TSEWG TP-7: PROTECTION SYSTEM DESIGN

ELECTRICAL COORDINATION ANALYSIS CRITERIA.

Introduction.

When a fault occurs within a system, the primary protection closest to the fault should act promptly to isolate the fault. Depending on the design and function, backup protection farther from the fault might begin to operate but should not actually initiate any tripping functions as long as the primary protection functions properly. If the primary protection fails to isolate the faulted condition, the backup protection should complete its operation to isolate the fault

Most facilities tend to have fully rated systems with some level of selective coordination available. Determine if electrical coordination is a design requirement for the electrical system or some portion of the electrical system. If coordination is a design requirement, a coordination study must be completed.

Coordination Study Description.

The coordination study provides information necessary for the selection of instrument transformer ratios; protective relay characteristics and settings; fuse ratings; and low voltage circuit breaker ratings, characteristics, and settings. The coordination study also provides information regarding relative protection and selectivity, coordination of devices, and the most desirable arrangement of these devices. To obtain complete coordination of the protective equipment applied, determine the following short-circuit currents for each bus.

- Momentary Duty. The maximum and minimum 0 to 1 cycle momentary duty currents are used to determine the maximum and minimum currents to which instantaneous and direct-acting trip devices must respond. They also verify the capability of the applied apparatus to withstand the maximum electromechanical stresses to which they could be subjected.

- Interrupting Duty. The maximum 3 to 8 cycle interrupting duty current, at maximum generation, is used to verify the ratings of circuit breakers, fuses, and cables. This is also the value of current at which the circuit protection coordination interval is established. The maximum 3 to 8 cycle interrupting duty current, at minimum generation, is needed to determine whether the circuit protection is sensitive enough to protect against damage that could result from low level faults.

- Ground Fault Currents. The most common faults in electrical systems are ground faults. The magnitudes of ground fault currents are calculated using the method of symmetrical components, using the impedance values for both the momentary duty and interrupting duty.

The ground fault current for a solidly grounded system can range from 25 percent to 125 percent of the bolted three-phase fault current values, but for most systems does not exceed the calculated three-phase fault current value. For low and high resistance grounded systems, the ground fault current is limited by the impedance of the grounding device and is substantially less than the three-phase fault current. The maximum and minimum generation cases need to be determined, just as for three-phase faults, to determine whether the circuit protection is sensitive enough to protect against damage that could result from low level faults. Separate ground fault relays are usually applied to the system with separate coordination studies performed for the GFP system.

Coordination Time Intervals.

Purpose. When plotting coordination curves, maintain certain time intervals between the curves of various protective devices in order to ensure correct sequential operation of the devices. These intervals are required because relays have overtravel; fuses have damage and tolerance characteristics; and circuit breakers have minimum speeds of operation. The coordination time interval is intended to allow the device closest to the fault the time necessary to detect, respond, and clear the fault before other upstream devices respond or suffer damage. The following provides the required coordination time intervals.

Overcurrent Relays. When coordinating inverse time overcurrent relays, the time interval or margin should be set between 0.3 to 0.4 second. Time margin is measured between relay curves either at the instantaneous setting of the load side feeder circuit breaker relay or the maximum short-circuit current (which can flow through both devices simultaneously) whichever is the lower value of current. The interval might consist of the following components:

- Circuit breaker opening time (5 cycles)—0.08 second.
- Overtravel—0.10 second (electromechanical relays only).
- Safety factor—0.12 to 0.22 second.

The 0.3 to 0.4 second margin can be decreased if field tests of relays and circuit breakers indicate the system still coordinates with the decreased margins; however, the facility maintenance program is then obligated to periodically confirm performance to ensure that coordination is maintained.

The overtravel of very inverse and extremely inverse time overcurrent relays is somewhat less than that for inverse relays. This allows a decrease in time interval to 0.3 second for carefully tested systems.

If electronic multifunction relays are used, overtravel is eliminated and the coordination time interval can be reduced by the amount normally included for overtravel.

