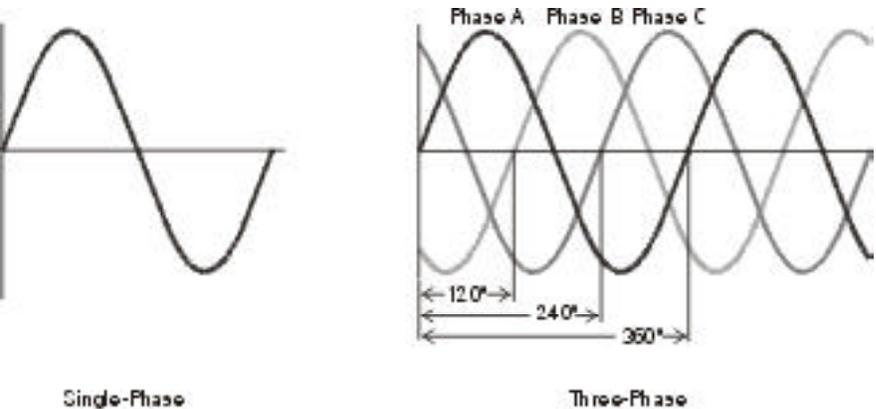
Measuring AC Values

Measuring AC is more complex than DC. Depending on the situation, it may be necessary to know the peak value, peak-to-peak value, instantaneous value, average value, or the RMS (root-mean-square) value of AC.
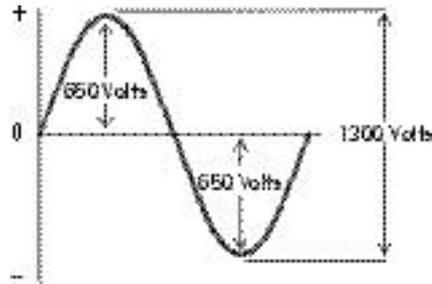
Peak Value

The peak value of a sine wave occurs twice each cycle, once at the positive maximum value and once at the negative maximum value. The peak voltage of a distribution system might be 650 volts, for example.

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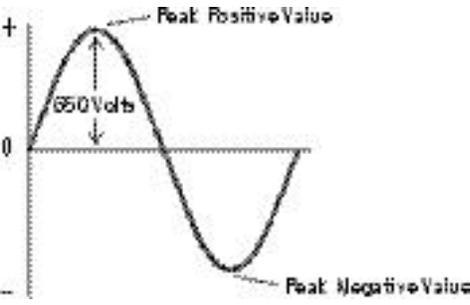
Peak-to-Peak Value

The peak-to-peak value is measured from the maximum positive value to the maximum negative value of a cycle. If the peak voltage is 650 volts, the peak-to-peak voltage is 1300 volts.


Instantaneous Value

The instantaneous value is the value at any one particular time along a sine wave. Instantaneous voltage is equal to the peak voltage times the sine of the angle of the generator armature. The sine value is obtained from trigonometric tables. The following table shows a few angles and their sine value.

Angle	Sin q	Angle	Sin q
30°	0.5	210°	-0.5
60°	0.866	240°	-0.866
90°	1	270°	-1
120°	0.866	300°	-0.866
150°	0.5	330°	-0.5
180°	0	360°	0

The instantaneous voltage at 150° of a sine wave with a peak voltage of 650 volts, for example, is 325 volts (650 x 0.5).
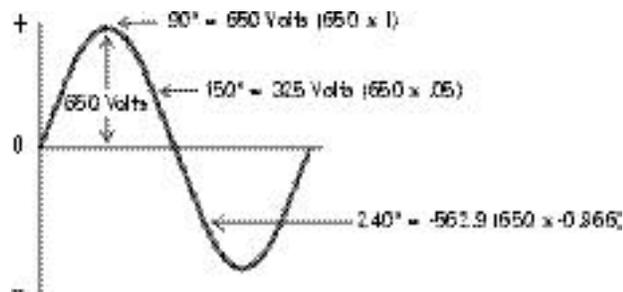
Average Value

The average value of a sine wave is zero. This is because the positive alternation is equal and opposite to the negative alternation. In some circuits it may be necessary to know the average value of one alternation. This is equal to the peak voltage times 0.637. The average value of a distribution system with 650 volts peak, for example, is 414.05 volts (650 x 0.637).
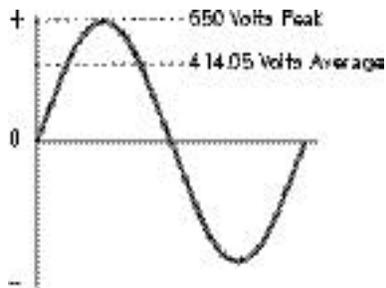
Effective Value

The effective value, also known as RMS (root-mean-square), is the common method of expressing the value of AC. The effective value of AC is defined in terms of an equivalent heating effect when compared to DC. One RMS ampere of current flowing through a resistance will produce heat at the same rate as a DC ampere. The effective value is 0.707 times the peak value. The effective value of a system with 650 volts peak, for example, is 460 volts (650 x 0.707 = 459.55 volts).
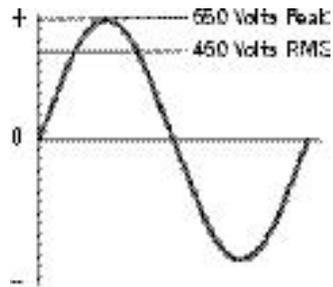
Linear Loads

It is important at this point to discuss the differences between a linear and nonlinear load. A linear load is any load in which voltage and current increase or decrease proportionately. Voltage and current may be out of phase in a linear load, but the waveforms are sinusoidal and proportionate. Motors, resistive heating elements, incandescent lights, and relays are examples of linear loads. Linear loads can cause a problem in a distribution system if they are oversized for the distribution system or malfunction. They do not cause harmonic distortion, which will be discussed later.

In Phase
Proportional

Out of Phase
Proportional
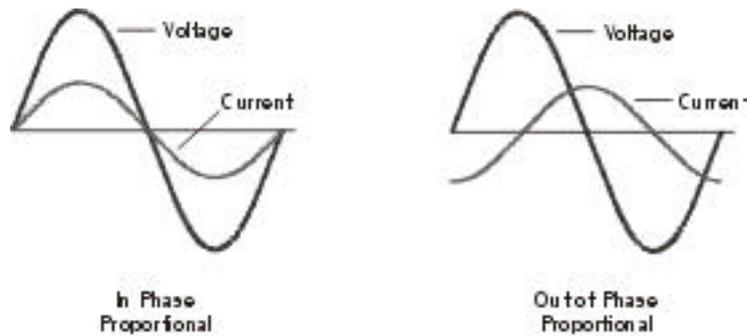
Nonlinear Loads

When instantaneous load current is not proportional to instantaneous voltage the load is considered a nonlinear load. Computers, television, PLCs, ballested lighting, and variable speed drives are examples of nonlinear loads. Nonlinear loads can cause harmonic distortion on the power supply. Harmonics will be discussed later in the course.

Crest Factor

Crest factor is a term used to describe the ratio of the peak value to the effective (RMS) value. A pure sinusoidal waveform has a crest factor of 1.41. A crest factor other than 1.41 indicates distortion in the AC waveform. The crest factor can be greater or lower than 1.41, depending on the distortion. High current peaks, for example, can cause the crest factor to be higher. Measuring the crest factor is useful in determining the purity of a sine wave.

Crest Factor = 1.41   Crest Factor > 1.41   Crest Factor < 1.41
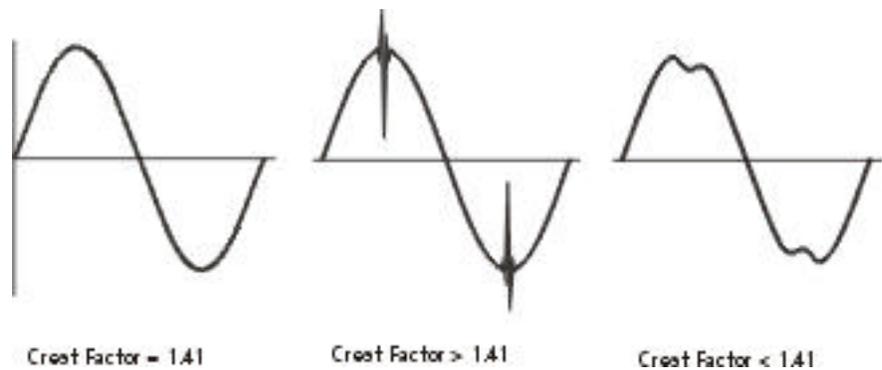
Conversion Chart

When using different types of test equipment it may be necessary to convert from one AC value to another. A voltmeter, for example, may be calibrated to read the RMS value of voltage. For purpose of circuit design, the insulation of a conductor must be designed to withstand the peak value, not just the effective value.

| To Convert	To	Multiply By
Peak-to-Peak	Peak	0.5
Peak	Peak-to-Peak	2
Peak	RMS	0.707
Peak	Average	0.637
RMS	Peak	1.414
RMS	Average	0.9
Average	Peak	1.567
Average	RMS	1.111

Changes in Voltage and Current

Even the best distribution systems are subject to changes in system voltage from time-to-time. The following industry terms can be used to describe given voltage conditions. Voltage changes can range from small voltage fluctuations of short duration to a complete outage for an extended period of time.

| Term	Condition
Voltage Fluctuations	Increase or decrease in normal line voltage within the normal rated tolerance of the electronic equipment. Usually short in duration and do not affect equipment performance.
Voltage Sag	Decrease in voltage outside the normal rated tolerance of the electronic equipment. Can cause equipment shutdown. Generally, two seconds or less in duration.
Voltage Swell	Increase in voltage outside the normal rated tolerance of the electronic equipment. Can cause equipment failure. Generally, two seconds or less in duration.
Long-Term Under/Overvoltage	Decrease/increase in voltage outside the normal rated tolerance of the electronic equipment. Can adversly affect equipment. Lasts more than a few seconds in duration.
Outage/Sustained Power Interruption	Complete loss of power. Can last from a few milliseconds to several hours.

Sags and undervoltage can be caused when high current loads, such as large motors are started. Undervoltage may also occur when a power utility reduces the voltage level to conserve energy during peak usage. Undervoltage is also commonly caused by overloaded transformers or improperly sized conductors.

Swells and overvoltage can be caused when high current loads are switched off, such as when machinery shuts down. Overvoltage may occur on loads located near the beginning of a power distribution system or improperly set voltage taps on a transformer secondary.


*Based on Equipment with Normal Rated Voltage Tolerance of ±10%
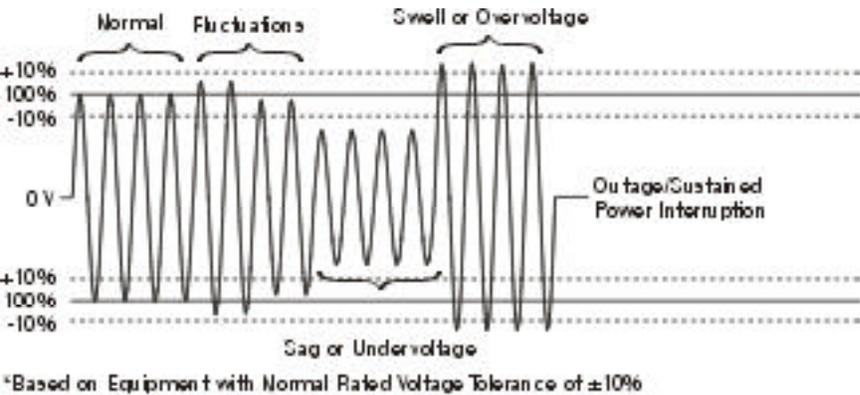
Voltage and Current Unbalance

Voltage unbalance occurs when the phase voltages in a three-phase system are not equal. One possible cause of voltage unbalance is the unequal distribution of single-phase loads. In the following illustration loads are equally divided.
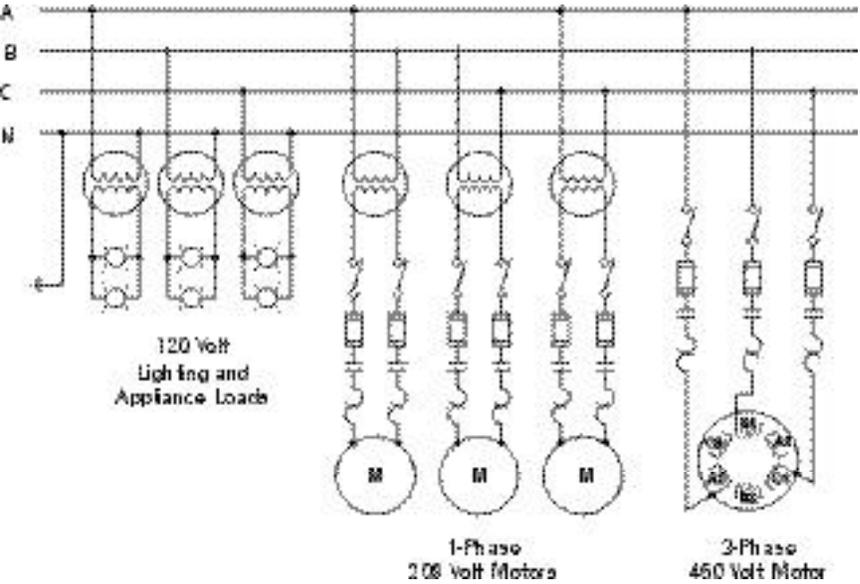
In this illustration, however, loads are unevenly divided. A large number of lighting and small appliance loads are connected to phase C . This can cause the voltage on phase C to be lower. Because a small unbalance in voltage can cause a high current unbalance, overheating can occur in the C phase winding of the 3-phase motor. In addition, the single-phase motors connected to phase C are operating on a reduced voltage. These loads will also experience heat related problems.

120 Volt
Lighting and
Appliance Loads

1-Phase
208 Volt Motors

3-Phase
460 Volt Motor
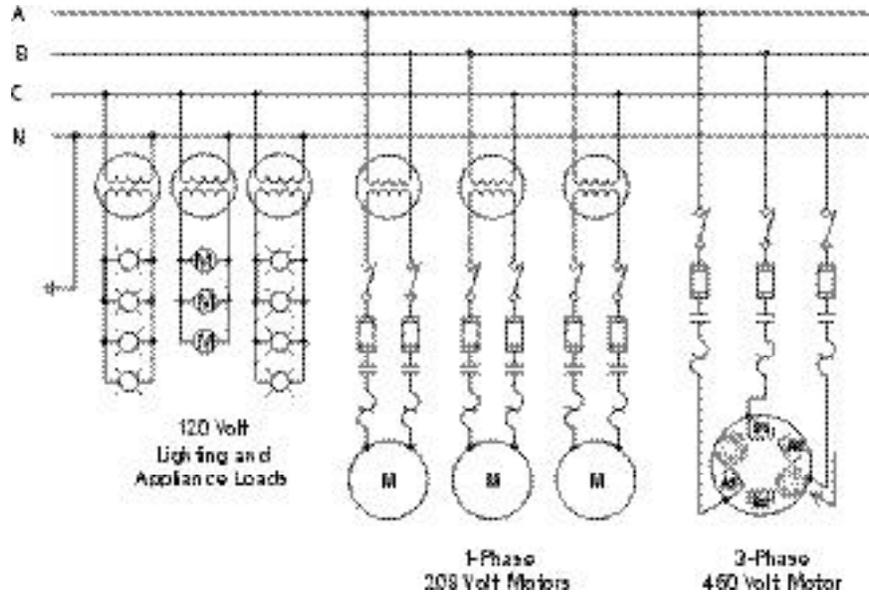
Transient Voltage

A transient voltage is a temporary, undesirable voltage that appears on the power supply line. Transient voltages can range from a few volts to several thousand volts and last from a few microseconds to a few milliseconds. Transients can be caused by turning off high inductive loads, switching large power factor correction capacitors, and lightning strikes.
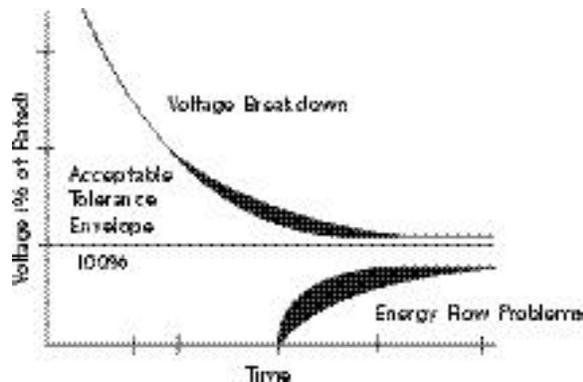

Transient Voltage
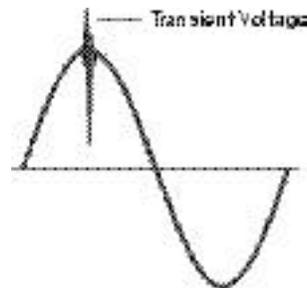
CBEMA and IEEE

The U.S. Department of Commerce, working with the Computer Business Equipment Manufacturers Association (CBEMA), published a set of guidelines for powering and protecting sensitive equipment. These guidelines were published in 1983 in FIPS Publication 94. As the use of computers has grown, other organizations have made additional recommendations. The Institute of Electrical and Electronic Engineers (IEEE) published IEEE 446-1987 which recommends engineering guidelines for the selection and application of emergency and standby power systems. While it is beyond the scope of this book to discuss in detail the recommendations of these documents it is useful to discuss their intent.

CBEMA Curve

The CBEMA curve is a useful tool that can be used as a guideline in designing power supplies for use with sensitive electronic equipment. The vertical axis of the graph is the percent of rated voltage applied to a circuit. The horizontal axis is the time the voltage is applied. The CBEMA curve illustrates an acceptable voltage tolerance envelope. In general, the greater the voltage spike or transient, the shorter the duration it can occur. Voltage breakdown and energy flow problems can occur when the voltage is outside the envelope.

Power Disturbance Types

There are three types of power disturbances. Type I disturbances are transient and oscillatory overvoltages lasting up to 0.5 Hz. Type I disturbances can be caused by lightning or switching of large loads on the power distribution system. Type II disturbances are overvoltages and undervoltages which last from 0.5 to 120 Hz. Type II disturbances can be caused by a fault on the power distribution system, large load changes, or malfunctions at the utility. Type III disturbances are outages lasting greater than 120 hertz.

