CHAPTER 21

SECONDARY ELECTRICAL DISTRIBUTION

21-1. General secondary electrical distribution

A secondary electrical distribution system is defined as an electrical distribution system having a voltage of 600 Vac and below. This is the electrical system that normally supplies power to process systems, habitability systems, and other loads within a facility. Typical equipment and components that comprise this system are switchgear, switchboards, and panelboards; transformers; power line conditioners; motor control centers; protective devices, fuses and circuit breakers; switches; feeder cables; and controls.

21-2. Switchgear, switchboards, and panelboards

Switchgear, switchboards, and panelboards are general terms covering switching and interrupting devices that control, meter and protect the flow of electric power. The component parts include circuit breakers, fuses, instrument transformers, transfer switches, voltage regulators, instruments, and protective relays and devices. The various configurations range in size from a single panel to an assembly of panels and enclosures. The components comprising the makeup of the main devices are usually in a grounded, metal enclosure. Equipment rated up to 1000 volts alternating current (AC) is classed as low voltage. Equipment equal to or greater than 1000 volts but less than 100,000 volts AC is classed as medium voltage.

21-3. Transformers

A transformer utilizes electromagnetic (EM) induction between circuits of the same frequency, usually with changed values of voltage and current. Transformers can be classified in various ways, but their basic construction consists of windings, magnetic cores on which windings are coiled, insulation, and any special connections applying to the type of load. Transformers used for secondary distribution are usually smaller than those for primary distribution, but depending on the voltage and demand can be large. Their main purpose is to transform alternating voltage and current from one level to another. At the secondary distribution point the voltage is brought down to a level that is suitable for operations. Small power transformers sometimes supply power to loads where continuity of service is critical and therefore a greater degree of attention is justified. While the percentage of transformer failures is low, failures that do occur are serious and result in extensive downtime and expense. The best assurance of continued high reliability is regular maintenance procedures. Transformers require very little attention when compared to most electrical apparatus. For a complete description of transformers see chapter 20.

21-4. Power line conditioners

Power line conditioning is often used to improve the quality of power for special applications such as computers. Although it is difficult to make any generalizations concerning the benefits that accrue from the use of line protective equipment, it has been estimated that clean power versus that taken directly from the "average" power line reduces load equipment outages by 40 percent and maintenance costs by 25 percent. The choice to use protective equipment is both an economic and technical consideration.

a. Isolation transformers. Isolation transformers are primarily intended to attenuate common-mode impulses. Some types also provide limited attenuation of normal mode impulses. Isolation transformers perform no voltage regulating function. Sags, surges, under voltages, or over voltages will be reproduced faithfully on the transformer secondary. If the power line voltage is consistently stable and high-frequency impulses or noise is the only problem, then a suitable isolation transformer may eliminate power line disturbance difficulties.

b. Line voltage regulators. Line voltage regulators do exactly what the name implies – their purpose is to maintain reasonably constant output voltage to the load in the face of variations in power line voltage. There are many different ways of accomplishing this and among the basic types there are innumerable variations, all with their own advantages and limitations.

c. Line conditioners. Line conditioners combine the functions of isolation transformers and line voltage regulators and thus both attenuate impulses and regulate output voltage. For this reason, a line conditioner can protect against the principal types of power line disturbances except for voltage dropouts and line interruptions. It is possible to create a line conditioner by placing separate voltage regulators and isolation transformers in series. Properly matching the two can be tricky, and the package is bulkier and generally more expensive than using a single unit designed to perform the total line conditioning function.

d. Motor-generator sets. Motor-generator sets consist of a motor driving an AC generator or alternator so that the load is completely electrically isolated from the power line. In the past, direct current (DC) or induction drive motors were used requiring close speed control to maintain stable frequency to the load. The tendency nowadays is to use synduction or synchronous motors. The synduction motor resembles an induction motor but runs at synchronous speed. With either of these unit types, alternator speed and thus frequency to the load is as stable as power line frequency. Motor-generator sets have been widely used to supply 415 hertz power to the mainframe computers which require this frequency, but recently there has been a substantial shift to the use of solid-state inverters.