For systems using induction disk relays, a decrease of the time interval can be made by using an overcurrent relay with a special higdropout instantaneous element. This is set at approximately the same pickup as the time element, with its contact wired in series with the main relay contact. This eliminates overtravel in the relay. The time interval often used on carefully calibrated systems with higdropout instantaneous relays is 0.25 second. The minimum time interval using a higdropout instantaneous relay could be 0.15 second (that is, 0.03 second instantaneous reset, plus 0.05 second circuit breaker opening time, plus 0.07 second safety factor).

Do not reduce the margin unless needed to resolve a particular coordination problem. Multifunction relays can be very accurate, which can allow for reduced margins if needed.

Relays and Fuses. When coordinating relays with downstream fuses, the relay overtravel and circuit breaker opening time do not exist for the fuse. The margin for overtravel is plotted beneath the relay curve, and because a safety factor is desirable above the total clearing time of the fuse, the same time margin is needed as for relay-to-relay coordination. Reduction of the margin is acceptable, however, when below 1 second. The same margin is used between a downstream relayed circuit breaker and the damage curve of the fuse. A similar process should be used for upstream fuses. The relay should actuate and the associated breaker should clear the fault before reaching the minimum melting time curve of the fuse. Once again, the time margin should be provided as for relay-to-relay coordination.

Direct-Acting Trip Circuit Breakers and Fuses. When coordinating direct-acting trip low voltage power circuit breakers or MCCBs with source-side fuses at the same voltage level, a 10 percent current margin can be used. This allows for possible fuse damage below the average melting time characteristics. The published minimum melting time-current curve should be corrected for ambient temperature or preloading if the fuse manufacturer provides the data necessary to perform this correction. If the fuse is preloaded to less than 100 percent of its current rating and the ambient temperature is lower than about 50 °C (122 °F), the correction to the minimum melting time-current curve of the fuse is usually less than 20 percent in time. Because the characteristic curves are relatively steep at the point where the margin is measured, the normal current margin applied is usually adequate to allow coordination without making a fuse characteristic correction also. Refer to IEEE 1015 for additional considerations regarding coordination of direct-acting trip circuit breakers with fuses.

Direct-Acting Trip and Relayed Circuit Breakers. When low voltage circuit breakers equipped with direct-acting trip units are coordinated with relayed circuit breakers, the coordination time interval should be 0.4 second. This interval can be decreased to a shorter time as explained previously for relay-to-relay coordination.

Direct-Acting Trip Circuit Breakers. When coordinating circuit breakers equipped with direct-acting trip units, the characteristic curves should not overlap. In this case, only a slight separation is necessary between the different characteristic curves. This lack of a specified time margin is based on the incorporation of all the variables plus the circuit breaker operating times for these devices within the band of the device characteristic curve.

Pickup Current.

Description. The term pickup has acquired several meanings. For many devices, pickup is defined as the minimum current that starts an action. It is accurately used when describing a relay characteristic. It is also used in describing the performance of a low voltage power circuit breaker. The term does not apply accurately to the thermal trip of a molded case circuit breaker, which operates as a function of stored heat.

Overcurrent Relay. The pickup current of an overcurrent protective relay is the minimum value of current that will cause the relay to close its contacts. For an induction disk time-overcurrent relay, pickup is the minimum current that will cause the disk to start to move and ultimately close its contacts. For solenoid-actuated devices with time-delay mechanisms, this same definition applies. For solenoid-actuated devices without time-delay mechanisms, the time to close the contacts is extremely short. Taps or current settings of these relays usually correspond to pickup current.

Low Voltage Circuit Breakers. For low voltage power circuit breakers, pickup is defined as that calibrated value of minimum current, subject to certain tolerances, which will cause a trip device to ultimately close its armature. This occurs when either unlatching the circuit breaker or closing an alarm contact. A trip device with a long-time delay, short-time delay, and an instantaneous characteristic will have three pickups. All these pickups are given in terms of multiples or percentages of trip-device rating or settings.

MCCBs. For MCCBs with thermal trip elements, tripping times, not pickups, are defined. The instantaneous magnetic setting could be called a pickup in the same way as that for low voltage power circuit breakers.

Coordination Curves.