Studies have shown that sensitive computer equipment is most vulnerable during a Type I overvoltage disturbance and a Type II undervoltage disturbance. Type II undervoltage disturbances are the most common cause of failure in sensitive computer equipment. It is important to note that the precise extent to which computers and other sensitive equipment is susceptible is difficult to determine.
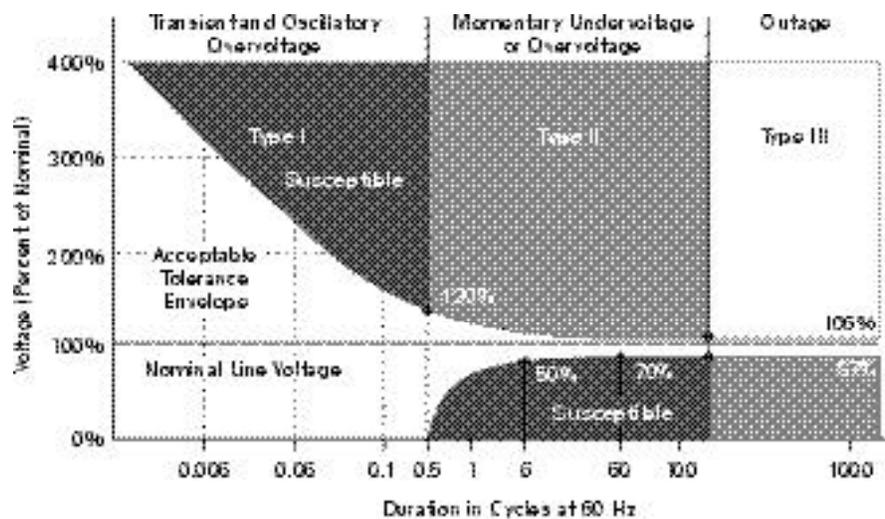
Review 2

1. _____ is a measurement of the number of alternations between positive and negative peak values in a measured amount of time.

   a. voltage
   b. current
   c. frequency
   d. power

2) The peak-to-peak value of an AC voltage with a peak voltage of 600 volts is _____ .

3) The instantaneous voltage measured at 120° of a sine wave with a peak voltage of 650 volts is _____ .

4) The most common method of expressing the value of AC voltage and current is _____ value.

   a. average
   b. effective
   c. peak
   d. instantaneous

5) A pure sinusoidal waveform has a crest factor of _____ .

6) Computer equipment is most vulnerable during a Type I overvoltage disturbance and a Type _____ undervoltage disturbance.

   a. I
   b. II
   c. III

Frequency and Harmonics

We learned earlier that frequency is a measurement of the number of times voltage and current rises and falls to alternating peak values per second. Frequency is stated in hertz. The standard power line frequency in the United States is 60 hertz (60 cycles per second). In many other parts of the world the standard frequency is 50 hertz.


1 Second
60 Hertz
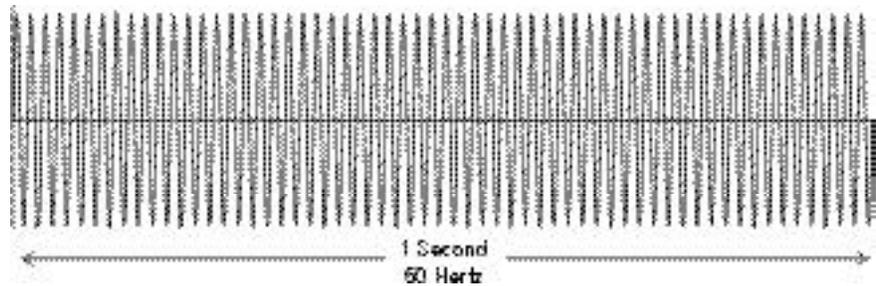
Harmonics

Harmonics are created by electronic circuits, such as, adjustable speed drives, rectifiers, personal computers, and printers. Harmonics can cause problems to connected loads.

The base frequency of the power supply is said to be the fundamental frequency or first harmonic. The fundamental frequency or first harmonic of a 60 Hz power supply is 60 Hz. Additional harmonics can appear on the power supply. These harmonics are usually whole number multiplies of the first harmonic. The third harmonic of a 60 Hz power supply, for example, is 180 Hz (60 x 3).

60 Hertz Power Supply
Fundamental Frequency
1st Harmonic Only

60 Hertz Power Supply
With 3rd Harmonic Present
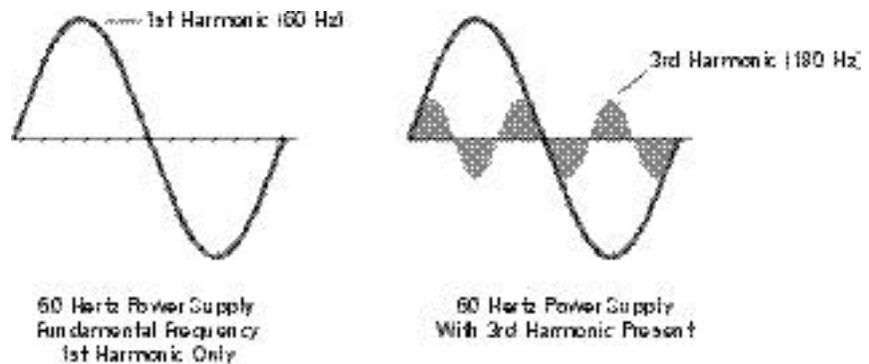
When a harmonic waveform is superimposed on the fundamental sine wave a distinctive waveform is produced. In this example, the third harmonic is seen superimposed on the fundamental frequency. The problem of waveform distortion becomes more complex when additional harmonics are present.


Resultant Waveform
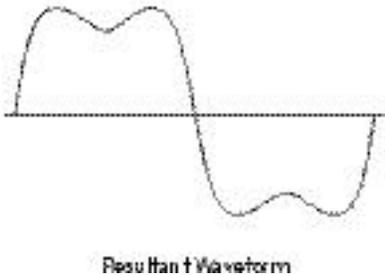
Total Harmonic Distortion

Harmonic distortion is a destructive force in power distribution systems. It creates safety problems, shortens the life span of transformers, and interferes with the operation of electronic devices. Total harmonic distortion (THD) is a ratio of harmonic distortion to the fundamental frequency. The greater the THD the more distortion there is of the 60 Hz sine wave. Harmonic distortion occurs in voltage and current waveforms. Typically, voltage THD should not exceed 5% and current THD should not exceed 20%. Some of the power meters offered by Siemens are capable of reading THD.
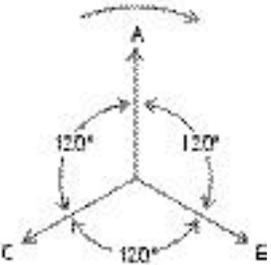
$$\% \text{ of THD} = \frac{\text{RMS of Total Harmonic Distortion Signal}}{\text{RMS of Fundamental Frequency}} \times 100$$

Phasors

Phase rotation describes the order in which waveforms from each phase cross zero. Waveforms can be used to illustrate this relationship. Phasors consist of lines and arrows and are often used in place of waveforms for simplification.
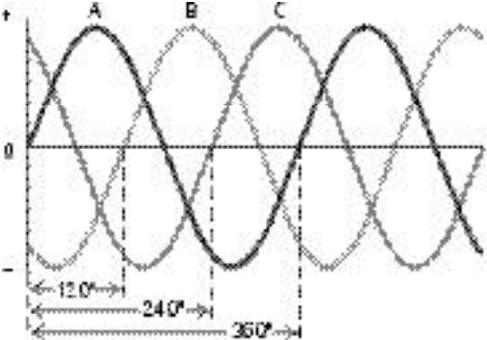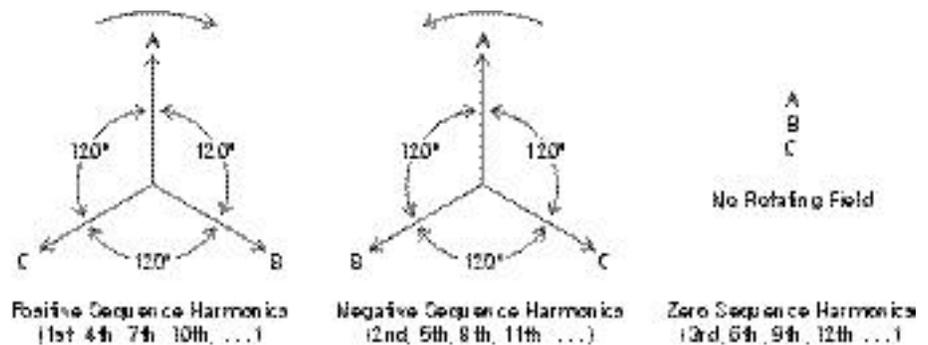

3-Phase Waveform

Phase Relationship

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Harmonic Sequence

A harmonic's phase rotation relationship to the fundamental frequency is known as harmonic sequence. Positive sequence harmonics (4th, 7th, 10th, ...) have the same phase rotation as the fundamental frequency (1st). The phase rotation of negative sequence harmonics (2nd, 5th, 8th, ...) is opposite the fundamental harmonic. Zero sequence harmonics (3rd, 6th, 9th, ...) do not produce a rotating field.

Harmonic	Frequency	Sequence
1st	**60**	**Fundamental**
2nd	120	Negative
3rd	180	Zero
4th	240	Positive
5th	300	Negative
6th	360	Zero
7th	420	Positive
8th	480	Negative
9th	540	Zero
10th	600	Positive

Odd numbered harmonics are more likely to be present than even numbered harmonics. Higher numbered harmonics have smaller amplitudes, reducing their affect on the power and distribution system.


Positive Sequence Harmonics (1st 4th 7th 10th, ...)

Negative Sequence Harmonics (2nd 5th 8th 11th ...)

Zero Sequence Harmonics (3rd 6th 9th 12th ...)

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Harmonic Effects

All harmonics cause additional heat in conductors and other distribution system components. Negative sequence harmonics can be problematic in induction motors. The reverse phase rotation of negative harmonics reduces forward motor torque and increases the current demand.

Forward Torque
(Fundamental Frequency)

Reverse Torque
(Negative Sequence Harmonics)
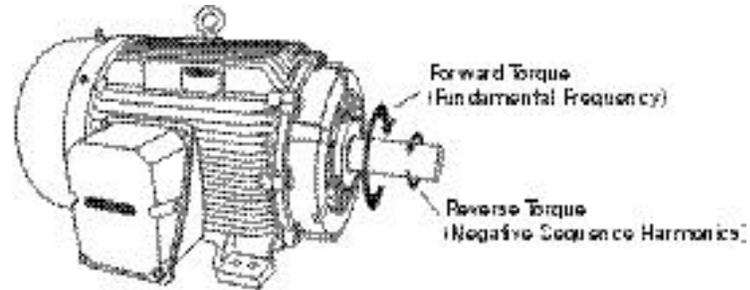
Zero sequence harmonics add together, creating a single-phase signal that does not produce a rotating magnetic field. Zero sequence harmonics can cause additional heating in the neutral conductor of a 3Ø, 4-wire system. This can be a major problem because the neutral conductor typically is not protected by a fuse or circuit breaker.

Protected Supply Conductors

Unprotected Neutral Conductor

Panelboard
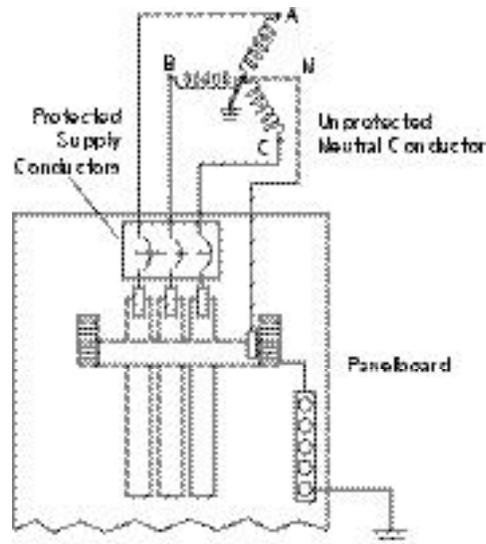
K Factor

K factor is a simple numerical rating that indicates the extra heating caused by harmonics. A transformer's ability to handle the extra heating is determined by a K factor rating. A standard transformer has a rating of K-1. A transformer might have a rating of K-5, which would be an indication of the transformer's ability to handle 5 times the heating effects caused by harmonics than a K-1 rated transformer.
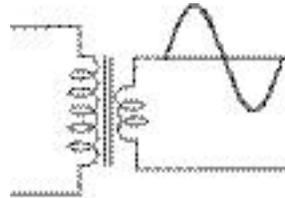
Standard Transformer
No Harmonics Present
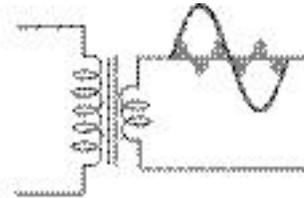
Transformer with K Factor Rating
Harmonics Present

Power and Power Factor

Load Types

Distribution systems are typically made up of a combination of various resistive, inductive, and capacitive loads.
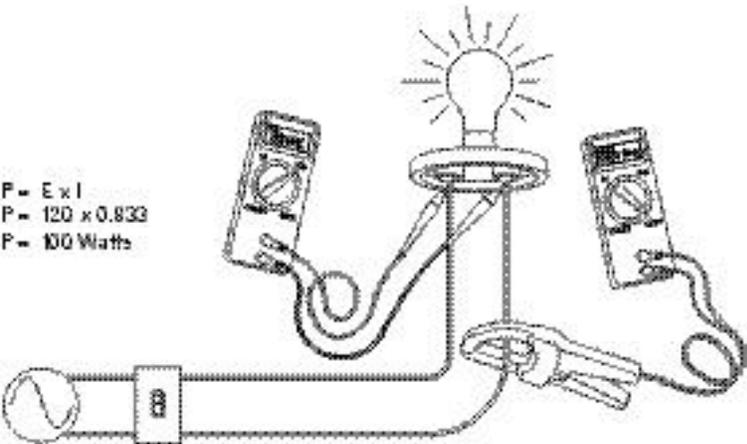
Resistive Loads

Resistive loads include devices such as heating elements and incandescent lighting. In a purely resistive circuit, current and voltage rise and fall at the same time. They are said to be " in phase."
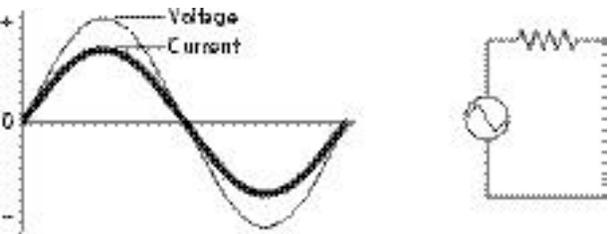

True Power

All the power drawn by a resistive circuit is converted to useful work. This is also known as true power in a resistive circuit. True power is measured in watts (W), kilowatts (kW), or megawatts (MW). In a DC circuit or in a purely resistive AC circuit, true power can easily be determined by measuring voltage and current. True power in a resistive circuit is equal to system voltage (E) times current (I).

In the following example, an incandescent light (resistive load) is connected to 120 VAC. The current meter shows the light is drawing 0.833 amps. In this circuit 100 watts of work is done (120 VAC x 0.833 amps).

P = E x I
P = 120 x 0.833
P = 100 Watts

Inductive Loads

Inductive loads include motors, transformers, and solenoids. In a purely inductive circuit, current lags behind voltage by 90°. Current and voltage are said to be "out of phase." Inductive circuits, however, have some amount of resistance. Depending on the amount of resistance and inductance, AC current will lag somewhere between a purely resistive circuit (0°) and a purely inductive circuit (90°). In a circuit where resistance and inductance are equal values, for example, current lags voltage by 45°.

Purely Inductive Circuit   Circuit with Equal Values of Resistance and Inductance
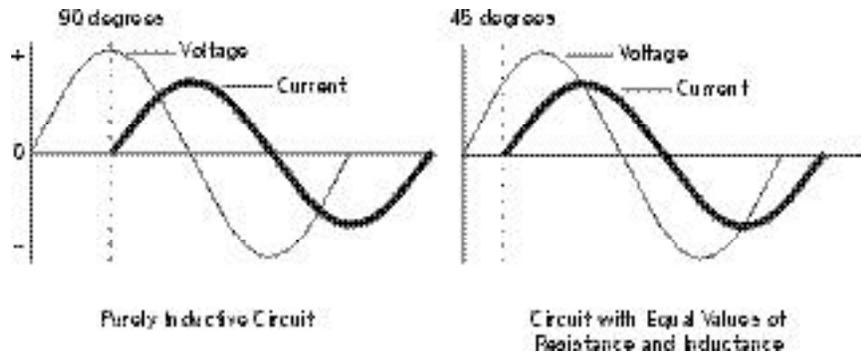
Capacitive Loads

Capacitive loads include power factor correction capacitors and filtering capacitors. In a purely capacitive circuit, current leads voltage by 90°. Capacitive circuits, however, have some amount of resistance. Depending on the amount of resistance and capacitance, AC current will lead voltage somewhere between a purely resistive circuit (0°) and a purely capacitive circuit (90°). In a circuit where resistance and capacitance are equal values, for example, current leads voltage by 45°.
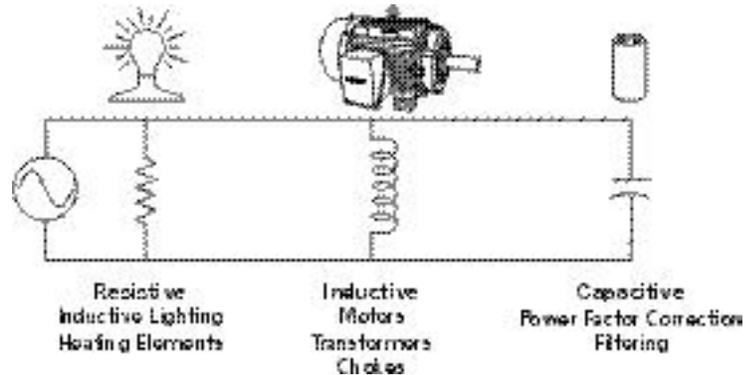

Purely Capacitive Circuit   Circuit with Equal Values of Resistance and Capacitance
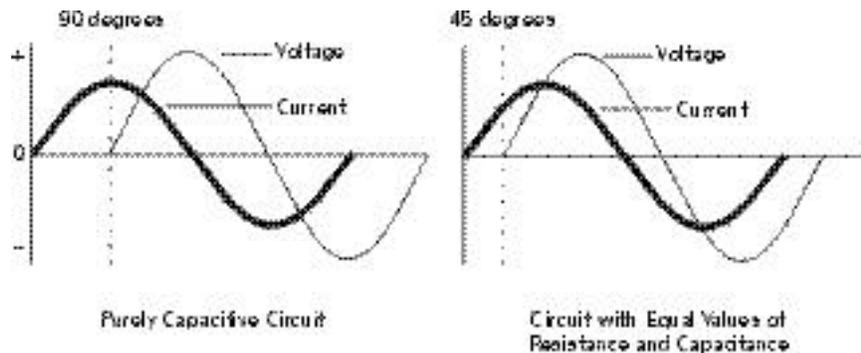
Reactive Loads

Circuits with inductive or capacitive components are said to be reactive. Most distribution systems have various resistive and reactive circuits. The amount of resistance and reactance varies, depending on the connected loads.