e. Uninterruptible power supplies. If continuous operation is necessary during a line voltage interruption lasting more than a half second or so, then an uninterruptible power supply (UPS) is required. The basic UPS consists of a rectifier/battery charger that takes AC line power of the proper voltage and frequency, a battery bank that takes the place of the rectified DC power source if line power fails, and an inverter that, with suitable filtering, converts the DC power back into a sinusoidal waveform. UPS systems are complex, expensive, somewhat inefficient, have a high output impedance, and frequently require special installation facilities and increased air-conditioning capacity to dissipate the heat. The proper UPS will protect the load equipment from all types of power line disturbances. UPS systems are further described in chapter 22.

f. Magnetic synthesizer. The magnetic synthesizer is a static EM three-phase AC power regenerator. The device, powered from the AC utility line, uses no mechanically moving parts in the generation process, and utilizes no semi-conductor elements in the power path. The output waveform of the device is EM generated, and is completed isolated and independent of the input in all parameters except two: the phase rotation and the frequency. The output phase rotation of the device is governed by the direction of the input phase rotation, while the output frequency is precisely keyed to the input line frequency. There is no electrical connection between the input and the output of the device. The improved quality of power results from the synthesis of three-phase 60 hertz voltage waveforms which remain essentially constant in magnitude and shape over a large range of input voltage excursions in both the positive direction (surges) and the negative directions (sags). The device consists solely of saturable iron core reactors and transformers, together with capacitors, and employs the principles of ferro-resonance for its operation.

21-5. Motor control centers

Motor control center (MCC) is the term given to a grouping of motor starters within a large enclosure. MCCs are used where several motors are to be operated from a single location. The starters themselves may be magnetic across-the-line starters or other types. A typical use would be in a boiler control room where the various fan, pump, conveyer, and other motors serving the boiler are all controlled from a central location

a. Construction. MCCs utilize plug-in type circuit breakers and combination starters in either a front only or a back-to-back freestanding construction, depending on space limitations. Main bus, starters, and breakers are braced to withstand a short circuit current of at least 22 kA, symmetrical. A power panel transformer and feeder breaker, complete with a 120/208 volt power panel and its own main breaker, may be built into the MCC.

b. Location. MCCs are strategically located to serve most of the motor loads, lighting transformers, motor operated devices, welding receptacles, and the like. Loads are grouped in such a manner as to result in relatively short feeder runs from the centers, and also to facilitate alternate power sources to vital services.

c. Connections. Connections to the MCCs are usually via overhead cable tray, and thus the top horizontal section of the MCC incorporates ample cable training space. Control and power leads terminate in each compartment. MCCs can be designed with all external connections brought by the manufacturer to terminal blocks in the top or bottom horizontal compartments.

21-6. Protective devices, fuses, and circuit breakers

Design of power system protection requires the proper application of overload relays, fuses, circuit breakers, protective relays, and other special purpose overcurrent protective devices.

a. Thermal overload relays. The most common overcurrent protective device is the thermal overload relay associated with motor starting contactors. Thermal overload relays detect motor overcurrents by converting the current to heat via a resistive element. Thermal overload relays are simple, rugged, inexpensive, and provide very effective motor running overcurrent protection. Also, if the motor and overload elements are located in the same ambient, the thermal overload relay is responsive to changes in ambient temperature. The relay trip current is reduced in a high ambient and increased in a low ambient. The thermal overload relay combines with the short-circuit device to provide total over-current protection (overload and short-circuit) for the motor circuit.

b. Magnetic current overload relays. Basically, magnetic current relays are solenoids. These relays operate magnetically in response to an over-current. When the relay operates, a plunger is pulled upward into the coil until it is stopped by an insulated trip pin that operates a set of contacts. Magnetic relays are unaffected by changes in ambient temperature. Magnetic current relays may be used to protect motors with long starting times or unusual duty cycles, but are not an alternative for thermal relays.

c. Fuses. A fuse is a non-adjustable, direct acting, single-phase device that responds to both the magnitude and duration of current flowing through it. Fuses may be time delay or non-time delay, current-limiting or non-current-limiting, low-voltage or high-voltage.