Provide coordination curves as part of the facility design package. On a coordination curve, time 0 is considered as the time at which the fault occurs, and all times shown on the curve are the elapsed time from that point. A coordination curve is arranged so the region below and to the left of the curve represents an area of no operation. The curves represent a locus of a family of paired coordinates (current and time) that indicate the period of time required for device operation at a selected current value. Protective relay curves are usually represented by a single line only. Circuit breaker tripping curves, which include the circuit breaker operating time and the trip device time, are represented as bands. The bands represent the limits of maximum and minimum times at selected currents during which circuit interruption is expected. The region above and to the right of the curve or band represents an area of operation. Fuse characteristics are represented by a tolerance band bounded by minimum melting time and total fault current interrupting time curves. A specific current above the fuse current rating is expected to blow the fuse at some value between these times.

Circuit breaker curves usually begin at a point of low current close to the trip device rating or setting and an operating time of 1,000 seconds. Relay curves begin at a point close to 1.5 times pickup and the corresponding time for this point. Curves usually end at the maximum short-circuit current to which the device under consideration can be subjected. A single curve can be drawn for any device under any specified condition, although most devices (except relays) plot an envelope within which operation takes place. This envelope takes into consideration most of the variables that affect operation. Some of these variables are ambient temperature, manufacturing tolerances, and resettable time delay.

Fuses are commonly used with breakers if short circuit currents are very high to accomplish a current-limiting function so as to protect the breaker. At relatively low short circuit currents, fuse clearing characteristics might not prevent the instantaneous breaker trip. Coordination within the breaker’s instantaneous trip region means that the fuse must exhibit current-limiting characteristics. Show the fuse time current curves as well as the breaker time current curves whenever fused breakers are used.

Coordination Analysis.

Protective device coordination requires a careful evaluation of the electrical system under various operating conditions. Perform the following steps to verify the protective coordination throughout the electrical system.

Obtain the following system information:

- System one-line diagram.
- Acceptable system lineups and operating configurations.

- Protective device locations.
- Protective device time-current characteristics.
- Load currents—normal and maximum.
- Motor full-load current, locked rotor current, starting time, and damage time.
- Fault currents at each protective device location.

Provide the following data on the one-line diagram and associated documentation:

- Apparent power and voltage ratings, as well as the impedance and connections of all transformers.
- Normal and emergency switching conditions.
- Nameplate ratings and subtransient reactance of all major motors and generators, as well as transient reactances of synchronous motors and generators, plus synchronous reactances of generators.
- Conductor sizes, types, and configurations, and type of insulating material.
- Current transformer ratios.
- Relay, direct-acting trip, and fuse ratings, characteristics, and ranges of adjustment.
- Cable lengths, particularly if an impedance diagram is not included.

Determine the minimum and maximum fault currents at each protective device location and at the end of all lines. The short-circuit current study should include maximum and minimum expected three-phase and ground fault duties, as well as available short-circuit current data from all sources.

Determine the settings for all protective devices. The settings have to be specified before time-current curves can be generated. Draw a composite set of time characteristic curves showing the coordination of all protective devices. A computer program designed specifically for plotting coordination curves is recommended. Although the coordination study plots can be prepared by hand, this UFC method will usually cost more than a computer-generated study. Also, a computer-generated study is more easily maintained.

Evaluate the results to verify that the selected settings are acceptable. Review the GFP and its coordination with other devices. Refer to ANSI/IEEE 242 for a detailed discussion of GFP coordination.

PROTECTIVE RELAYS.

Protective relays are designed to provide various types of electrical protection. Protective relays detect abnormal conditions and isolate these conditions from the rest of the electrical system by initiating circuit breaker operation. If used, protective relays will usually be located at the service entrance or at major load centers in applications 480 volts and above. Relays are often provided as part of standby power systems.

Protective relaying is an integral part of electrical power system design. The fundamental objective of system protection is to quickly isolate a problem so that the unaffected portions of the system can continue to function, but also should not interrupt power for acceptable operating conditions, including tolerable transients.

Ensure protective relays comply with ANSI/IEEE C37.90, *Relays and Relay Systems Associated with Electric Power Apparatus*.