Resistive	Inductive	Capacitive
Inductive Lighting	Motors	Power Factor Correction
Heating Elements	Transformers	Filtering
	Chokes	

Reactance

Just as resistance is opposition to current flow in a resistive circuit, reactance is opposition to current flow in a reactive circuit. It should be noted, however, that where frequency has no effect on resistance, it does effect reactance. An increase in applied frequency will cause a corresponding increase in inductive reactance and a decrease in capacitive reactance.

$$R = \frac{E}{I}$$

R = Resistance in Ω
E = Voltage
I = Current

Resistance

$$X_L = 2\pi fL$$

X_L = Inductive Reactance (Ω)
π = 3.14
f = Applied Frequency (Hz)
L = Inductance (Henrys)

Inductive Reactance

$$X_c = \frac{1}{2\pi fC}$$

X_c = Capacitive Reactance
π = 3.14
f = Applied Frequency (Hz)
C = Capacitance (Farads)

Capacitive Reactance

Energy in Reactive Circuits

Energy in a reactive circuit does not produce work. This energy is used to charge a capacitor or produce a magnetic field around the coil of an inductor. Current in an AC circuit rises to peak values (positive and negative) and diminishes to zero many times a second. During the time current is rising to a peak value, energy is stored in an inductor in the form of a magnetic field or as an electrical charge in the plates of a capacitor. This energy is returned to the system when the magnetic field collapses or when the capacitor is discharged.
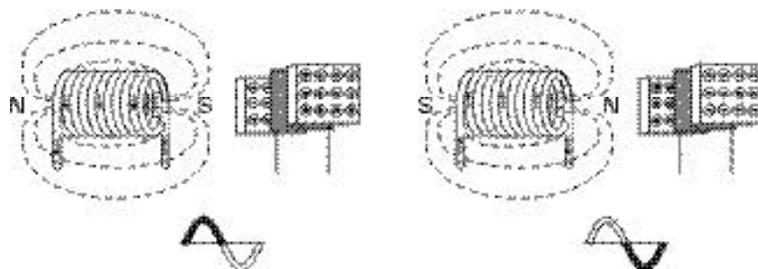
Reactive Power

Power in an AC circuit is made up of three parts; true power, reactive power, and apparent power. We have already discussed true power. Reactive power is measured in volt-amps reactive (VAR). Reactive power represents the energy alternately stored and returned to the system by capacitors and/or inductors. Although reactive power does not produce useful work, it still needs to be generated and distributed to provide sufficient true power to enable electrical processes to run.

Apparent Power

Not all power in an AC circuit is reactive. We know that reactive power does not produce work; however, when a motor rotates work is produced. Inductive loads, such as motors, have some amount of resistance. Apparent power represents a load which includes reactive power (inductance) and true power (resistance). Apparent power is the vector sum of true power, which represents a purely resistive load, and reactive power, which represents a purely reactive load. A vector diagram can be used to show this relationship. The unit of measurement for apparent power is volt amps (VA). Larger values can be stated in kilovolt amps (kVA) or megavolt amps (MVA).

Power Factor

Power factor (PF) is the ratio of true power (PT) to apparent power (PA), or a measurement of how much power is consumed and how much power is returned to the source. Power factor is equal to the cosine of the angle theta in the above diagram. Power factor can be calculated with the following formulas.
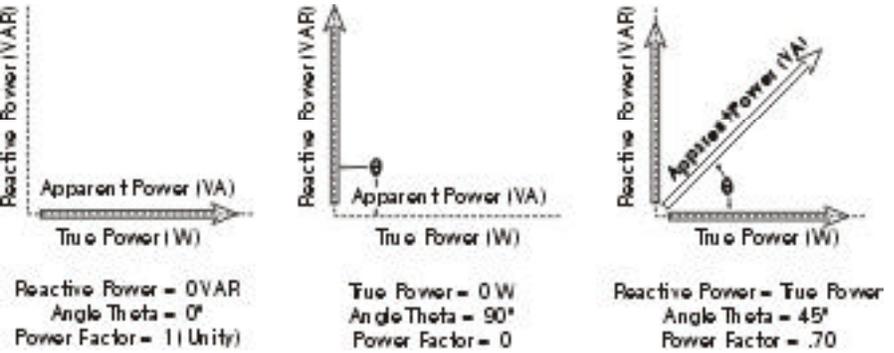
$$PF = \frac{PT}{PA}$$

or

$$PF = \cos \theta$$

Power factor can be given as a percent or in decimal format. The following table shows the power factor for a few sample angles.
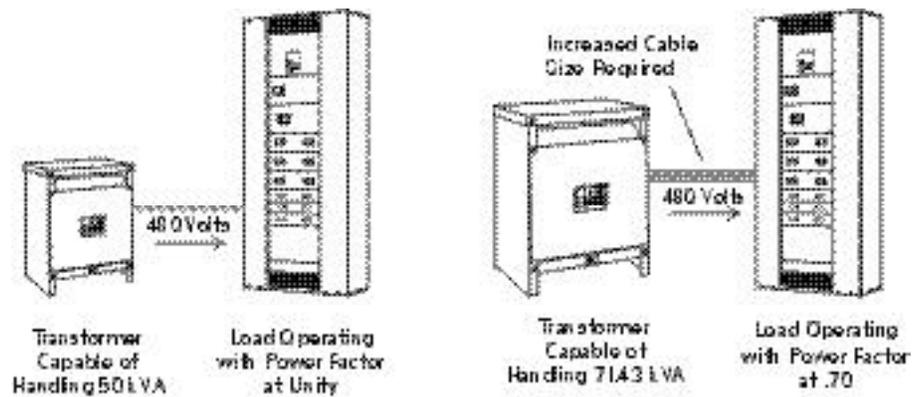
Angle Theta	Cosine of Angle Theta	Power Factor (%)	Power Factor (Decimal)
0	1	100%	1
10	0.98	98%	.98
20	0.94	94%	.94
30	0.87	87%	.87
45	0.70	70%	.7
60	0.50	50%	.5
70	0.34	34%	.34
80	0.17	17%	.17
90	0	0%	0

In purely resistive circuits, apparent power and true power are equal. All the power supplied to a circuit is consumed or dissipated in heat. The angle of theta is 0° and the power factor is equal to 1. This is also referred to as unity power factor. In purely reactive circuits, apparent power and reactive power are equal. All power supplied to a circuit is returned to the system. The angle theta is 90° and the power factor is 0. In reality, all AC circuits contain some amount of resistance and reactance. In a circuit where reactive power and true power are equal, for example, the angle of theta is 45° and power factor is 0.70.

Reactive Power = 0 VAR
Angle Theta = 0°
Power Factor = 1 (Unity)

True Power = 0 W
Angle Theta = 90°
Power Factor = 0

Reactive Power = True Power
Angle Theta = 45°
Power Factor = .70

Power Factor Problems

It can be seen that an increase in reactive power causes a corresponding decrease in power factor. This means the power distribution system is operating less efficiently because not all current is performing work. For example, a 50 kW load with a power factor of 1 (reactive power = 0) could be supplied by a transformer rated for 50 kVA. However, if power factor is 0.7 (70%) the transformer must also supply additional power for the reactive load. In this example a larger transformer capable of supplying 71.43 kVA (50 ÷ 70%) would be required. In addition, the size of the conductors would have to be increased, adding significant equipment cost.

Transformer Capable of Handling 50 kVA — Load Operating with Power Factor at Unity — Increased Cable Size Required — 480 Volts — Transformer Capable of Handling 71.43 kVA — Load Operating with Power Factor at .70

The Cost of Power

Utility companies sell electrical power based on the amount of true power measured in watts (W). However, we have learned that in AC circuits not all power used is true power. The utility company must also supply apparent power measured in volt-amps (VA). Typically utilities charge additional fees for increased apparent power due to poor power factor.
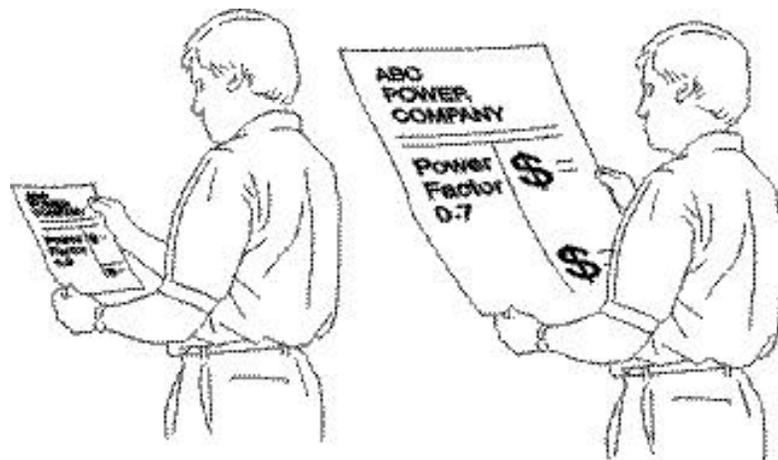
The following table shows the amount of apparent power (VA = W ÷ PF) required for a manufacturing facility using 1 MW (megawatt) of power per hour for a few sample power factors. If, for example, a manufacturing facility had a power factor of 0.70 the utility company would have to supply 1.43 MVA (mega volt-amps) of power. If the power factor were corrected to 0.90 the power company would only have to supply 1.11 MVA of power.

True Power (MW)	Power Factor	Apparent Power (MVA)
True Power	÷ Power Factor	= Apparent Power
	1	1
	0.95	1.053
	0.90	1.11
1	0.85	1.18
	0.80	1.25
	0.75	1.33
	0.70	1.43

Leading and Lagging Power Factor

Since current leads voltage in a capacitive circuit, power factor is considered leading if there is more capacitive reactance than inductive reactance. Power factor is considered lagging if there is more inductive reactance than capacitive reactance since current lags voltage in a inductive circuit. Power factor is unity when there is no reactive power or when inductive reactance and capacitive reactance are equal, effectively cancelling each other.

It is usually more economical to correct poor power factor than to pay large utility bills. In most industrial applications motors account for approximately 60% or more of electric power consumption, resulting in a lagging power factor (more inductive than capacitive). Power factor correction capacitors can be added to improve the power factor.

33
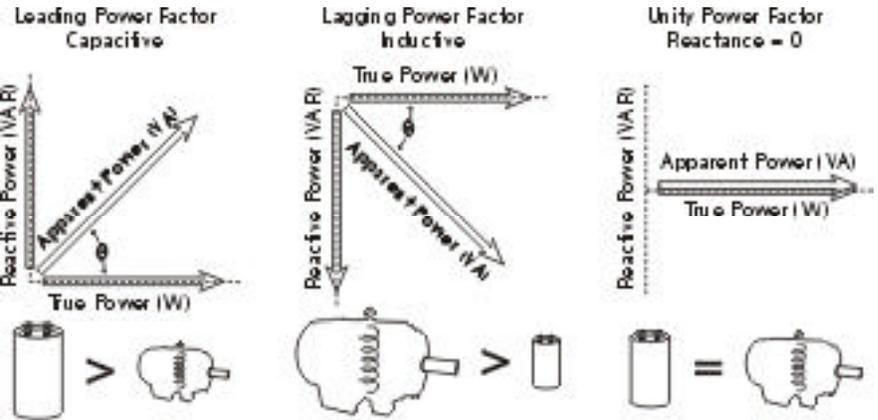
Power Demand

Demand is the average energy consumed over a specified period of time. The interval is usually determined by the utility company and is typically 15 or 30 minutes. The utility measures the maximum demand over the 15 or 30 minute period. Utility companies must install larger equipment to handle irregular demand requirements. For this reason utility companies may charge large customers an additional fee for irregular power usage during peak times. If the maximum demand is greater than the average consumption, the utility company will need to provide increased generating capacity to satisfy the higher demand. Demand is usually low in the morning and evening. During the day there is more demand for electrical power.

Siemens power meters have a sliding window adjustment that allows the user to monitor time segments specified by the utility company.
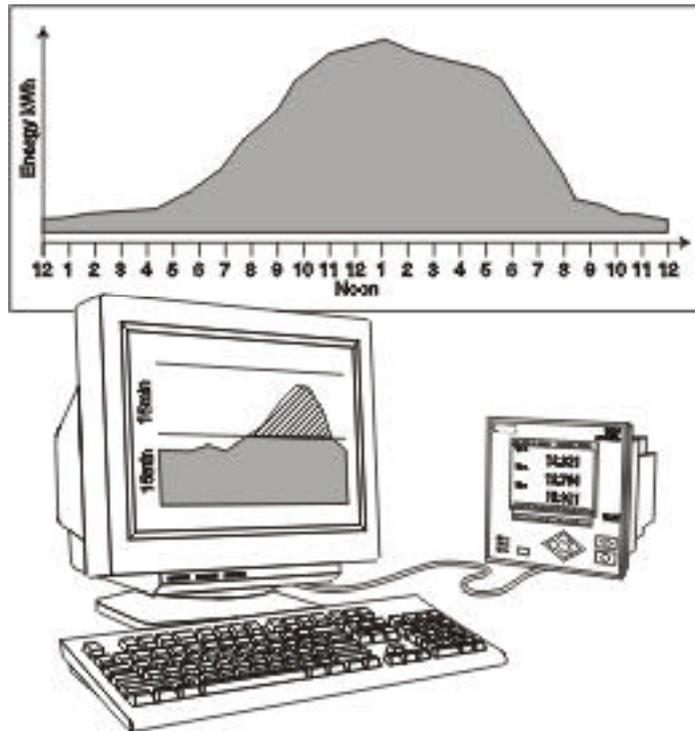
Solutions

As we have learned, there are a number of things that can affect power quality. The following table provides some basic guidelines to solve these problems. It should be remembered that the primary cause and resulting effects on the load and system should be considered when considering solutions.

Problem	Effect	Solution
Sag	Computer shutdown resulting in lost data, lamp flicker, electronic clock reset, false alam.	Voltage regulator, power line conditioner, proper wiring.
Swell	Shorten equipment life and increase failure due to heat.	Voltage regulator, power line conditioner.
Undervoltage	Computer shutdown resulting in lost data, lamp flicker, electronic clock reset, false alam.	Voltage regulator, power line conditioner, proper wiring.
Overvoltage	Life expectency of motor and other insulation resulting in equipment failure or fire hazard. Shorten life of light bulbs	Voltage regulator, power line conditioner.
Momentary Power Interruption	Computer shutdown resulting in lost data, lamp flicker, electronic clock reset, false alam, motor circuits trip.	Voltage regulator, power line conditioner, UPS system.
Noise	Erractic behavior of electronic equipment, incorrect data communication between computer equipment and field devices.	Line filters and conditioners, proper wiring and grounding.
Transients	Premature equipment failure, computer shutdown resulting in lost data.	Surge suppressor, line conditioner, isolation transformers, proper wiring, grounding.
Harmonics	Overheated neutrals, wires, connectors, transformers, equipment. Data communication errors.	Harmonic filters, K-rated transformers, proper wiring and grounding.
Power Factor	Increased equipment and power costs	Power factor correction capacitors.

Review 3

1. The second harmonic of a 60 Hz power supply is _____ Hz.

2. Typically, the total harmonic distortion (THD) of a voltage waveform should not exceed _____ %.

3. _____ sequence harmonics do not produce a rotating magnetic field.

   a. Positive
   b. Negative
   c. Zero

4. A transformer's ability to handle the extra heating caused by harmonics is determined by a _____ rating.

5. In a purely _____ circuit, voltage and current are in phase.

   a. resistive
   b. inductive
   c. capacitive

6. _____ power represents a load which includes reactive power and true power.

7. _____ is the ratio of true power to apparent power.

8. An increase in reactive power would require a corresponding _____ in transformer size.

   a. increase
   b. decrease

9. It is possible to correct for sag with the addition of a _____ .

   a. voltage regulator
   b. power line conditioner
   c. proper wiring
   d. all of the above

ACCESS System

Up to this point we have looked at how various factors effect power quality. The following sections will focus on components of the ACCESS system and how they can be used as a complete power monitoring and management system.

Supervisory Devices

In general, ACCESS works on two levels: supervisory and field. Supervisory devices, such as WinPM™, collects and displays information from a network of field devices. A supervisory device sends requests and receives feedback from field devices over a serial network. This process, called polling, allows the supervisory and field devices to exchange information. Siemens WinPM software runs on a personal computer (PC).

Field Devices

Field devices include meters, circuit breakers, protective relays, I/O devices, motor protectors, and personal computers (PCs). Field devices send and receive information about an electrical system.

In the following sections we will look at ACCESS system products used as supervisory devices, in network communication, and field devices.
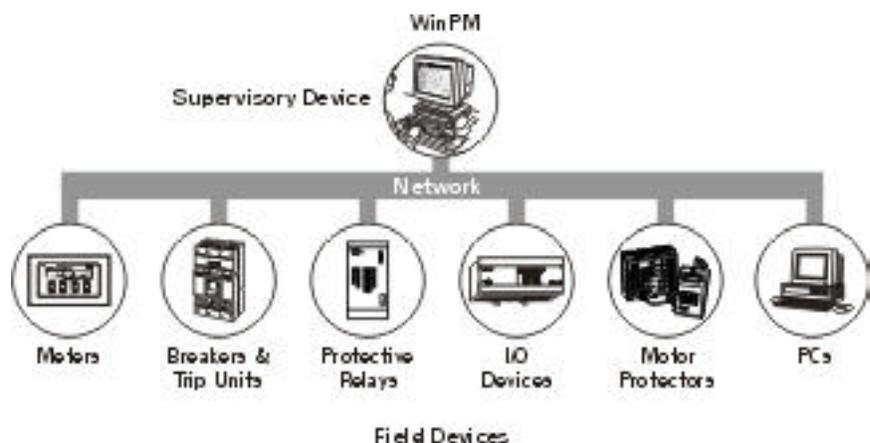
WinPM and SIEServe

WinPM

WinPM™ is supervisory software designed for monitoring and control of any facility's electrical distribution system. WinPM can run on a single computer or in a networked environment. Multiple computers running WinPM can share data and control devices over a LAN using TCP/IP. WinPM can monitor an entire electrical system consisting of hundreds of field devices in multiple locations.
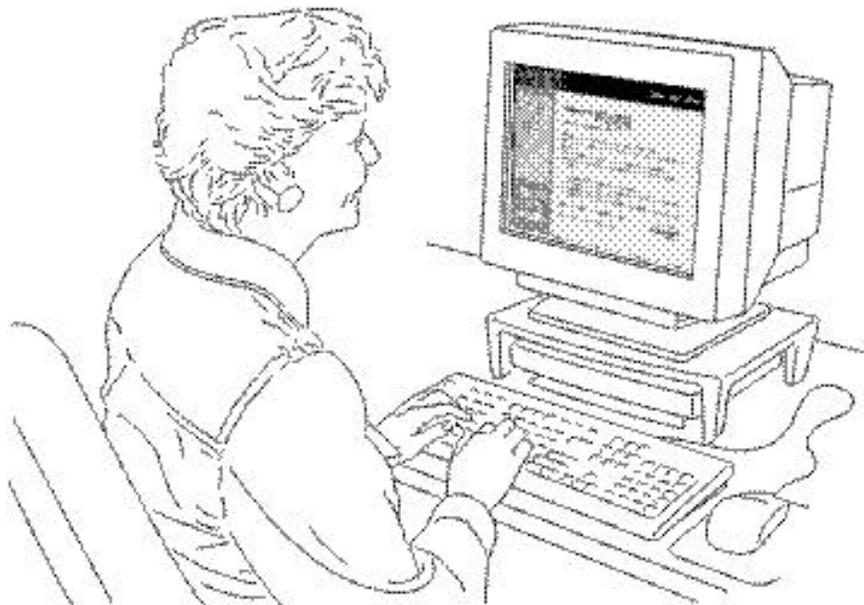
Electrical System Management

WinPM monitors and collects data of an electrical system by interfacing to any communicating electrical device such as power meters, relays, and trip units. Alarms can be setup to trigger if a specific value, such as voltage, current, or KW demand, is exceeded. Alarms can alert via audible and visual messages on a PC, fax, or pager message, and/or automatically control a connected device.

