Appendix C

Numbering System for Protective Devices, Control and Indication Devices for Power Systems

C.1 APPLICATION OF PROTECTIVE RELAYS, CONTROL AND ALARM DEVICES FOR POWER SYSTEM CIRCUITS

The requirements for the different types of HV and LV circuits in a typical oil industry power system are summarised below. The IEEE device numbers commonly used in the oil industry are listed in sub-section C.2.

1. **Utility intake above 11 kV.**
   25, 27, 51V, 51N, 86, 87.
2. **Unit transformer-generator intake above 11 kV.**
   Primary circuit, see note 1.
   Secondary circuit 25, 26, 27, 32, 40, 46, 51V, 51G, 59, 64, 81, 86, 87.
3. **Switchgear busbar zone protection above 11 kV.**
   86, 87 see note 2.
4. **Switchgear bus-section and bus-couplers above 11 kV.**
   25, 27 see note 3, 86.
5. **Transformer feeders above 11 kV.**
   Primary circuit, 23 see note 4, 49, 50, 51, 51N, 86, 87.
   Secondary circuit, 23 see note 4, 51G see note 5, 64 see note 6, 86.
6. **Unit transformer-motor feeders above 11 kV.**
   Primary circuit, 23 see note 4, 26, 27, 59, 86, 87.
   Secondary circuit, 23 see note 4, 51G, 64, 87 see note 1.
   Motor, 25 see note 4, 26, 46, 49, 50, 51N, 87.
7. **Overhead line feeder above 11 kV.**
   51, 51N, 86.

Handbook of Electrical Engineering: For Practitioners in the Oil, Gas and Petrochemical Industry. Alan L. Sheldrake
 ISBN: 0-471-49631-6

8. **HV generator intake-turbine driven.** See Figure 12.2.
   26, 27, 32, 40, 46, 51V, 51G, 58, 59, 64, 81, 86 see note 7, 87.
9. **HV overhead line intake.**
   25, 27, 51V, 51N, 86, 87 see note 8.
10. **HV/HV/tertiary transformer feeder.** See Figure 12.11.
    Primary circuit, 23 see note 4, 49, 50, 51, 51N, 86, 87.
    Loaded secondary circuit, 23 see note 4, 51, 51G, 64, 81, 86, 87.
    Loaded tertiary circuit, 23 see note 4, 51, 51G see note 5, 64 see note 6, 86, 87.
11. **HV/LV transformer feeder, rated 5 MVA and above.** See Figure 12.9.
    Primary circuit, 23 see note 4, 49, 50, 51, 51N, 86, 87.
    Secondary circuit, 23 see note 4, 51G, 58 see note 5, 81 see note 6, 86.
12. **HV/LV transformer feeder, rated below 5 MVA.** See Figure 12.10.
    Primary circuit, 23 see note 4, 49, 50, 51, 51N.
    Secondary circuit, 23 see note 4, 51G see note 5, 64 see note 6, 86.
13. **HV switchgear bus-section and bus-coupler circuit breakers.**
    25 see note 2, 27, 86.
14. **HV DOL induction motors, 2.5 MW and above, see note 9.** See Figure 12.15.
    26, 46, 49, 50, 51N, 86, 87.
15. **HV DOL induction motors, below 2.5 MW, see note 9.** See Figure 12.15.
    26, 46, 49, 50, 51N, 86.
16. **HV variable speed drive induction motors.**
    At the switchboard, see note 10. 50N, 51, 86, 87 see note 12.
    At the unit control panel, see note 11. 27, 46, 49, 50, 50N, 58, 59.
17. **HV static loads, see note 10.**
    50, 50N, 51, 86.
18. **HV interconnectors, single and parallel cables, protection at both ends.** See Figure 12.14.
    51, 51N, 86 see note 13.
19. **HV single and parallel submarine cables, protection at both ends.** See Figure 12.14.
    51, 51N, 86 see note 13.
20. **HV busbar earthing transformer for busbars in switchboards.**
    49, 50, 51, 51G, 86.
21. **HV overhead line feeders, see note 14.**
    51, 51N, 86.
22. **HV plain cable feeders.** See Figure 12.14.
    51, 51N, 86.
23. **LV main generator intake-engine driven.**
    26, 27, 32, 40, 51V, 51G, 58, 59, 64, 81, 86.
24. **LV emergency generator intake-engine driven.**
    26, 27, 32, 40, 51V, 51G, 58, 59, 81, 86.