The most common condition requiring protection is a short circuit or overload. Protective relays will be used to provide overcurrent protection for medium voltage applications and possibly for larger low voltage load centers. Lower voltages usually have overcurrent protection provided by direct-trip breakers or fuses. There are other abnormal conditions that also require protection, including undervoltage, overvoltage, open-phase, overcurrent, unbalanced phase currents, reverse power flow, underfrequency, overfrequency, and overtemperature. Larger power systems require even more types of protection. These types of protection require the use of protective relays. Refer to IEEE 242 for guidance regarding electrical protection of specific equipment types.

The functions performed by protective relays can be accomplished using electromechanical or electronic multifunction devices. Originally, all protective relays were electromechanical devices and it is not uncommon for a 50 year old electromechanical relay to still be in service. Solid-state designs have been available for many years and are preferentially used for new installations. Solid-state relays are also referred to as multi-function relays because a single relay can be configured to provide different types of protection simultaneously. This relay type is preferred because it minimizes the variability of relay types throughout the power system.

Select overcurrent relays to maximize the level of selective coordination with other devices. By selecting a relay with inverse, very inverse, or extremely inverse characteristics, coordination can be improved for a specific situation.

Solid-state relays can be programmed for a specific overcurrent response. Refer to IEEE 242 for additional guidance.

In areas of limited panel mounting space, multifunction relays should be used because they offer the advantage of including several relay protective functions in a single enclosure. By this design, more protective functions can be implemented in a smaller space.

INSTRUMENT TRANSFORMERS.

Background.

Instrument transformer design and performance is an important part of relay design. Protective relays can be no more accurate than the instrument transformers that provide the input information. Instrument transformers operate on the same principles as ordinary transformers; however, they are specifically designed to duplicate the input waveform as closely and predictably as possible.

Ensure instrument transformers comply with IEEE C57.13, *Instrument Transformers*.

Current Transformers (CT).

CTs should deliver a secondary current that is directly proportional to the primary current with as little distortion as possible. In most cases, the secondary output current is usually reduced to a level less than 5 amperes. Although CTs are available with 1 ampere or 10 ampere secondaries, the most common rating of 5 amperes should be used.

All CT circuits require a shorting terminal block. Confirm that CT shorting blocks have been installed.

Include an evaluation of CT saturation in the design and selection of CTs. Design for the highest CT ratio that provides acceptable performance. Multiratio CTs are acceptable for use.

Evaluate CT accuracy in accordance with IEEE 242.

Potential Transformers (PT).

For the typical primary voltages used in facilities, design the PT turns ratio to provide an output voltage of 120 volts.

FUSES.

Fuses can be current limiting or non-current limiting, and can be rated for low voltage or high voltage applications. Ensure that current-limiting fuses are designed to operate within their current-limiting range. Refer to IEEE 242 for a detailed discussion of fuse types and fuse applications.

The interrupting rating denotes the maximum symmetrical fault current permitted at the fuse location. Generally, both symmetrical and asymmetrical root-mean-square (RMS) ratings are given. Select an interrupting rating greater than the maximum expected short-circuit current at the installed location.

The voltage rating of a fuse is the nominal system voltage application. Associated with the voltage rating is the maximum design voltage, marked on the nameplate, which is the highest system voltage for which the fuse is designed to operate. Apply the fuse for the proper phase-to-phase circuit voltage.

Table 1 shows the various UL fuse classes. Each UL class defines certain required operating characteristics; however, a certain fuse classification does not mean that its operating characteristics are identical to those of the same class provided by other manufacturers. Class RK and Class L fuses are preferred over Class K and Class H because of their greater interrupting capacity. Ensure low voltage fuses comply with the appropriate UL standard.

Table 1 Low Voltage Fuse Classifications

UL Class	Rating		Interrupting Rating (Amperes)	Typical Application—Comments
	AC Volts	Amperes		
L	600	601–6,000	200,000	Transformers, mains
J	600	1 – 600	200,000	Motors, mains, load centers, panelboards—current limiting, high interrupting capacity
RK1	250, 600	0.1 – 600	200,000	Motors, mains, load centers, panelboards— current limiting
RK5	250, 600	0.1 – 600	200,000	Transformers, motors—current limiting
CC	600	0.1 – 30	200,000	Transformer control circuit—current limiting, high interrupting capacity
G	480	1 – 60	100,000	Current limiting, high interrupting capacity
T	300, 600	1 – 1,200	200,000	Current limiting, high interrupting capacity
K5	250, 600	1 – 600	50,000	Motor, branch circuit—non current limiting labeled although they might have current limiting features
H	250, 600	1 – 600	10,000	Residential use

OVERLOAD RELAYS.