Analysis	Power quality, such as transients, sags, swells, and harmonics, can be monitored and analyzed by viewing triggered waveforms, continuous data sampling, relay trip logs, and setpoint event messages.

Historical data logs can be generated to provide load profile information, kilowatt demand usage patterns, harmonic, and power factor trends. These historical data logs can provide trending on any measured value.

Device Configuration	ACCESS field devices can be configured remotely by specifying protective settings. Certain field devices can be configured to record waveforms.

Device Control	Certain devices can be controlled directly from WinPM. For example, motors can be started and stopped using Siemens Advanced Motor Master System (SAMMS) devices.

SIEServe	SIEServe™ is another electrical distribution software product designed by Siemens. SIEServe allows for the retrieval and display of data from Siemens power meters, trip units, and relays. SIEServe, though not as robust as WinPM, provides a simple way to monitor an electrical distribution system from a desktop. Data retrieved by SIEServe can be linked to spreadsheets for charting or word processing programs for other reporting functions. SIEServe does not have the control capabilities of WinPM.

Industrial Computer

Siemens software, such as WinPM and SIEServe, will run on most personal computers. In some applications it may be desirable to locate a supervisory computer in a harsh industrial environment. The Siemens industrial personal computer was designed for this purpose. The Siemens industrial computer is dust proof and drip proof to NEMA 4, NEMA 4X, and NEMA 12 specifications. There is a 10.4″ flat screen monitor and full keypad with an integrated pointing device. This computer is designed for panel mounting.
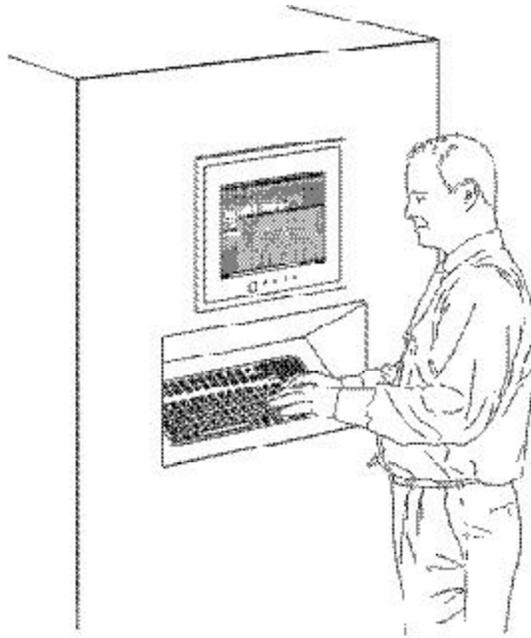
Communication Protocols and Standards

The ACCESS system allows a variety of devices to communicate electronically. In the following illustration, for example, several power meters are connected to a single computer.
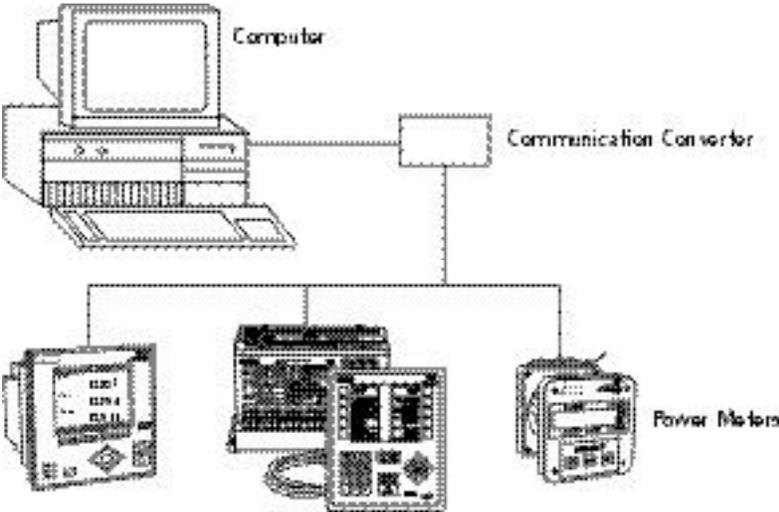

Straight-Line Topology

Field devices can be connected to supervisory devices with either straight-line or loop topology. In straight-line topology the supervisory device connects to a field device, which in turn connects to another field device, terminating at the farthest device. Straight-line topology allows for longer runs; however, if a break in the line should occur the supervisory device would be unable to communicate with devices on the far side of the break.
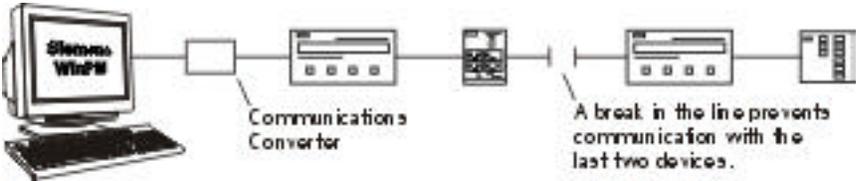
Loop Topology

In loop topology the cable is connected in a similar manner to straight-line topology. Rather than terminating the connection at the farthest device, a complete loop is formed by bringing the cable back to the supervisory device. Loop topology requires more cable than straight-line topology, which adds expense to the system and shortens the distance from the last device on the loop to the supervisory device. The main advantage to loop topology is the ability to continue to communicate with each device if there is a break in the system.
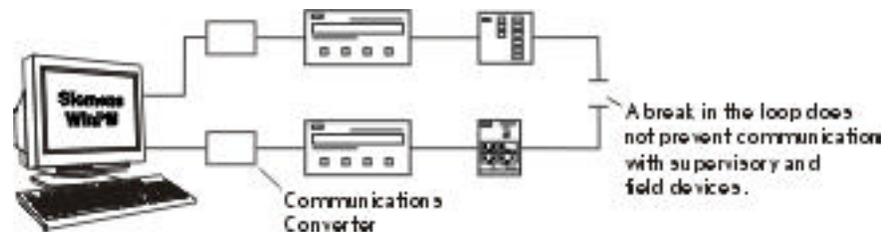
Protocols

Network protocols are rules that allow devices to communicate with each other. A protocol identifies how devices should identify each other, the form communicated data takes, and how the data is interpreted at its final destination. Several protocol standards have evolved in the electrical industry. Siemens ACCESS supports the following protocols at various levels.

PROFIBUS DP

PROFIBUS DP is an open bus standard for a wide range of applications in various manufacturing and automation applications. PROFIBUS DP works at the field device level such as, power meters, I/O devices, motor protectors, circuit breakers, and lighting controls. An advantage to PROFIBUS DP is the ability to communicate between devices of different manufacturers.
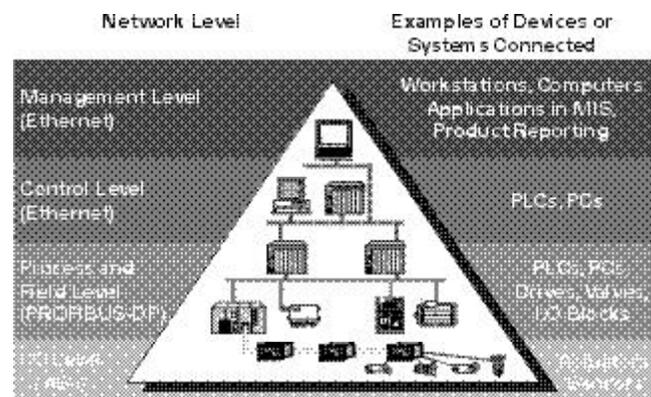
ModBus RTU

ModBus RTU is a protocol originally developed by MODICON, which is now part of Schneider Automation. ModBus RTU protocol has been widely used by other companies.

DNP 3.0

Distributed Network Protocol 3.0 (DNP 3.0) was developed by Harris Distributed Automation Products. This protocol is an open and public protocol based on standards developed by the International Electrotechnical Commission (IEC). This protocol is often used by large power utility companies.

SEABus and SEABus Plus

The rules that govern the communication of the ACCESS system are known collectively as SEABus and SEABus Plus. Both protocols are used to communicate between supervisory and field devices. SEABus and SEABus Plus are open protocols available to anyone who wants to connect their equipment to the ACCESS system.

A supervisory device can support unlimited field devices. Each field device in the ACCESS system has a unique address. A packet is simply a unit of data that is routed between an origin (supervisory device) and a destination (field device). Data bytes are grouped into packets containing from 5 to 260 characters. Data bytes contain a unique address for a given field device and instructions for the field device.

A supervisory device, for example, may initiate communication by sending a packet requesting information such as voltage from a specific field device. The field device would respond by sending a packet back with the requested information.
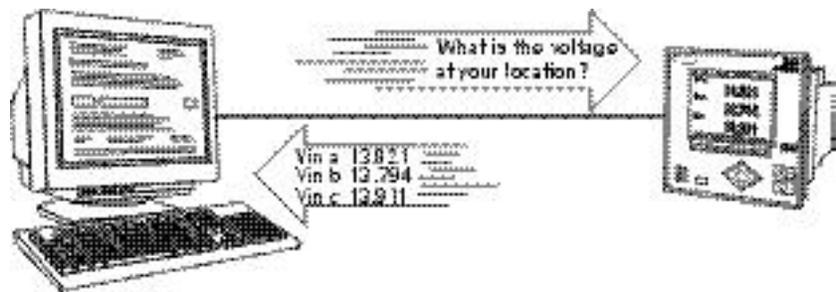
Local Area Networks

Local Area Network (LAN)

In any complex power monitoring system the need for rapid information flow is critical. Conditions at any point in the system may impact the entire power distribution system. This need for information flow often requires that intelligent devices, such as supervisory PCs, be interconnected by a local area network (LAN). A LAN is a communication system designed for private use in a limited area.

A node is an active device, such as a computer or printer, connected to the network. A LAN can be arranged with nodes in a bus, star, or a combination of bus and star.

One example of a widely used LAN is Ethernet. Ethernet uses a bus topology and an access control system that allows devices to initiate communication only if a carrier signal is not present. By comparison, Token Ring networks use a ring topology and a signal called a token to determine which device can communicate.

Bus   Star   Combination
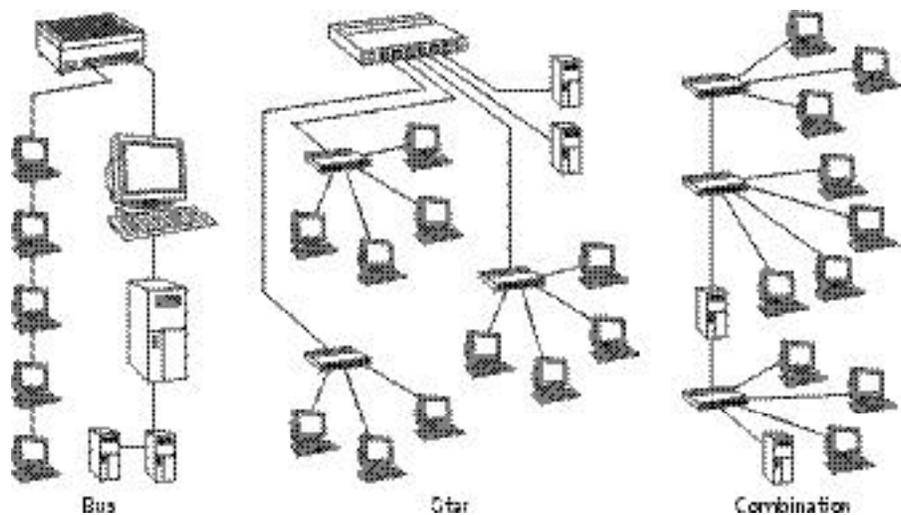
Ethernet Converter

The Siemens Ethernet converter connects many ACCESS field devices throughout a facility to a supervisory computer. The Ethernet converter can be configured so that Siemens ACCESS components can communicate through the Ethernet or Token Ring.

The Ethernet converter can connect RS-232 and RS-485 devices directly to a LAN.

The converter is also capable of connecting up to two protocols, such as SEABus and ModBus RTU.
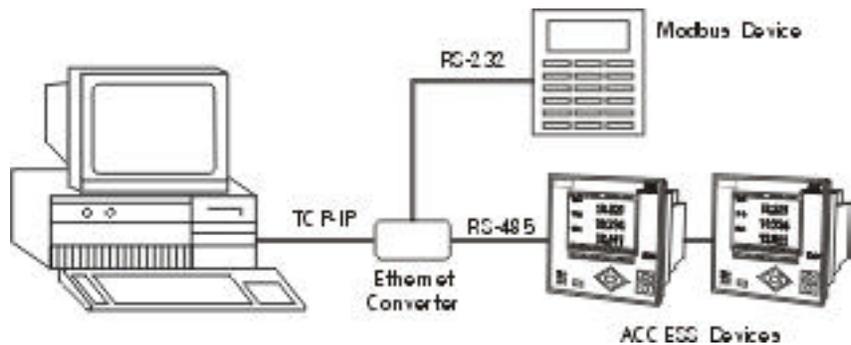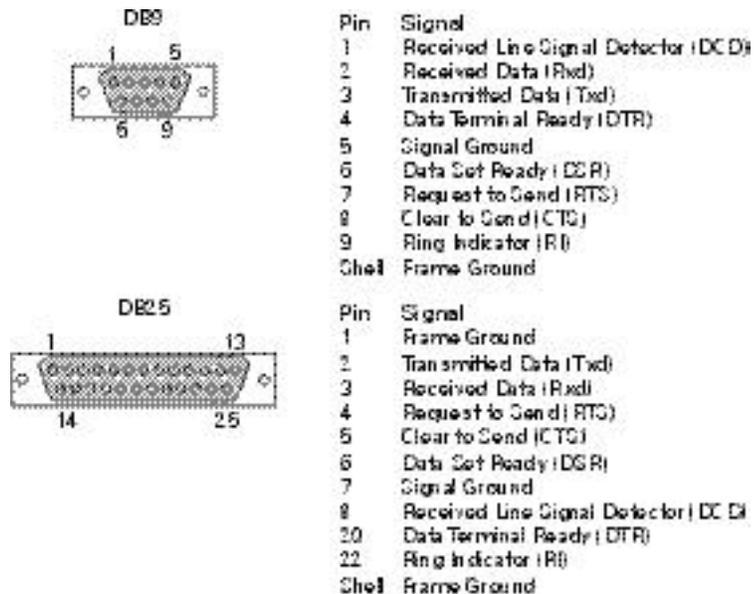
Serial Communication

RS-232 and RS-485 are Electronic Industries Association (EIA) specifications commonly used for serial data communication. Siemens ACCESS devices support the RS-485 as standard. Some ACCESS devices also support the RS-232 standard.

RS-232

RS-232 is a serial communication protocol which sends and receives information through twisted pair cable. It is common to see both 9-pin and 25-pin RS-232 connectors. It is important to note that although the RS-232 standard consists of 25 transmission lines, many applications do not require all the lines available. Depending on the device, manufacturers use various combinations of the transmission lines available. The following illustration, for example, shows the connector requirements for equipment used in the Siemens ACCESS system.

DB9 Pin	Signal
1	Received Line Signal Detector (DCD)
2	Received Data (Rxd)
3	Transmitted Data (Txd)
4	Data Terminal Ready (DTR)
5	Signal Ground
6	Data Set Ready (DSR)
7	Request to Send (RTS)
8	Clear to Send (CTS)
9	Ring Indicator (RI)
Shell	Frame Ground

| DB25 Pin	Signal
1	Frame Ground
2	Transmitted Data (Txd)
3	Received Data (Rxd)
4	Request to Send (RTS)
5	Clear to Send (CTS)
6	Data Set Ready (DSR)
7	Signal Ground
8	Received Line Signal Detector (DCD)
20	Data Terminal Ready (DTR)
22	Ring Indicator (RI)
Shell	Frame Ground

RS-232 uses what is referred to as an unbalanced signal or communication method. There is one signal wire for each circuit with a common return. The driver sends a series of binary signals to the receiver. These binary pulses make up predefined words that either give the status of a system being monitored or provide commands to control an event. This method is susceptible to unwanted electrical noise. The RS-232 standard supports only one driver (transmitter) and one receiver with distances limited to no greater than 50 feet.