d. Circuit breakers. A circuit breaker is a device that allows automatic opening of a circuit in response to overcurrent, and also manual opening and closing of a circuit. Low-voltage circuit breakers are classified as molded-case circuit breakers or power circuit breakers. A molded-case circuit breaker is an integral unit enclosed in an insulated housing. A power circuit breaker is designed for use on circuits rated 1000 Vac and 3000 Vdc and below, excluding molded-case circuit breakers. Molded-case circuit breakers have traditionally been used in panelboards or loadcenters where they are fixed-mounted and accessible. Low-voltage power circuit breakers, on the other hand, are traditionally used in industrial plants and installed in metal-enclosed assemblies. All power circuit breakers are now of the drawout-type construction, mounted in metal clad switch-gear. Low-voltage circuit breaker trip units may be of the electromechanical (thermal-magnetic or mechanical dashpot) or solid-state electronic type. Low-voltage circuit breakers may include a number of trip unit characteristics. These characteristics include long-time pick-up, long-time delay, short-time pick-up, short-time delay, instantaneous pick-up, ground-fault pick-up, and ground-fault delay. The continuous current rating may be fixed or adjustable. Molded-case breakers with solid-state trips and power breakers normally have adjustable long-time and short-time functions. Most molded-case circuit breakers, especially in the smaller sizes, are not provided with long-time adjustments, short-time functions, or ground-fault functions.

(1) The inverse-time (or thermal-magnetic) circuit breaker contains a thermal and a magnetic element in series and is similar in operation to time delay fuses. This circuit breaker will trip thermally in response to overload currents and magnetically in response to short-circuit currents. Magnetic tripping is instantaneous while thermal tripping exhibits an inverse-time characteristic (i.e., the circuit breaker operating characteristics of time and current are inversely proportional). Inverse-time circuit breakers have three basic current ratings: trip rating, frame rating, and interrupting rating. Trip rating is the minimum continuous current magnitude required to trip the circuit breaker thermally. The frame rating identifies a particular group of circuit breakers and corresponds to the largest trip rating within the group. Each group consists of physically interchangeable circuit breakers with different trip ratings. The interrupting rating describes the short-circuit withstand capability of a circuit breaker.

(2) The instantaneous-trip circuit breaker is nothing more than an inverse-time circuit breaker with the thermal element removed and is similar in operation to the non-time delay fuse. This circuit breaker is often referred to by other names, such as, magnetic circuit breaker, magnetic-only circuit breaker, or motor circuit breaker. Instantaneous-trip circuit breakers may be used in motor circuits, but only if adjustable, and if part of a circuit breaker type, combination motor controller with overload relays. Such an arrangement is called a Motor Circuit Protector (MCP) and provides short-circuit protection (circuit breaker magnetic element), overload protection (overload relays), motor control, and disconnecting means all in one assembly. Instantaneous-trip circuit breakers have frame and interrupting ratings but do not have trip ratings. They do have an instantaneous current rating which, for motor circuits, must be adjustable.

e. Protective relays. Protective relays are classified according to their function, and there are a wide variety of protective relays available. The overcurrent relay, for example, monitors current and operates when the current magnitude exceeds a preset value. Other types of protective relays provide protection for other abnormal conditions such as overvoltage or ground faults.

21-7. Switches

Switches are devices that typically isolate equipment from its main source of power. Large sectionalizing switches are used in substations as described in chapter 20. Control switches are used in lower voltage applications to stop and start motors, turn on lights, and to switch from one source of power to another source of power. Several switches may be required within the control circuit of a major component depending on the complexity. These may be a local switch at the device or area, a main control switch used for remote operation located at a main facility console, and an auxiliary switch located in another remote location used for emergency or abnormal operation.

21-8. Feeder cables

Feeder cables are generally defined as those cables providing the main source of power to a motor control center, panelboard, or motor. Power cables are generally made up of three components: conductor, insulation and protective covering. The single most important component of a cable is its insulation. The best way to ensure continued reliability of a power cable is through visual inspection and electrical testing of its insulation. They are sized based on the current requirements of the load, the distance from the source of power, and the short circuit withstand capability of the load. The cable sizing may also consider such factors as environmental conditions, location, and raceway fill. Power cables will generally be run in galvanized rigid steel conduit to the termination points.

21-9. Controls

Electric control is a method of using low voltages (typically, 24 Vac) or line voltages (110 Vac) to measure values and effect changes in controlled variables. Electronic controls use solid-state, electronic components used for measurement and amplification of measured signals and the generation of proportional control signals. Common duties of electrical control systems include performing automatic functions, monitoring equipment status, indicating trouble conditions, recording events, generating reports, and indicating maintenance functions.