Overload relays provide motor overload protection. If an overcurrent condition persists that can cause motor damage by overheating, the overload relay responds to clear the overcurrent. Thermal overload relays detect and respond to motor overcurrent by converting the line current to heat by a resistive element. Solid-state overload relays can also be used and have programmed response characteristics. Overload relays are designed to protect against an overload condition; other protective devices provide short circuit current protection.

Two types of thermal overload relays are available:

- Bimetallic thermal overload relays in which a bimetallic element bends as it heats, eventually causing a set of contacts to open. Bimetallic relays automatically reset as they cool; however, the design frequently includes a manual reset switch.

- Melting alloy overload relays in which the heat generated by the current melts a metallic alloy. These relays are usually reset after a few minutes when the alloy solidifies again. Melting alloy overload relays are not the preferred type for use.

Standard, slow, and fast response relays are available. Standard units should be used for motor starting times up to 7 seconds. Slow units should be used for motor starting times in the 8 to 12 second range. Fast units should be applied only to special purpose applications with very fast starting times.

Thermal overload relays are sensitive to ambient temperature; they trip sooner in a high temperature and longer at a low temperature. Use ambient temperature-compensated overload relays if the motor is located in a nearly constant ambient temperature environment and the thermal overload device is located in a varying environment.

Magnetic overload relays are solenoids that respond magnetically to an overcurrent. Magnetic overload relays are used only for unusual applications and should not normally be considered an alternative to solid-state or thermal overload relays.

Apply overload protection to each motor 0.125 horsepower (93.25 watts) and larger. Provide three phase motors with overload protection in each ungrounded conductor.

Verify that an overload relay is properly sized for the associated motor and then check the overload relay tripping time for the motor’s rated locked rotor current. The overload relay tripping time as a function of current should allow sufficient time for the motor to start, accelerate, and reach full speed. The selected overload relay should not actuate throughout the motor’s operating current range, from starting current to long term operation at full load current. If the overload relay size is not adequate to start the motor or carry the load, the next higher size overload relay is permitted by the NEC, provided that it does not exceed the following percentages of motor full load rating:

- 140 percent for motors with a marked service factor of not less than 1.15.

- 140 percent for motors marked with a temperature rise not over 40 °C (104 °F).

- 130 percent for all other motors.

Overload protection can be provided as an integral part of the motor or controller. If necessary for the design, the overload protection can be installed in a separate enclosure, provided that the enclosure is accessible and is clearly marked regarding its purpose.

Verify overload relay coordination by the following process:

- Determine motor full-load amperes.
- Select overload relay ampere rating.
- Evaluate overload relay time-current characteristic curves.
- Evaluate overload relay performance in relation to motor locked rotor amperes and starting time.
- Evaluate overload relay performance in relation to motor locked rotor ampere damage time for medium voltage motors.

Ensure overload relays comply with NEMA ICS 2 and UL 508, *Industrial Control Equipment*.

CIRCUIT BREAKERS.

Low voltage power breakers, insulated case breakers, and MCCBs contain integral current sensing and trip units. Smaller breakers usually have electromechanical trip devices and larger breakers usually have solid-state trip units. Solid-state trip units offer greater flexibility in coordination and can be set more precisely to obtain the desired level of protection.

NEC Article 230.95 (2005 Edition) requires ground fault protection (GFP) to be provided for solidly grounded, wye electrical services of more than 150 volts to ground, but not exceeding 600 volt phase-to-phase for each service disconnecting means rated 1,000 amperes or higher. If GFP is provided at the service entrance, it should be provided at downstream branch panels also. Although this will add to the overall system cost, it can be difficult to coordinate the service entrance GFP by itself with other overcurrent protective devices. By incorporating downstream GFP, the overall facility coordination can often be improved so that a single ground fault event is less likely to deenergize the entire facility. Verify that the service entrance GFP is set high enough to allow coordination with downstream devices.

PROTECTIVE DEVICE DESIGNATIONS.