RS-485

RS-485 is a communication standard that is better suited for industrial applications that involve distances greater than 50 feet. The RS-485 standard can support up to 32 devices over a maximum distance of 4000 feet.
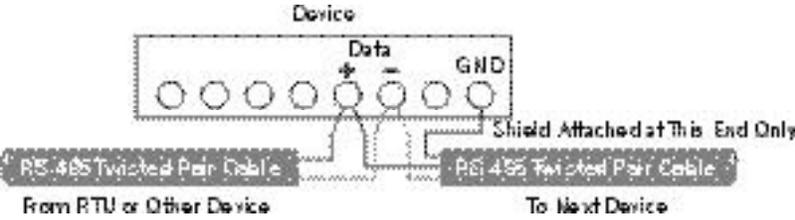
The RS-485 standard uses a twisted pair of wires for each circuit with differential drivers and receivers. This method provides a balanced signal which cancels out signal noise to allow for better data integrity.
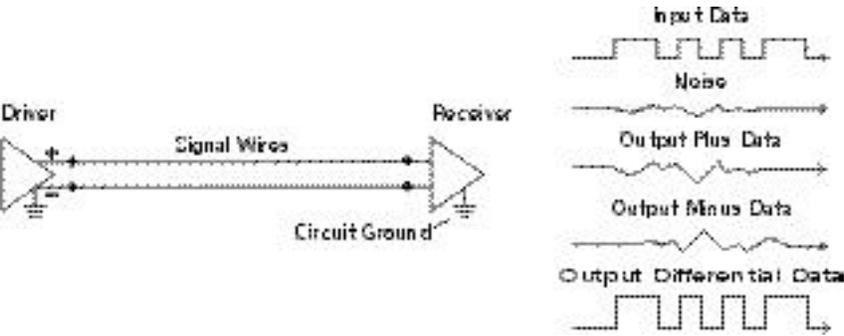
Typically, at the top level of a communication system is a host computer with an RS-232 interface. The host computer may have to communicate with an RS-485 device. In this situation a converter, such as a Siemens isolated multi-drop converter can be used.
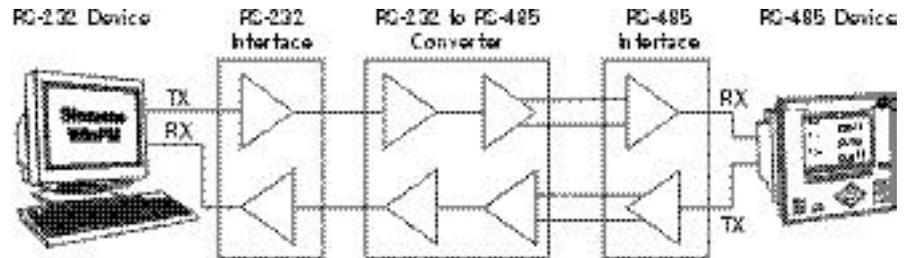

Isolated Multi-Drop Converter

The Isolated Multi-Drop Converter is an RS-232 to RS-485 converter that provides connectivity between a computer's RS-232 serial port and a Siemens SEABus RS-485 communications loop for ACCESS field devices. A multi-drop converter will accept up to four RS-485 input loops. Each input loop will support up to 32 devices. One isolated multi-drop converter can handle up to 128 field devices.
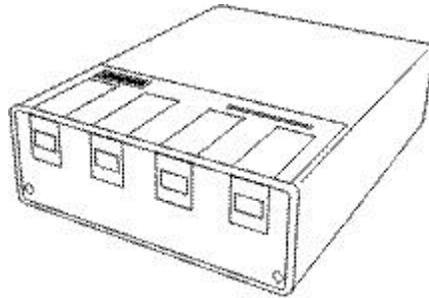
Using the Isolated Muli-Drop Converter

In the following illustration a computer communicates with various ACCESS field devices through an RS-232 interface and isolated multi-drop converter.
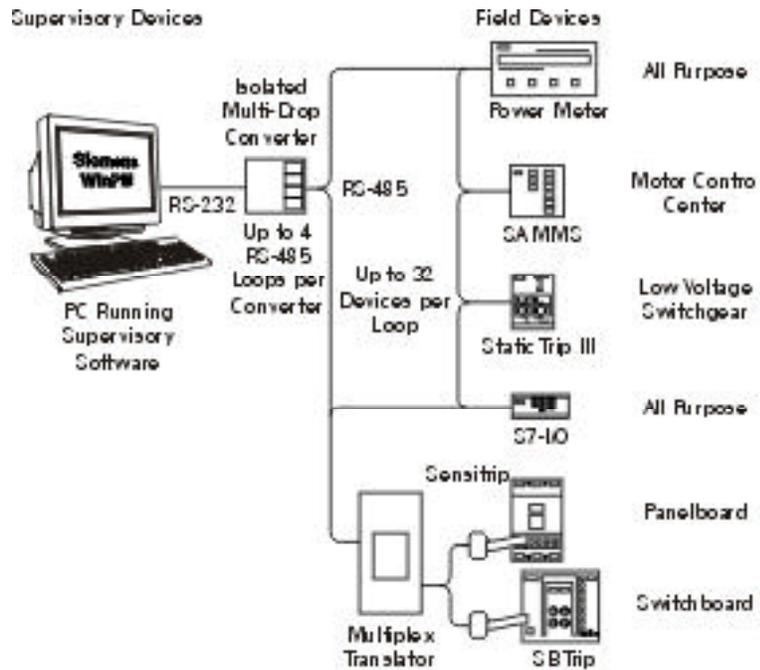

Communicating on a LAN

Field devices in the Siemens ACCESS product line that cannot communicate directly on a LAN, such as Ethernet, can be connected to the LAN through an Ethernet converter. When more than 32 field devices are used an isolated multi-drop converter is also required.


49
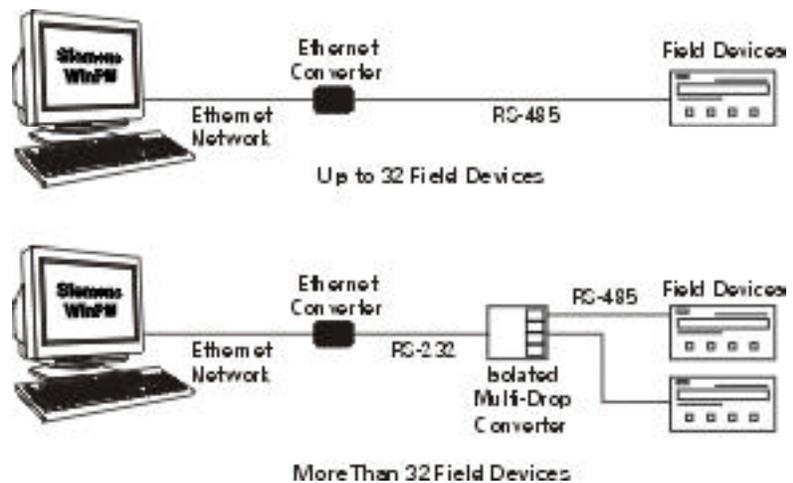
Modem

Modems are electronic devices used for sending and receiving data over long distances. The Siemens ACCESS system also supports data communication through a modem. In the following illustration a remote computer communicates to an isolated multi-drop converter through a modem.
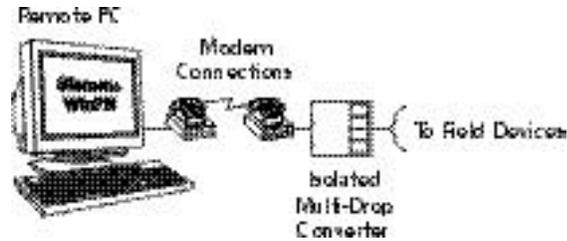

Fiber Optics

Fiber optics is a method for transmitting data using light. A basic system consists of a transmitting device which generates a light signal, a fiber optic cable, and a receiving device. In the following illustration a supervisory computer is connected to a fiber optic converter through an RS-232 interface. At the other end of the fiber optic cable is another RS-232 to fiber optic converter which is connected to an isolated multi-drop converter. The RS-485 output of the multi-drop converter is connected to various field devices.
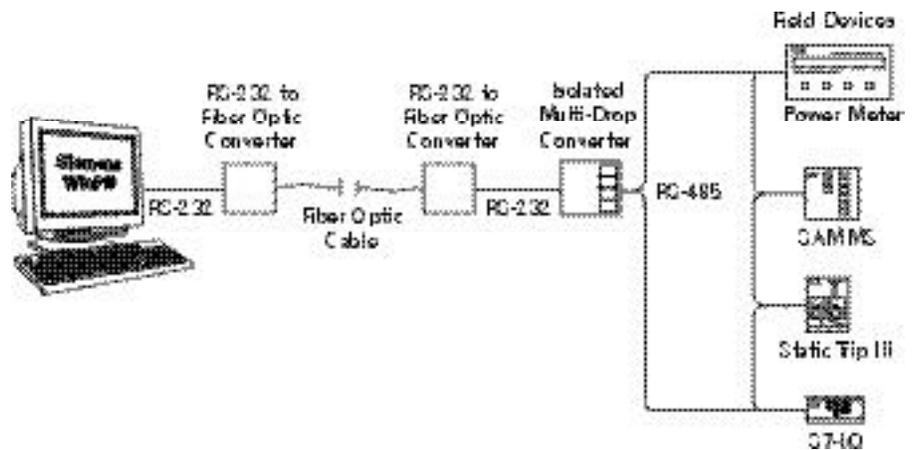
DTU3005

The DTU3005 is a multiple-function data transfer unit, which acts as an intelligent device to request information from up to 32 ACCESS devices. The requested information is then made available to PLCs and various industrial automation networks such as ModBus and PROFIBUS DP. There are two models, the DTU3005-P and DTU3005-B.
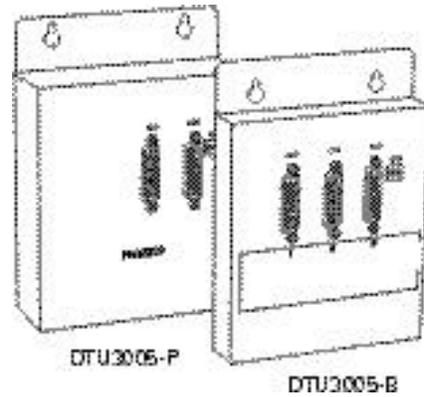

The following illustration shows two possible configurations. Up to 32 Siemens ACCESS devices can be connected to one port of the DTU3005. In one example, a PLC or ModBus master device can be connected to one port of a DTU3005-B. A second ModBus device or an optional supervisory PLC can be connected with SEABus to another port.

In the second example, PROFIBUS devices are connected via an RS-485 port on the DTU3005-P. A supervisory PC is connected to an available port.
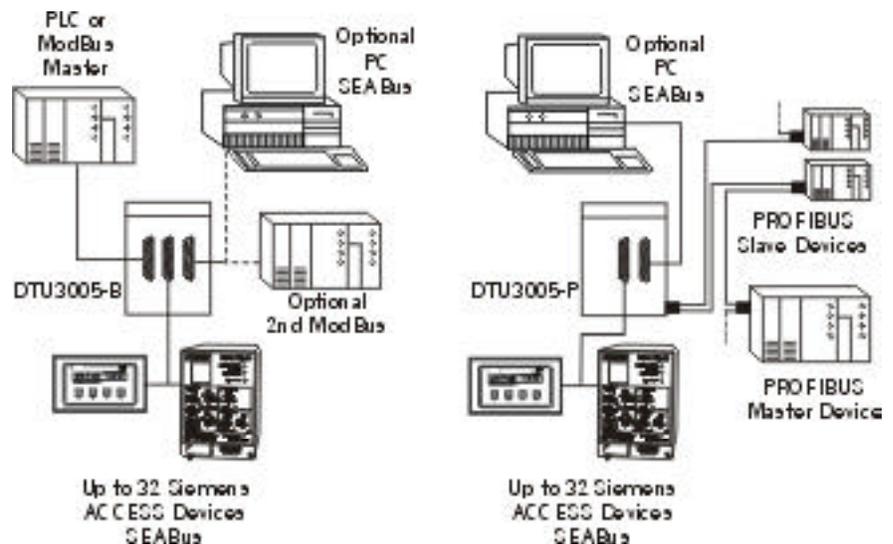
Local Display Unit

The Local Display Unit (LDU) works with the SEABus network to poll data from Siemens ACCESS compatible devices. The LDU can be mounted in harsh industrial environments and is suitable for mounting in panelboards, switchboards, and switchgear.
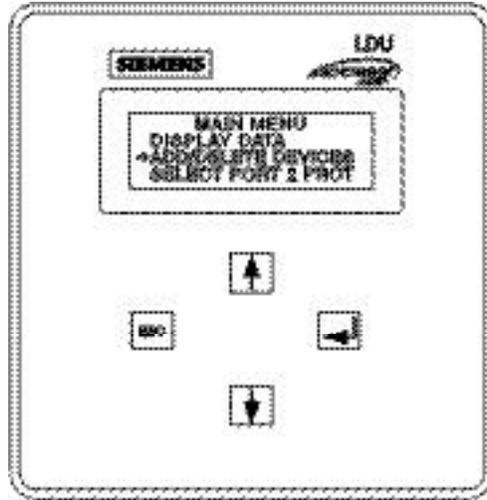
The LDU can be connected through SEABus to up to 32 ACCESS devices. A second port can be connected through RS-232 to a WinPM monitoring station.
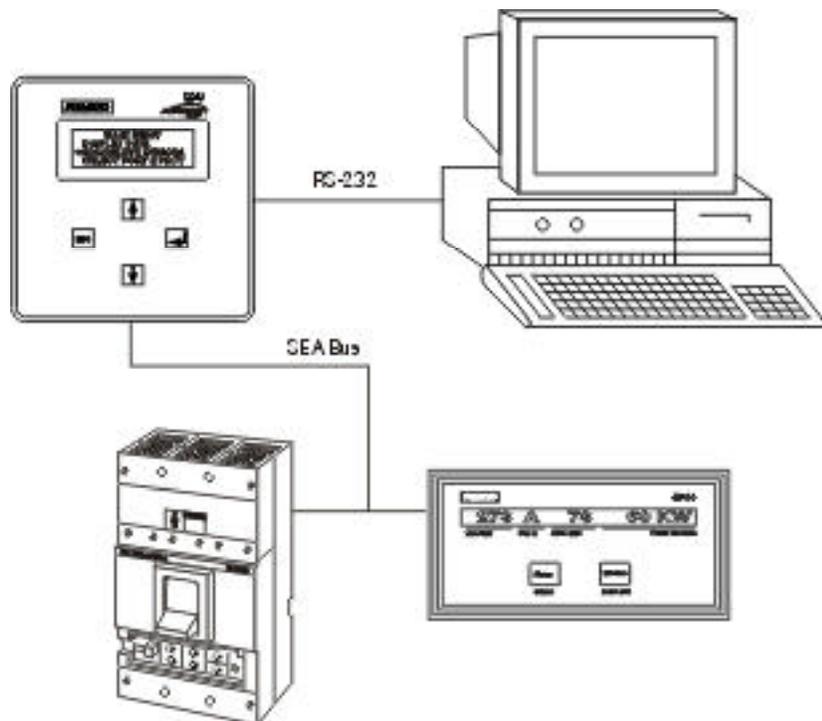
Review 4

1. WinPM is an example of a _____ device.

   a. supervisory
   b. field

2. A Siemens ACCESS power meter is an example of a _____ device.

   a. supervisory
   b. field

3. The rules that govern the communication fo the ACCESS system are known collectively as _____ and _____ Plus.

4. A _____ is an active device, such as a computer or printer, connected to the network.

5. Siemens _____ _____ can connect RS-232 and RS-485 devices directly to a LAN.

6. RS-232 is limited to transmission distances no greater than _____ feet.

7. RS-485 can support 32 different drivers and receivers over a maximum distance of _____ feet.

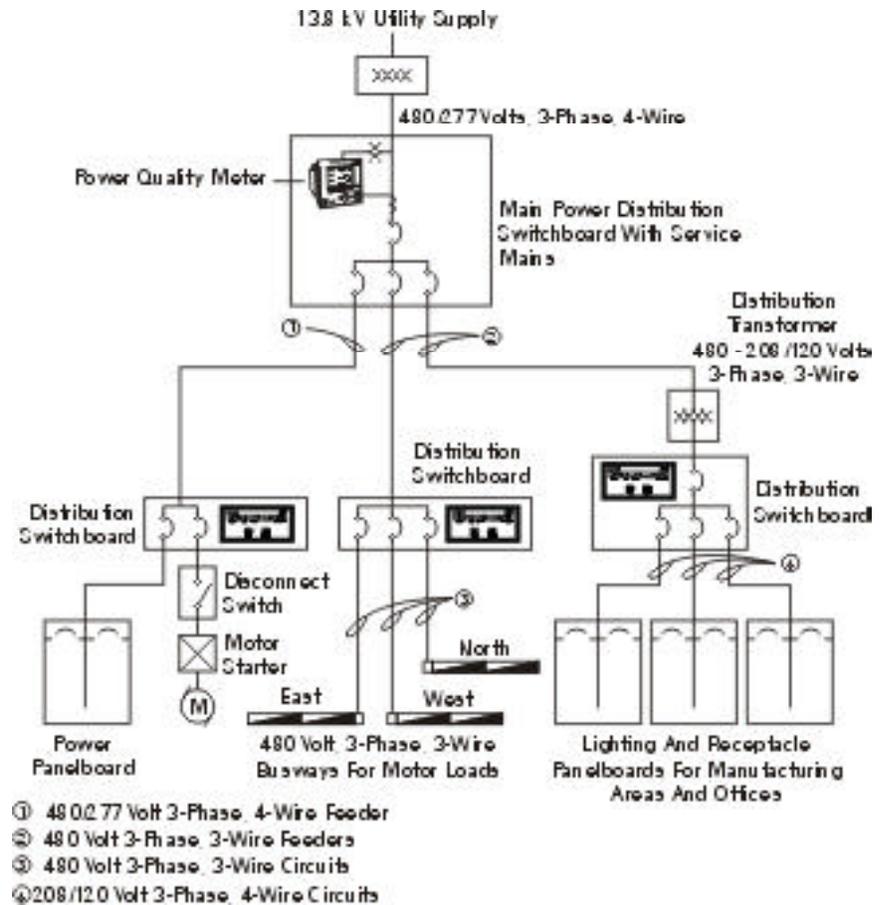8. The LDU can be connected to up to _____ ACCESS devices.

Power Metering

In today's electronic environment, power management requires sophisticated meters. Voltage, current, and kW meters alone do not provide an adequate indication of power quality and energy consumption. Siemens power meters, in addition to measuring voltage, current, frequency, harmonics energy, power, and power factor, also capture system disturbances, log historical data, monitor the status of other equipment, and control loads.