25. **LV switchgear bus-section and bus-coupler circuit breakers.**
    86.
26. **LV interconnectors, single and parallel cables, protection at both ends.**
    51, 51N, 86.
27. **LV DOL induction motors, 37 kW to 250 kW.** See Figure 12.19.
    46, 49, 50, 50N see note 15, 86.
28. **LV DOL induction motors, below 37 kW.** See Figure 12.19.
    49 see note 16, 50 see note 16.
29. **LV static loads and feeders to distribution boards.**
    51, 51N see note 17, 86 see note 18.

C.1.1 Notes to sub-section C.1

1. In the situation where a generator has a unit transformer it is recommended that two forms for differential protection are provided. One will be for the generator by itself, and denoted 87G. The second will be an overall scheme for the generator and the unit transformer, and denoted 87T.
2. Bus-zone protection is recommended to be of the high-speed balanced voltage type. Each section of busbars should be protected as one zone. There are other options available that are technically more complex and hence more expensive. It is normal practice to overlap adjacent zones at bus-section and bus-coupler circuit breakers. The bus-zone protection scheme can also be provided with a test facility that can be used while the switchboard is in its normally energized state.
3. The undervoltage relay is usually provided with time delay settings, and used to trip the consumers fed from the particular bus-section.
4. A device required for starting and stopping forced air-cooling fans.
5. An unrestricted earth fault relay that is connected in the star-point earth circuit of the equipment being protected. The characteristic is time dependent so that time coordination is achieved with the 50 N devices downstream.
6. A restricted earth fault relay is used with generators and transformers to detect internal faults. The relay will usually be of the voltage operated instantaneous type.
7. The generator switchgear is recommended to have two separate lockout relays. One will receive all the electrical protection relay trip signals, and denoted as 86–1. The other will receive a master trip signal (or several trip signals) from the turbine unit control panel, and denoted as 86–2.
8. Normally only required on critical circuits.
9. Modern relays combine the 46, 49, 50, 51 N and 86 functions; together with others such as motor stalling, number of starts, thermal state at the time of starting, undercurrent, overloading, high-set current limit.
10. The manufacturers of the static loads and variable speed drives may require special protection devices for their equipment.
11. The manufacturer of the variable speed drive may provide some protection devices in the unit control panel. These devices may be inter-tripped with the main circuit breaker.
12. The manufacturer of the variable speed drive may recommend the 87 relay. It may be part of the UCP as mentioned in Note 11. It should not be necessary for motors below 2.5 MW.

13. A relay common to the parallel circuits would normally be adequate.
14. The relays would be fitted into the main switchboard, not at intermediate locations along the overhead line route.
15. The use of a 50 N relay is recommended in relation to the maximum earth-loop impedance allowed for the particular consumer. This will be a function of the motor rated power, the route length and the type of armouring used for the motor power cable.
16. The use of the 49 and 50 relay(s) may be replaced by thermal and magnetic elements within the circuit breaker or starter unit for the particular motor. This is normally only required for small motors.
17. The use of a 51 N should be considered when time coordination is required with distribution board consumers e.g. lighting, small power socket outlets and welding socket outlets. Static loads which do not feed downstream consumers should be fitted with a 50 N relay.
18. The hand-reset feature of a moulded case or miniature circuit breaker may replace the 86 relay. There may be a project requirement to use fuses. For low power circuits an auto-reset device (29) may be acceptable, provided that it does not reclose the circuit breaker or contactor.
19. The need for trip circuit supervision depends to a large extent on the importance of the circuit connected by the power circuit breaker, e.g. utility company incomers, main generators, HV circuits. One of the IEEE code numbers in the range 95 to 99 can be used to identify the trip circuit supervision relay.