Every protective device has an associated device function number. These numbers are designated by ANSI/IEEE C37.2, *IEEE Standard Electrical Power System Device Function Numbers*. The numbering scheme defined by this national standard is used in electrical schematics, engineering specifications, textbooks, and other documents referring to electrical devices. The designations most likely to be used in interior electrical facilities are provided in Table 2. Refer to ANSI/IEEE C37.2 for a complete list of protective device designations. Use these designations as applicable on all electrical drawings.

Table 2 Protective Device Designations

Device Function Number	Definition and Function
1	Master Element is the initiating device, such as a control switch, voltage relay, or float switch, which serves either directly, or through such permissive devices as protective and time-delay relays to place an equipment in or out of operation.
2	Time-Delay Starting, or Closing, Relay is a device that functions to give a desired amount of time delay before or after any point or operation in a switching sequence or protective relay system, except as specifically provided by device numbers 62 or 79 described later.
3	Checking or Interlocking Relay is a device that operates in response to the position of a number of other devices, or to a number of predetermined conditions in an equipment to allow an operating sequence to proceed, to stop, or to provide a check of the position of these devices or of these conditions for any purpose.
4	Master Contactor is a device, generally controlled by device number 1 or equivalent, and the necessary permissive and protective devices, which serves to make and break the necessary control circuits to place an equipment into operation under the desired conditions and to take it out of operation under other or abnormal conditions.
5	Stopping Device functions to place and hold an equipment out of operation.
6	Starting Circuit Breaker is a device whose principal function is to connect a machine to its source of starting voltage.
8	Control Power Disconnecting Device is a disconnecting device - such as a knife switch, circuit breaker, or pull-out fuse block - used for the purpose of connecting and disconnecting, respectively, the source of control power to and from the control bus or equipment. Control power is considered to include auxiliary power that supplies such apparatus as small motors and heaters.

Device Function Number	Definition and Function
23	Temperature Control Device functions to raise or to lower the temperature of a machine or other apparatus, or of any medium, when its temperature falls below, or rises above, a predetermined value.
27	Undervoltage Relay is a device that functions on a given value of undervoltage.
29	Isolating Contactor is used expressly for disconnecting one circuit from another for the purposes of emergency operation, maintenance, or test.
30	Annunciator Relay is a nonautomatically reset device that gives a number of separate visual indications upon the functioning of protective devices, and that may also be arranged to perform a lockout function.
32	Directional Power Relay is one that functions on a desired value of power flow in a given direction, or upon reverse power resulting from arc back in the anode or cathode circuits of a power rectifier.
33	Position Switch makes or breaks contact when the main device or piece of apparatus, which has no device function number, reaches a given position.
46	Reverse-Phase, or Phase-Balance, Current Relay is a device that functions when the polyphase currents are of reverse-phase sequence, or when the polyphase currents are unbalanced or contain negative phase-sequence components above a given amount.
47	Phase-Sequence Voltage Relay is a device that functions upon a predetermined value of polyphase voltage in the desired phase sequence.
48	Incomplete Sequence Relay is a device that returns the equipment to the normal, or off, position and locks it out if the normal starting, operating, or stopping sequence is not properly completed within a predetermined time.
49	Machine, or Transformer, Thermal Relay is a device that functions when the temperature of an ac machine armature, or of the armature or other load carrying winding or element of a dc machine, or converter or power rectifier or power transformer (including a power rectifier transformer) exceeds a predetermined value.
50	Instantaneous Overcurrent, or Rate-of-Rise Relay is a device that functions instantaneously on an excessive value of current, or on an excessive rate of current rise, thus indicating a fault in the apparatus or circuit being protected.
51	AC Time Overcurrent Relay is a device with either a definite or inverse time characteristic that functions when the current in an ac circuit exceeds a predetermined value.