4300

4700

9240

9300

9500
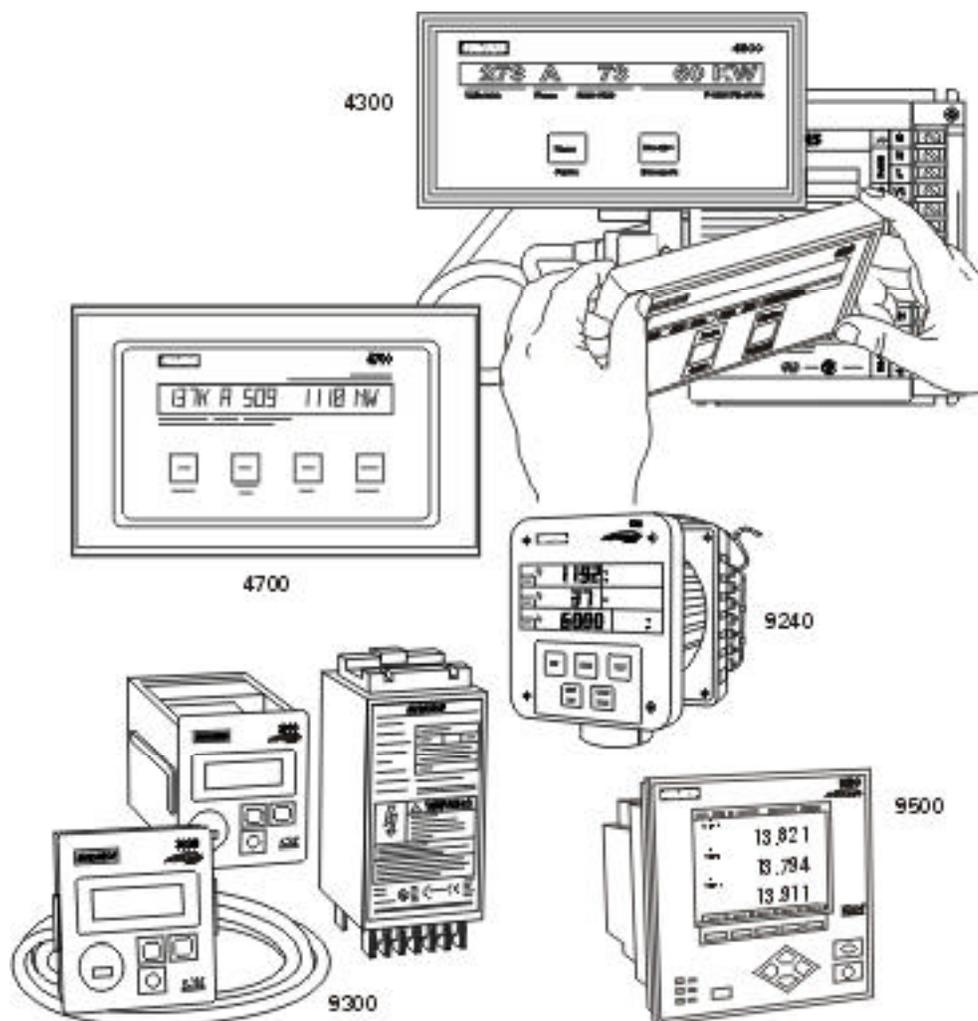
Meter Location

Power meters should be located at key points in the electrical distribution system to effectively monitor power consumption and quality. In some applications, it is sufficient to monitor energy consumption on significant loads and monitor power quality at the utility supply point. In critical power applications it may be desirable to monitor power quality throughout the distribution system.


① 480/277 Volt 3-Phase, 4-Wire Feeder
② 480 Volt 3-Phase, 3-Wire Feeders
③ 480 Volt 3-Phase, 3-Wire Circuits
④ 208/120 Volt 3-Phase, 4-Wire Circuits

9230 Meter

The 9230 power meter measures real power. It will provide a readout of watts, watt-hours, and watt demand (configurable demand period). The 9230 is a full four-quadrant power meter providing bidirectional monitoring and separate positive and negative watt-hour accumulators.


The 9230 meter measures voltage and current to calculate power. Alarm functions can be programmed to operate two relay contacts. A KYZ relay provides pulses for energy management systems. These pulses represent accumulated positive or negative watt-hours. The pulse value is configurable. SEABus communication converters or analog output modules are available.
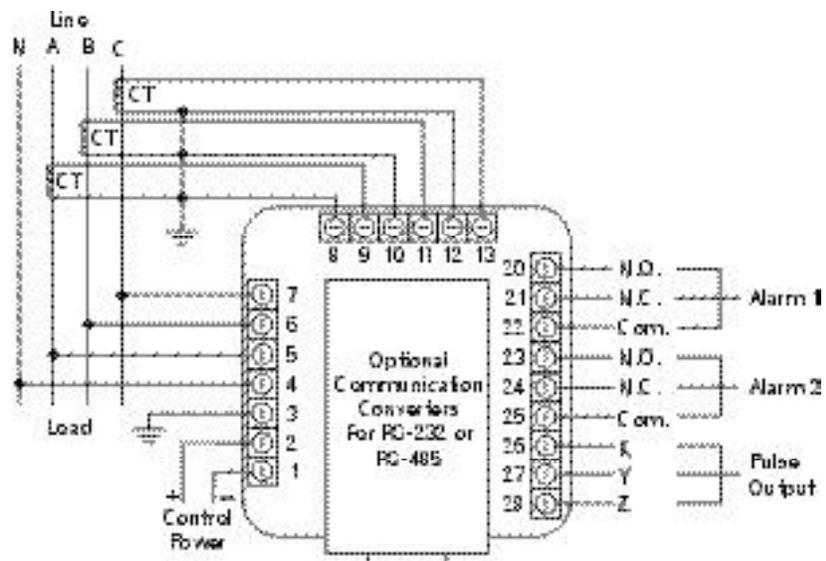
4300 Meter

The 4300 meter provides a readout of phase current, average phase current, line voltage, average line voltage, frequency, watts, watt-hours, peak watt demand, and power factor. Like the 9230, the 4300 is a full four-quadrant power meter. A standard communications module connects the 4300 to the Siemens ACCESS system. A separate display eliminates the need for voltage transformers on most low voltage applications because line voltage can be connected directly to the base module.
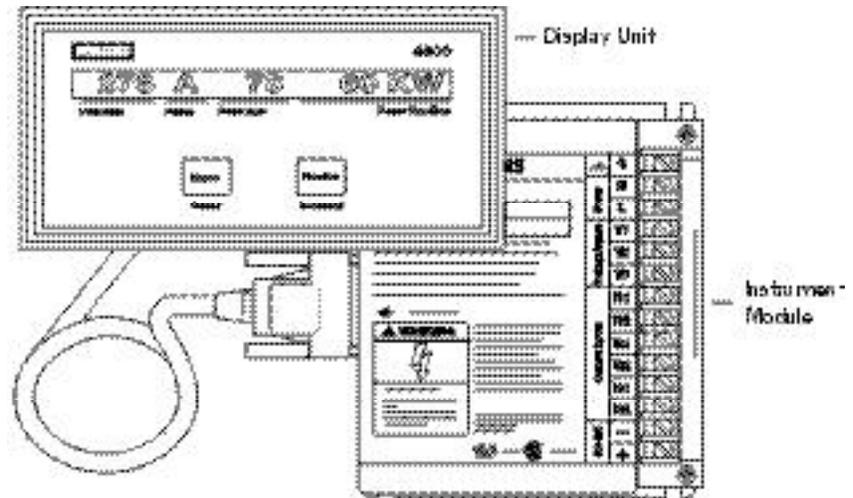
The 4300 meter is designed to fit in new or retrofit applications. The display unit will fit standard U.S. analog meter drilling patterns.
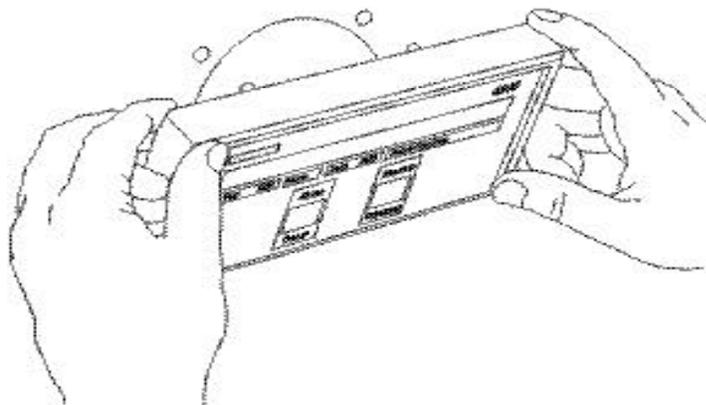
9240 Meter

The 9240 meter provides all significant parameters of the power system including; 3-phase volts, 3-phase current, neutral current, watts, VAR, VA, watt-hours, power factor, and frequency. The 9240 records the maximum and minimum values for most measured parameters. Three KYZ pulses are available for energy readings. The 9240 uses standard cutouts and will replace most existing analog meters.

The 9240 has several protocol options to support many systems. Available protocols include SEABus (for the ACCESS system), ModBus RTU, ModBus Plus, and DNP 3.0.
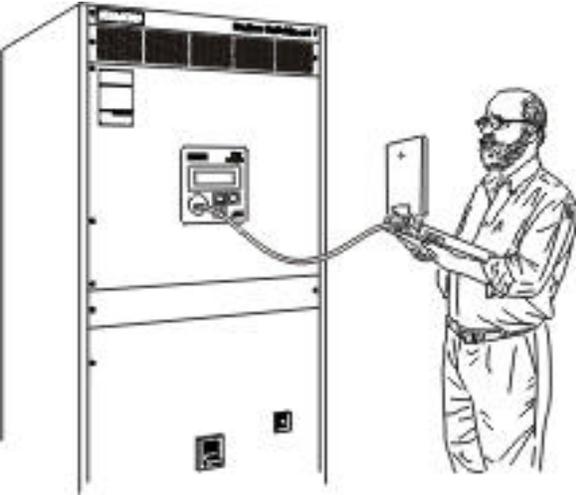

9300 Meter

The 9300 meter also provides all significant parameters of the power system. The 9300 meter can make predicted demand calculations based on past data. The 9300 meter monitors individual phase harmonics (up to the 15th), total harmonic distortion, and K-factor.

The 9300 includes four binary outputs that can be operated from remote software or configured as kWH pulse signals. The 9300 comes standard with SEABus (for the ACCESS System) and ModBus RTU or, optionally, with PROFIBUS DP. An Ethernet card may also be installed.


58
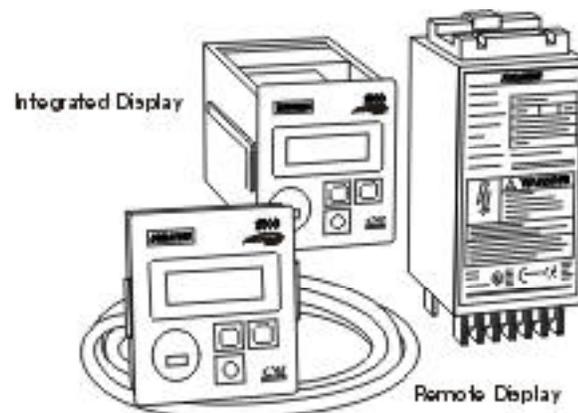
The 9300 includes a front optical data port for accessibility by a portable PC.

9330 Meter

The 9330 meter offers the same features as the 9300 meter. In addition, the 9330 includes setpoint capability to operate any of the four binary outputs. All events are recorded in the event log. The 9330 can also sample data continuously for future trend analysis.

The 9330 meter features Ethernet or telephone modem connections as options. The 9330 can act as a gateway between these connections and other devices that are connected to the 9330 with an RS-485 cable. The 9330 comes standard with SEABus, ModBus RTU, and DNP 3.0.
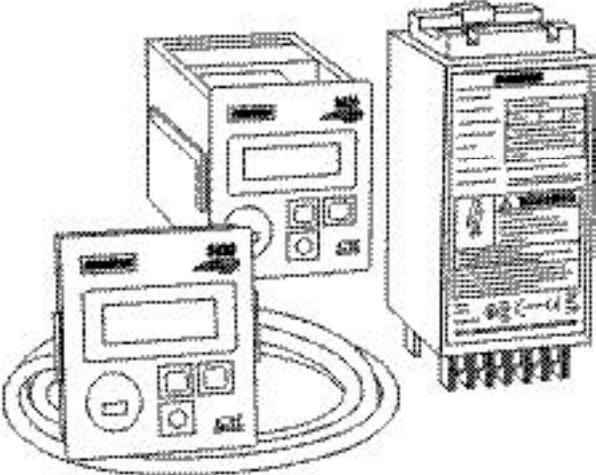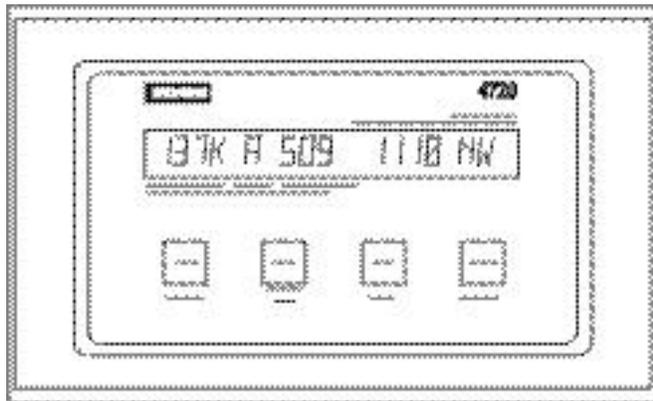
4700 Meter

In addition to providing information on all significant parameters of a power system, the 4700 includes waveform capture for harmonic analysis up to the 63rd harmonic. The 4700 includes 4 binary inputs and 1 analog input to monitor external equipment.

There are 3 relay outputs that can be operated by set-points or used as kWh and kVARH pulse signals. The 4700 meter also includes one transducer-type analog output.
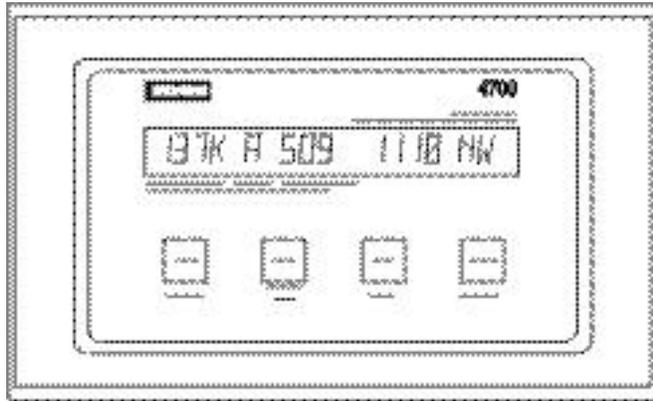
4720 Meter

The 4720 meter provides all of the same features as the 4700 meter. In addition, the 4720 provides on-board harmonic analysis up to the 15th harmonic. Like the 9330, the 4720 logs events and does continuous data sampling. The 4720 provides a 2-cycle trigger to record up to 36 cycles of a disturbance. The 4720 has an optional communications card for SEABus protocol.
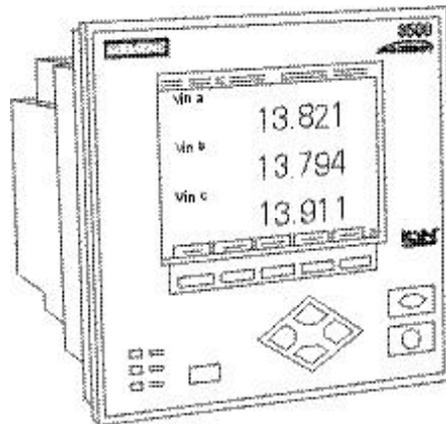
9500 Meter

The 9500 offers three-phase power monitoring on a large, easy to read screen. The 9500 meter monitors K-factor, crest factor, individual harmonics, and total harmonics up to the 63rd harmonic.

In addition to displaying values, the 9500 also displays graphical phasor diagrams and bar graph representations. The 9500 provides a 0.5 cycle trigger and up to 4 MB of memory for extensive waveform recording of system disturbances, as well as a special sag/swell module.

Advanced features include utility-style rate structure calculations. The 9500 meter meets the accuracy requirements of the ANSI C12.20 revenue standard. The 9500 provides transformer and line loss calculations. The 9500 can communicate with the Internet and transmit email.

The 9500 comes standard with several protocols including SEABus, ModBus RTU, and DNP 3.0. In addition to RS-232 and RS-485, the 9500 can include a telephone modem, an Ethernet card, and a fiber optic port. Simultaneous connections are supported.

The 9500 can be equipped with 7 binary outputs, 16 binary inputs, 4 analog outputs, and 4 analog inputs.

Another unique feature of the 9500 is the optional ability to connect to the Global Position Satellite (GPS) system for time synchronization with other 9500 meters in the distribution system.
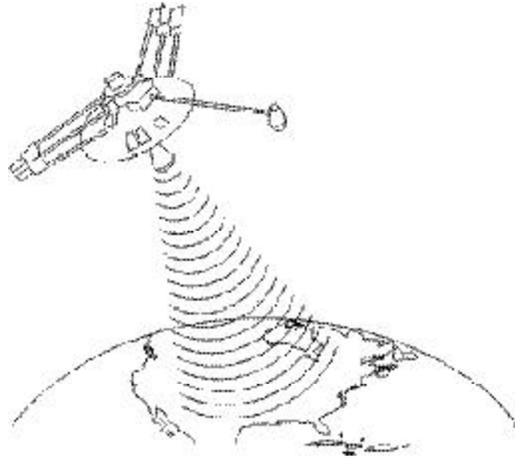
Power Meter Features