C.2 ELECTRICAL POWER SYSTEM DEVICE NUMBERS AND FUNCTIONS

The devices in switching equipment are referred to by numbers, with appropriate suffix letters when necessary, according to the functions they perform.

These numbers are based on a system adopted as standard for automatic switchgear by the IEEE, and incorporated in American Standard C37.2–1970. (updated 1991). The suffix letters are also shown in the IEEE standard. The following are the most frequently encountered in the oil industry.

Device Number	Definition and Function
21	**Distance relay** is a device that functions when the circuit admittance or impedance or reactance increases or decreases beyond predetermined limits.
23	**Temperature control device** functions to raise or lower the temperature of a machine or other apparatus, or of any medium, when its temperature falls below, or rises above, a predetermined value.
25	**Synchronising or synchronism-check device** operates when two AC circuits are within the desired limits of frequency, phase angle or voltage, to permit or to cause the paralleling of these two circuits.
26	**Apparatus thermal device** functions when the temperature of the shunt field or the damper winding of a machine, or that of a load limiting or load shifting resistor or of a liquid or other medium exceeds a predetermined value. It also functions if the temperature of the protected apparatus, such as a power rectifier, or of any medium decreases below a predetermined value.

Device Number	Definition and Function
27	**Undervoltage relay** is a device that functions on a given value of undervoltage.
32	**Directional power relay** is one which functions on a desired value of power flow in a given direction, or upon reverse power resulting from arc back in the anode or cathodic circuits of a power rectifier.
37	**Undercurrent or under-power relay** functions when the current or power flow decreases below a predetermined value.
38	**Bearing protective device** functions on excessive bearing temperature, or on other abnormal mechanical conditions, such as undue wear, which may eventually result in excessive bearing temperature.
40	**Field relay** functions on a given or abnormally low value or failure of machine field current, or on an excessive value of the reactive component of armature current in an AC machine indicating abnormally low field excitation.
46	**Reverse-phase, or phase-balance, current relay is a relay** which functions when the poly-phase currents are of reverse-phase sequence, or when the poly-phase currents are unbalanced or contain negative phase-sequence components above a given amount.
49	**Machine, or transformer, thermal relay** is a relay that functions when the temperature of a machine armature, or other load carrying winding or element of a machine, or the temperature of a power rectifier or power transformer (including a power rectifier transformer) exceeds a predetermined value.
50	**Instantaneous overcurrent, or rate-of-rise relay** is a relay 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 relay with either a definite or inverse time characteristic that functions when the current in an AC circuit exceeds a predetermined value.
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.
58	**Rectification failure relay** is a device that functions if one or more anodes of a power rectifier fail to fire, or to detect an arc-back or on failure of a diode to conduct or block properly.
59	**Overvoltage relay** is a relay that operates on a given difference in voltage, or current input or output of two circuits.
60	**Voltage or current relay** is a relay that operates by comparing these variables in two circuits, in the form of a difference relay, e.g. star-point comparator for capacitor banks.
64	**Ground protective relay** is a relay 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.

(*continued overleaf*)

Device Number	Definition and Function
	It should be noted that this function is assigned only to a relay which 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 current transformer, or in the secondary neutral of current transformer, connected in the power circuit of a normally grounded system.
65	**Governor** is the assembly of fluid, electrical or mechanical control equipment used for regulating the flow of water, steam, or other medium to the prime mover for such purposes as starting, holding speed or load, or stopping.
67	**AC directional overcurrent relay** is a relay that functions on a desired value of AC overcurrent flowing in a predetermined direction.
74	**Alarm relay** is a device other than an annunciator, which is used to operate, or to operate in connection with, a visual or audible alarm.
81	**Frequency relay** is a relay that functions on a predetermined value of frequency – either under or over or on normal system frequency – or rate of change of frequency.
86	**Locking-out relay** is an electrically operated, hand or electrically reset, relay that functions to shut down and hold an equipment out of service on the occurrence of abnormal conditions.
87	**Differential protective relay** is a protective relay that functions on a percentage or phase angle or other quantitative difference of two currents or of some other electrical quantities.