Device Function Number	Definition and Function
52	AC Circuit Breaker is a device that is used to close and interrupt an ac power circuit under normal conditions or to interrupt this circuit under fault or emergency conditions.
53	Exciter or DC Generator Relay is a device that forces the dc machine field excitation to build up during starting or that functions when the machine voltage has built up to given value.
54	HigSpeed DC Circuit Breaker is a circuit breaker that starts to reduce the current in the main circuit in 0.01 second or less, after the occurrence of the dc overcurrent or the excessive rate of current rise.
55	Power Factor Relay is a device that operates when the power factor in an ac circuit becomes above or below a predetermined value.
56	Field Application Relay is a device that automatically controls the application of the field excitation to an ac motor at some predetermined point in the slip cycle.
57	Short-Circuiting or Grounding Device is a power or stored energy operated device that functions to short-circuit or to ground a circuit in response to automatic or manual means.
59	Overvoltage Relay is a device that functions on a given value of overvoltage.
60	Voltage Balance Relay is a device that operates on a given difference in voltage between two circuits.
61	Current Balance Relay is a device that operates on a given difference in current input or output of two circuits.
62	Time-Delay Stopping, or Opening, Relay is a time-delay device that serves in conjunction with the device that initiates the shutdown, stopping, or opening operation in an automatic sequence.
64	Ground Protective Relay is a device that functions on failure of the insulation of a machine, transformer or of other apparatus to ground, or on flashover of a dc machine to ground. This function is assigned only to a relay that detects the flow of current from the frame of a machine or enclosing case or structure of a piece of apparatus to ground, or detects a ground on a normally ungrounded winding or circuit. It is not applied to a device connected in the secondary circuit or secondary neutral of a CT, or CTs, connected in the power circuit of a normally grounded system.
67	AC Directional Overcurrent Relay is a device that functions on a desired value of ac overcurrent flowing in a predetermined direction.

Device Function Number	Definition and Function
69	Permissive Control Device is generally a two-position manually operated switch that in one position permits the closing of a circuit breaker, or the placing of an equipment into operation, and in the other position prevents the circuit breaker or the equipment from being operated.
72	DC Circuit Breaker is used to close and interrupt a dc power circuit under normal conditions or to interrupt this circuit under fault or emergency conditions.
73	Load-Resistor Contactor is used to shunt or insert a step of load limiting, shifting, or indicating resistance in a power circuit, or to switch a space heater in circuit, or to switch a light, or regenerative, load resistor of a power rectifier or other machine in and out of circuit.
76	DC Overcurrent Relay is a device that functions when the current in a dc circuit exceeds a given value.
79	AC Reclosing Relay is a device that controls the automatic reclosing and locking out of an ac circuit interrupter.
86	Lockout Relay is a hand or electrically reset auxiliary relay that is operated upon the occurrence of abnormal conditions to maintain associated equipment or devices inoperative until it is reset.
87	Differential Protective Relay is a protective device that functions on a percentage or phase angle or other quantitative difference of two currents or of some other electrical quantities.
94	Tripping, or Trip-Free, Relay is a device that functions to trip a circuit breaker, contactor, or equipment, or to permit immediate tripping by other devices; or to prevent immediate reclosure of a circuit interrupter, in case it should open automatically even though its closing circuit is maintained closed.

A similar series of numbers, prefixed by the letters RE (for “remote”) are normally used for interposing relays performing functions that are controlled directly from a supervisory system. For example, a remote stopping device controlled by the remote supervisory system would be designated RE5.

A device function number can include a letter suffix. A suffix provides additional information about auxiliary equipment associated with the device, distinguishing features or characteristics of the device, or conditions that describe the use of the device. Because a suffix letter can have more than one meaning, care should be used when interpreting device function numbers that contain a suffix. If ambiguity exists regarding the meaning of a suffix, refer to ANSI/IEEE C37.2 to help with an interpretation. Table 3 lists common suffixes used in conjunction with protective relay device function numbers.

Table 3 Protective Device Suffix Designations

Suffix Letter	Relay Application	Amplifying Information
A	Alarm only or automatic	
B	Bus protection	
G	Ground-fault or generator protection	System neutral type
GS	Ground-fault protection	Toroidal or ground sensor type
L	Line protection	
M	Motor protection	
N	Ground-fault protection	Relay coil connected in residual CT circuit
T	Transformer protection	
V	Voltage	
U	Unit protection	Generator and transformer

REFERENCE DOCUMENTS.

Refer to UFC 3-500-10, IEEE 141, IEEE 241, and IEEE 242 for additional guidance regarding electrical protection and coordination.