Siemens power meters have various features, depending on specific application needs. With a number of meters to choose from it may seem confusing when trying to decide which meter is right for which job. The following chart and tables are provided to help identify various features and performance capabilities for Siemens power meters. The chart is arranged in order of performance feature. The table on the following page details available features for each power meter.
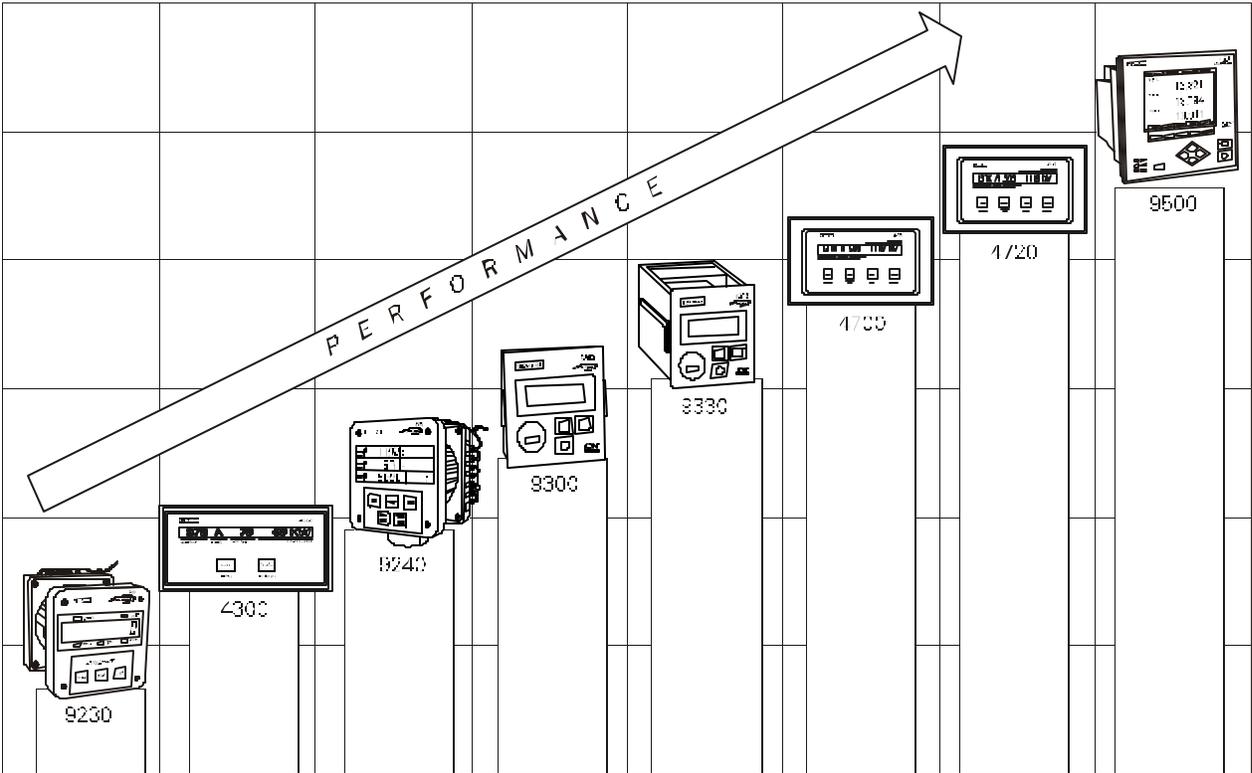
	9230	4300	9240	9300	9330	4700	4720	9500
Measurements								
Real Power	●	●	●	●	●	●	●	●
Bi-Directional Energy	●	●	●	●	●	●	●	●
Sliding Window Demand	●	●	●	●	●	●	●	●
Reactive & Apparent Power		●	●	●	●	●	●	●
Voltage & Current		●	●	●	●	●	●	●
Power Factor		●	●	●	●	●	●	●
Frequency		●	●	●	●	●	●	●
Harmonic Analysis				●	●	●	●	●
Thermal & Predicted Demand				●	●		●	●
Power Harmonics								
Symmetrical Components								
Data Logging								
Min/Max		●	●	●	●	●	●	●
Data Sampling				●	●	●	●	●
Event Logging				●	●	●	●	●
Waveform Recording							●	●
Display								
Easy to read Alpha-numeric Display	●	●	●	●	●	●	●	
High resolution graphical Display								●
I/O								
Relays/Pulse Outputs	●		●	●	●	●	●	●
Counter/Status Inputs				●	●	●	●	●
Analog Outputs	●					●	●	●
Analog Inputs						●	●	●
Advanced Functions								
Set-point Control	●					●	●	●
Phase Reversal / Unbalance		●				●	●	●
TOU & Line Loss Compensation						●		●
Math & Logic						●		●
GPS Time Synch								●
Sag/Swell Detection								●
Transient Detection								
Communications								
SEABus	●	●	●	●	●	●	●	●
Modbus RTU				●	●	●		●
DNP 3.0		●			●			●
Profibus DP				●				
RS232 / RS485	●	●	●	●	●	●	●	●
Ethernet				●	●			●
Modem					●			●
Fiber Optic								●

Review 5

1. Power meters should be located at _____ points in the electrical distribution system.

2. The _____ and _____ meters include a front optical data port for accessibility by a portable PC.

3. The 4720 meter provides on-board harmonic analysis up to the _____ harmonic.

4. A unique feature of the 9500 meter is the optional ability to connect to _____ for time synchronization with other 9500 meters in the distribution system.

5. The _____ meter has a high resolution graphical display.

Protective Relays and Trip Units

The term switchgear is used to describe coordinated devices used for control and protection of equipment such as generators, transformers, capacitor banks, motors, and distribution lines. SIPROTEC 7SJ61, 62, and 63 are microprocessor-based protective relays designed to provide protective relay functions, metering, and control associated with switchgear circuit breaker installations.
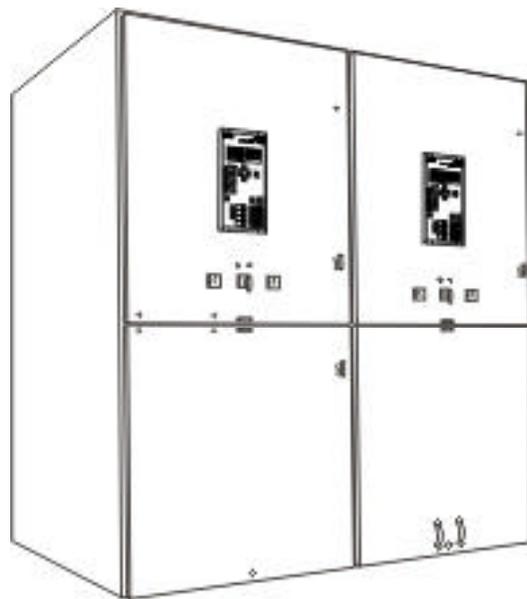

Type GM MV Switchgear

SIPROTEC

SIPROTEC is a trade name used by Siemens to identify a group of Siemens multifunction protection relays, such as the 7SJ61, 7SJ62, and 7SJ63. Multifunction protection relays provide the basic protection required in power systems, such as phase and ground overcurrent protection on feeder circuits, motors, and transformers. However, since they are microprocessor based, they can also communicate what is happening to the equipment they are protecting.

Examples of information they can communicate to the ACCESS power monitoring system include: protective element status, trip diagnostics, and integrated metering of the power at its input. SIPROTEC relay features are integrated into the ACCESS single-line animation, waveform support, and alarm handling.

SIPROTEC relays have integrated PLC logic and support multiple protocols. DIGSI is a software package available for SIPROTEC which supports documentation, archiving of relay data, and advanced diagnostics.
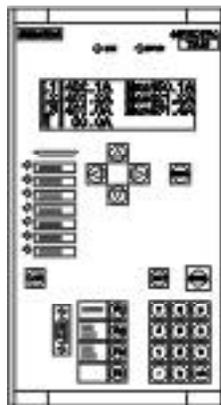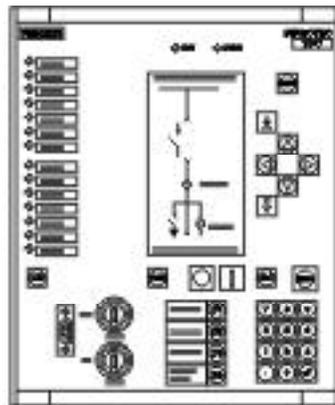

7SJ61   7SJ63
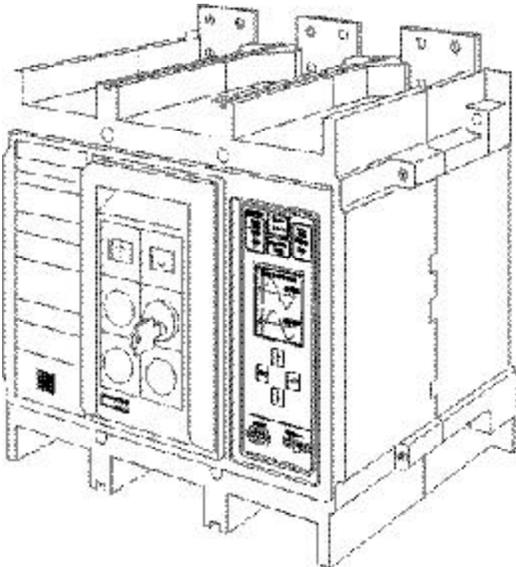
Circuit Breaker Trip Units

The following sections describe low voltage insulated case (ICCB), molded case (MCCB) circuit breakers, and Type RL circuit breakers with Static Trip III™ available for use with the ACCESS system.

ICCB

Siemens Sentron® ICCB circuit breakers are available in ratings from 800 to 5000 amps and are designed to supply high short time withstand and high interrupting ratings. Two types of interchangeable trip units are available for use with the ICCB and ACCESS system; the basic type TL trip unit and the high performance System Breaker Energy Communicating trip unit (SB-EC). Both trip units use a microprocessor to execute the numerous functions programmed in the unit.
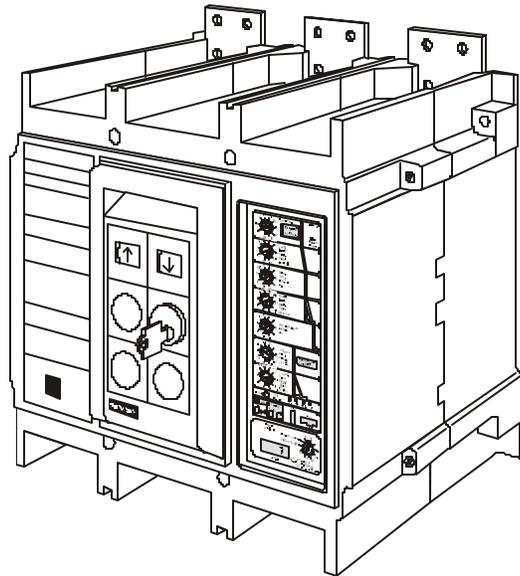
The TL trip unit features a full range of industry standard protective settings. The high-performance Systems Breaker Energy Communicating trip unit (SB-EC Trip Unit) offers advanced metering, protective relaying, time-stamped logs, and power quality monitoring functions. An LCD graphical display provides real-time voltage and current waveforms.


MCCB

Siemens Sentron MCCB circuit breakers are available in a digital version, referred to as Sensitrip® III. Sensitrip III circuit breakers utilize a microcomputer which makes it possible to customize overcurrent protection to match the loads of an electrical system. In addition, the Sensitrip III trip unit has communications capability when provided with an expansion plug and connected to a Multiplexer Translator. Sensitrip III can measure and communicate RMS phase current, pickup status, and communications status.
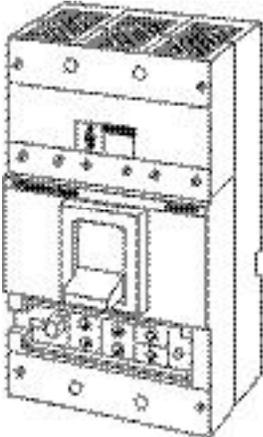

Sensitrip III MCCB
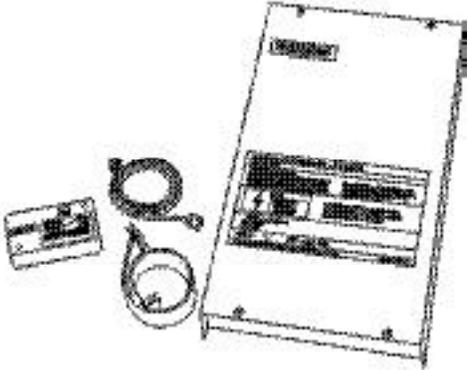
Multiplexer Translator Module with Cables and Expansion Plug

Type RL Circuit Breaker

Siemens RL series low voltage power circuit breakers are used in Siemens low voltage switchgear. RL series circuit breakers are designed for up to 600 volt service with current capacities up to 5000 amps. The RL circuit breaker in the following illustration is shown with a Static Trip III™ trip unit.
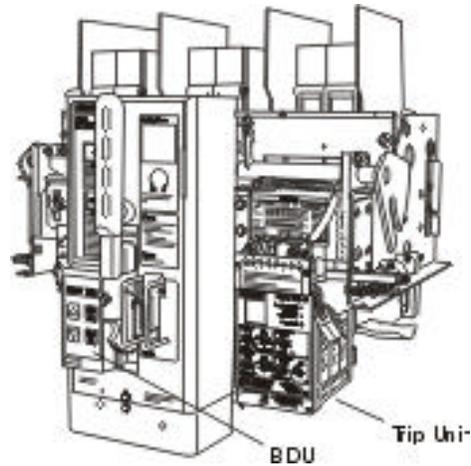
Static Trip III

Static Trip III™ units are microprocessor controlled, overcurrent protective devices for use on Type RL low-voltage power circuit breakers. An optional Breaker Display Unit (BDU) can be added to communicating trip units. The BDU displays real-time measurements, trip log, event log, and min/max values.
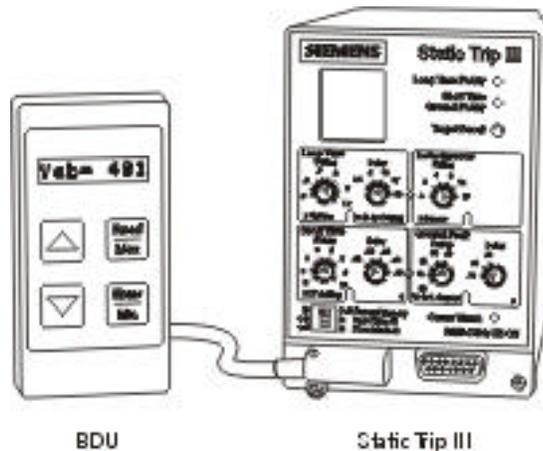
The Static Trip III consists of four models:

Static Trip Family	
III	Basic Overcurrent Protection
IIIC	Added Communications and Current Metering
IIICP	Added Power Metering
IIICPX	Extended Protective Relaying

A standard feature of the Static Trip IIIC, IIICP, and IIICPX trip units is an alarm output. Any measured parameter can be set to activate the alarm based on threshold and time delay set points. These units also include several logging functions for recording trip events, pickup conditions, alarm activity, and min/max measured values.

Static Trip IIIC, IIICP, and IIICPX trip units have added communication ability. Metered parameters can be displayed and configured locally on the BDU or remotely via the RS-485 communications port through the ACCESS system.

| Measured Value	STIIIC	STIIICP/CPX	Accuracy
Phase Current	■	■	1.00%
Average Current	■	■	1.00%
Ground Current	■	■	1.00%
Phase Line-to-Neutral Voltage		■	1.00%
Average Line-to-Neutral Voltage		■	1.00%
Line-to-Line Voltage for all Phases		■	1.00%
Average Line-to-Line Voltage		■	2.00%
kW Total for all Phases		■	2.00%
kWh Total for all Phases		■	2.00%
kW Reverse		■	2.00%
kW Demand		■	2.00%
kVA		■	2.00%
kVAR		■	2.00%
kVARh Total for all Phases		■	2.00%
Power Factor		■	4.00%
Frequency		■	0.25%

SAMMS

The Siemens Advanced Motor Master System (SAMMS™) is a microprocessor-based motor control and protection device. SAMMS LV units provides all motor starting functions and thermal protection. SAMMS is a compact system with programmable control logic that replaces timers, control relays, push-buttons, selector switches, pilot devices, and associated wiring.

Some of the more powerful features of the SAMMS unit include: motor run time hours, number of motor starts, number of motor trips, set point alarms, and ground fault protection.
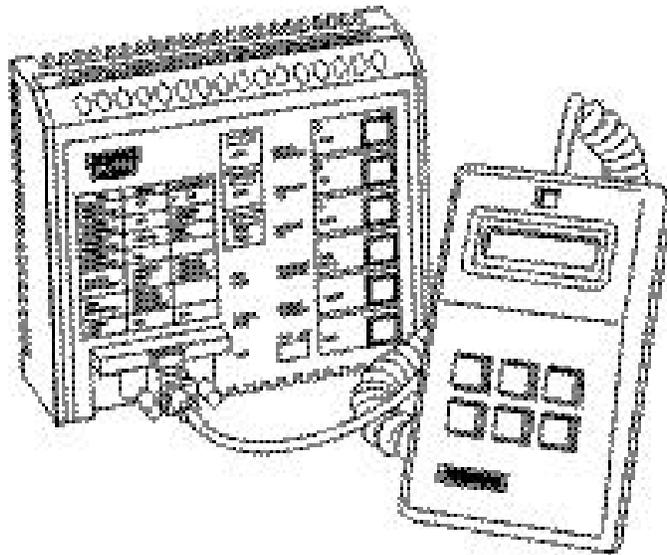
ACCESS Communication   SAMMS connects to SEABus through an optional SAMMS
Communication Module (CM-1). The CM-1 provides an RS-485
interface to communicate with the ACCESS system.
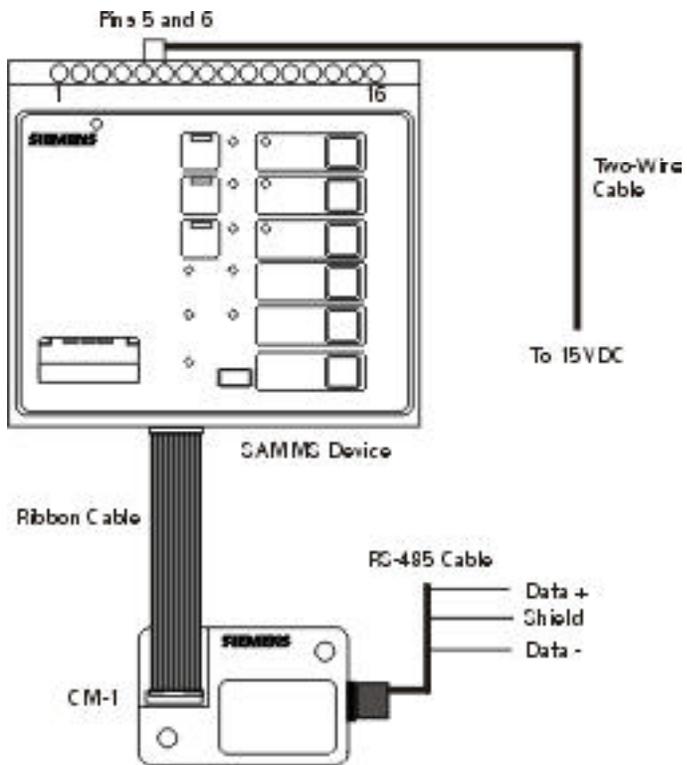
S7 I/O Device

The S7 I/O™ device is an addressable modular input/output (I/O) device that links power system components to the ACCESS system. This device is a programmable logic controller (PLC), customized to communicate using SEABus.
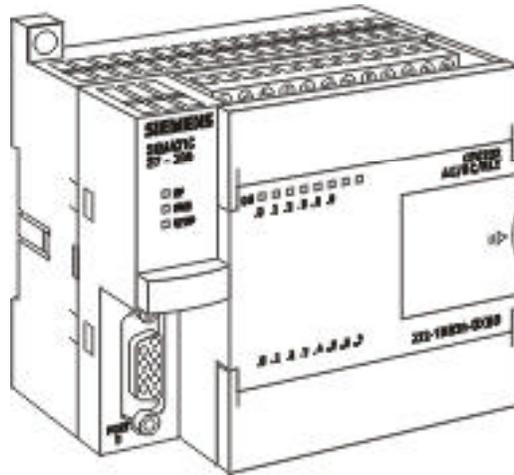
PLCs consist of input modules or points, a central processing unit (CPU), and output modules or points. An input to a PLC may come from a variety of digital or analog signals from various field devices. The PLC converts the input signal into a logic signal that can be used by the CPU. Output modules convert control signals from the CPU into a digital or analog signal that can be used to control various field devices.
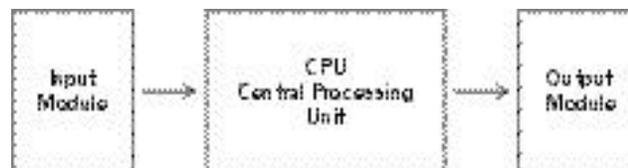
The S7-I/O device provides the capability to monitor and control power system elements that are not specifically designed for ACCESS. Remote monitoring of any device equipped with an auxiliary contact is possible. Inputs such as the temperature relay of a motor or transformer can be input into the I/O device. Status of any circuit breaker with auxiliary contacts can also be monitored. This is especially useful to monitor MCCB status when metering functionality is not required.

The outputs can be used to close contactors, trip circuit breakers, and provide remote indication. In combination with a power meter analog values such as current and voltage can be monitored.

Status of the input and output states, counter data, and event log data is communicated to other components of the ACCESS system through an RS-485 serial link.
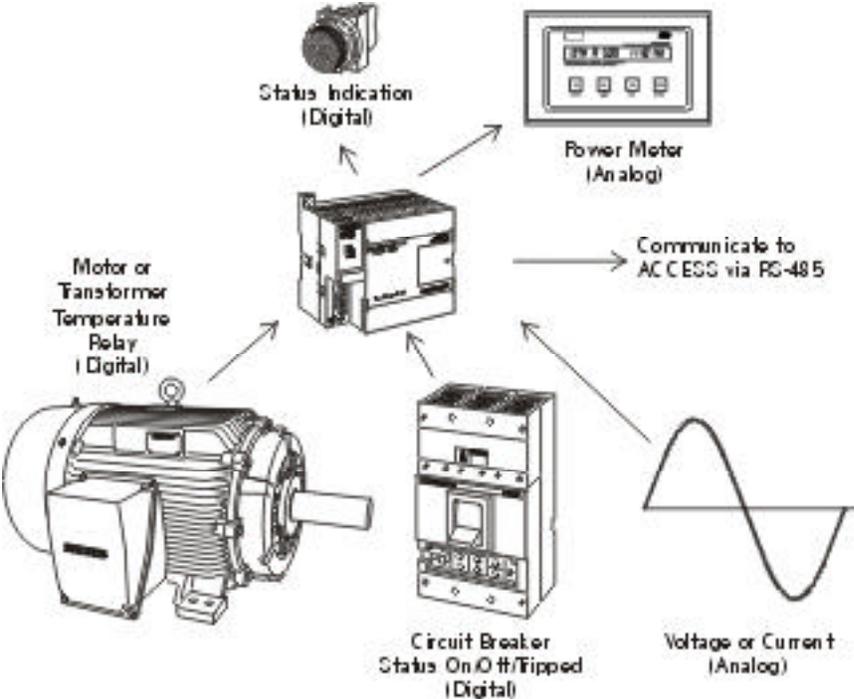
Lighting Control System

Lighting accounts for a large percentage of commercial and industrial power consumption. With a lighting control system, interior and exterior lights can be controlled via override switches, photocells, motion sensors, and a time clock. This will significantly cut energy costs as well as offer a safe and user-friendly environment for occupants.

New energy codes are requiring lighting control on a state-by-state basis. ASHRAE 90.1 – 1999 calls for motion sensors, override switches and time clocks for commercial applications. These codes apply to buildings larger than 5000 square feet, non-24 hour operation, and non-emergency operation. California and Wisconsin have already adopted ASHRAE 90.1-1999 and several other states are expected to follow.
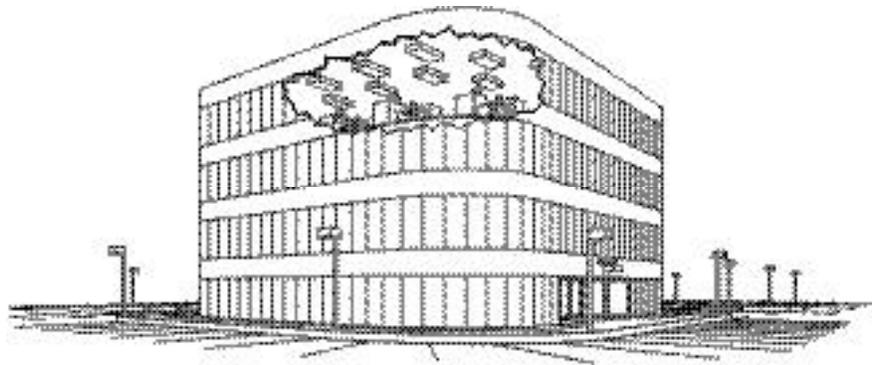
LCP Products

The LCP (Lighting Control Panel) family of lighting control systems is perfect for commercial applications such as schools, recreation centers, fast food, office buildings, prisons, and a variety of other applications. Depending on the specific LCP product, a lighting control panel can have up to 32 inputs and outputs. Four models are available: LCP 500, LCP 1000, LCP 1500, and LCP 2000. The LCP comes fully assembled with all specified relays in a NEMA 1 enclosure.

LCP 500
4 Inputs
4 Outputs

LCP 1000 & LCP 1500
8 Inputs
8 Outputs

LCP 2000
32 Inputs
Up to 32 Outputs
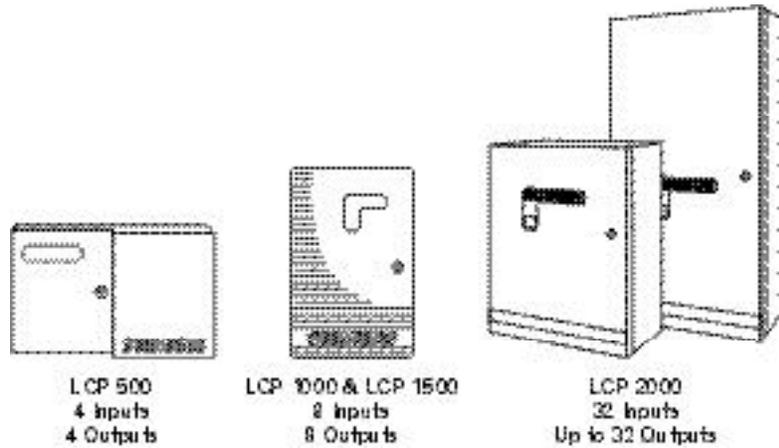
Time Clock and Keypad

The Siemens LCP also includes an astronomical clock for controlling timed events. Self-prompting instructions on an LCD screen make programming easy. A keypad is used to enter instructions for lighting circuit control. Optional EZ CONFIG software allows programming of a single cabinet or an entire lighting control network locally or via modem.
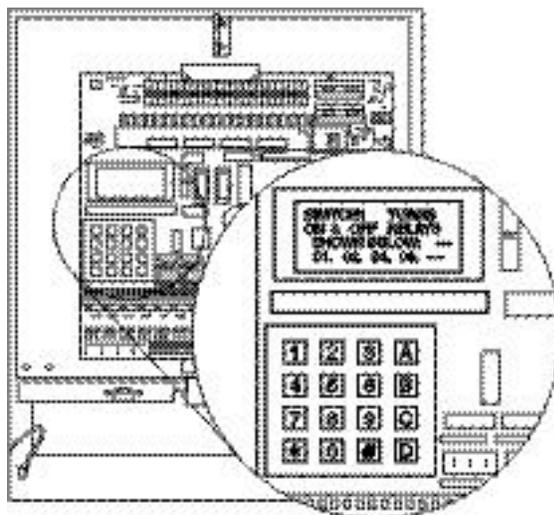
System Accessories

Several accessories are available to enhance the operation of LCP products. A photocell can be used to control lights based on the amount of ambient light in an area. Touch-tone phone control (LCP TIM) allows you to use any phone to override the lighting. The LCP 2000 seamlessly integrates with HVAC and building management systems via the ModBus gateway. This integration allows control by other systems of each individual LCP relay or group of relays from a single RS-485 connection. Up to 127 LCP's can be on a single network.
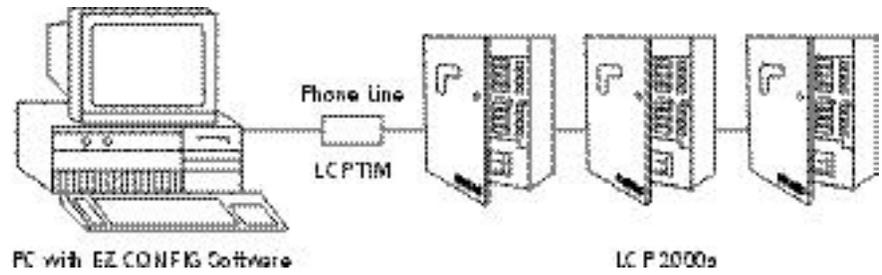
VISION TOUCH

VISION TOUCH software, working in conjunction with LCP PC programming software, provides a graphical interface of a lighting system. Once panels have been programmed, VISION TOUCH graphics offer real-time lighting management. Simply touch the area that you wish to control or use a mouse to select one of the preset buttons. Common applications include schools, stadiums, and prisons.

In the following example an LCP is used to control lighting of a gym with three basketball courts, a running track, and various exercise areas. VISION TOUCH is available only for the LCP 2000.
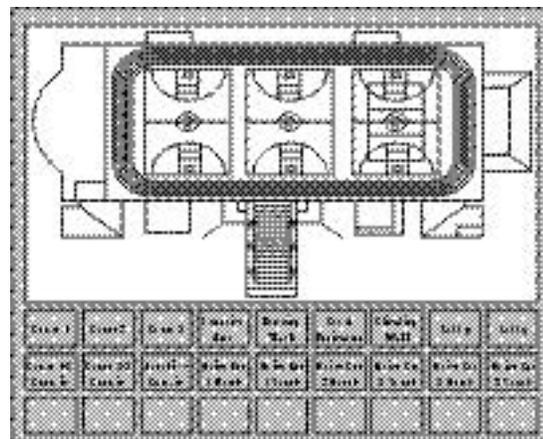
ACCESS System Application Example

The following illustration shows an example of Siemens ACCESS system including hardware, software, and field devices. In this example Siemens power meters are located throughout the distribution system. Siemens software, WinPM and SIEServe, are used to record voltage, current, power, and harmonic events for use in other parts of the system. Several other components that make up the ACCESS system such as circuit breakers, SIPROTEC series relays, SAMMS, ethernet converters, and isolated multi-drop converters are also utilized.

ACCESS components are installed in Siemens switchboards, switchgear, and motor control centers. Siemens ACCESS devices are also installed in a retrofit application which could have been provided by another manufacturer.
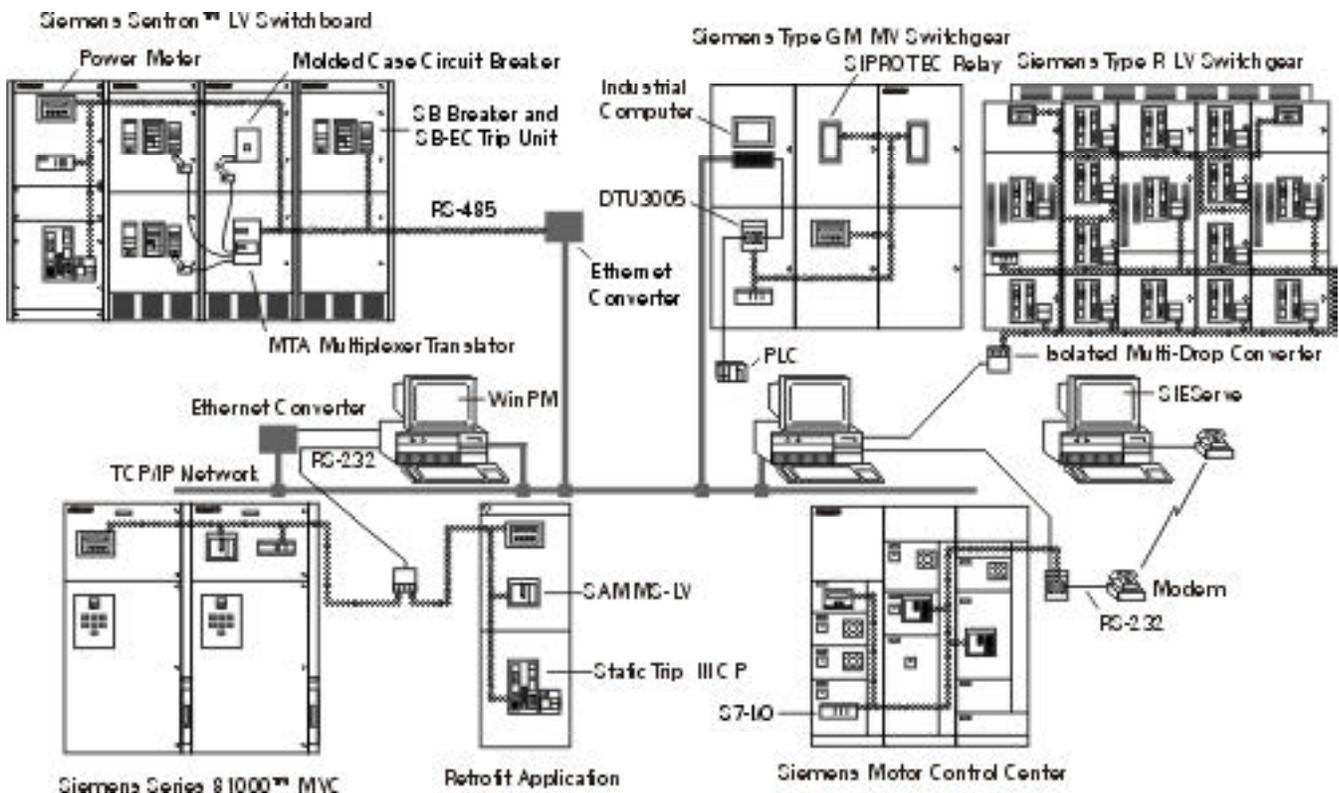
Review 6

1. _____ is a trade name used by Siemens to identify a group of multifunction protection relays.

2. Siemens Sentron ICCB circuit breakers are available in ratings from 800 to _____ amps.

3. Static Trip III overcurrent protective devices for use on Type _____ low-voltage power circuit breakers.

4. Static Trip _____ features extended protective relaying.

   a. III
   b. IIIC
   c. IIICP
   d. IIICPX

5. _____ is microprocessor-based motor control and protection device.

6. VisionTouch software is available for use with the _____ .

   a. LCP 500
   b. LCP 1000
   c. LCP 1500
   d. LCP 2000

7. The LCP 2000 can have up to _____ inputs and _____ outputs.

Review Answers

Review 1   1) f; 2) 60; 3) current; 4) a

Review 2   1) c; 2) 1200; 3) 562.9; 4) b; 5) 1.41; 6) b

Review 3   1) 120; 2) 5; 3) c; 4) K factor; 5) a; 6) Apparent; 7) Power factor;
8) a; 9) d

Review 4   1) a; 2) b; 3) SEABus, SEABus; 4) node; 5) Ethernet converters;
6) 50; 7) 4000; 8) 32

Review 5   1) key; 2) 9300, 9330; 3) 15th; 4) GPS; 5; 9500

Review 6   1) SIPROTEC; 2) 5000; 4) RL; 4) d; 5) SAMMS; 6) d; 7) 32, 32

Final Exam

The final exam is intended to be a learning tool. The book may be used during the exam. A tear-out answer sheet is provided. After completing the test, mail the answer sheet in for grading. A grade of 70% or better is passing. Upon successful completion of the test a certificate will be issued.

Questions

1. Which of the following is a supervisory device?

   a. 9500 Power Meter   b. WinPM
   c. SIEServe   d. LCP

2. Which of the following is an example of a linear load?

   a. Incandescent lighting
   b. Ballested lighting
   c. Variable speed drives
   d. Computers

3. The crest factor of a pure sinusoidal waveform is
   _____ .

   a. 0.707   b. 0.9
   c. 1.41   d. 2

4. A _____ is when there is an increase or decrease in normal line voltage within the normal rated tolerance of the electronic equipment. These are usually short in duration and do not affect equipment performance.

   a. Voltage Swell
   b. Undervoltage
   c. Outage
   d. Voltage Fluctuation

5. Type _____ disturbances last up to 0.5 Hz.

    a.   Type I   b.   Type II
    c.   Type III   d.   Type IV

6. The _____ harmonic is a positive sequence harmonic.

    a.   1st   b.   2nd
    c.   3rd   d.   4th

7. To help reduce the effects of harmonics it may be necessary to install _____ .

    a.   power factor correction capacitors
    b.   a UPS system
    c.   K-rated transformers
    d.   a voltage regulator

8. The _____ meter has a high resolution graphical display.

    a.   9230   b.   4300
    c.   4720   d.   9500

9. The _____ meter includes a front optical data port for accessibility by a portable PC.

    a.   4720   b.   9240
    c.   9300   d.   4700

10. An advantage to loop topology over straight-line topology is the ability to _____ .

    a.   communicate with each device in the event of a break in the communication cable
    b.   reduce the amount of communication wire required
    c.   connect additional field devices
    d.   have longer runs

11. The rules that govern the communication of the ACCESS system are known collectively as _____ .

   a. DNP 3.0   b. SEABus
   c. ModBus   d. Profibus DP

12. A LAN can be arranged with nodes in a _____ configuration.

   a. bus   b. star
   c. combination   d. all of the above

13. _____ developed RS-232 and RS-485 standards.

   a. CBEMA
   b. Electronic Industries Association
   c. Institute of Electrical and Electronic Engineers
   d. U.S. Department of Commerce

14. _____ software provides a graphical interface of a lighting system when used with an LCP 2000.

   a. SIEBus
   b. VISION TOUCH
   c. WinPM
   d. SIEServe

15. One Isolated Multi-Drop Converter can handle up to _____ field devices.

   a. 4   b. 32
   c. 128   d. 232

16. _____ protective relays are designed to provide protective relay functions, metering, and control associated with switchgear circuit breaker operation.

   a. SIPROTEC   b. LCP 2000
   c. S7/IO   d. SAMMS

17. The Static Trip _____ provides basic overcurrent protection, metering, and extended protective relaying.

   a. III   b. IIIC
   c. IIICP   d. IIICPX

18. _____ is a motor control protection device

   a. SAMMS   b. SIPROTEC
   c. Static Trip III   d. Sensitrip

19. **Which of the following meters does** not feature harmonic analysis?

   a. 9300   b. 4700
   c. 9230   d. 9500

20. Which of the following meters features GPS time synch?

   a. 9230   b. 9500
   c. 9330   d. 4720

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