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Criteria for Working out Relay Settings and Coordination of Electrical Distribution of Industrial Plant

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ABSTRACT*:* One of the prime requirements to maintain the reliability of electrical network is adopting correct relay settings of its protection system. The incorrect relay settings may result into equipment failure, damage to equipment and people, loss of power to the healthy system, inadvertent operation of circuit breaker/isolating device, loss of production etc. Accurate relay setting and coordination is one of the requirement for a reliable electrical system. This paper describes the criteria for working out relay settings and coordination of electrical distribution system of a typical industrial plant.

KEYWORDS: Relay settings and coordination, Phase fault, Ground fault, IDMT characteristic, Instantaneous, DMT characteristic, Backup protection, Primary protection, Stability, Sensitivity, Discrimination, Selectivity, Pickup setting.

I.INTRODUCTION

One of the prime requirements to maintain the reliability of electrical network is adopting correct relay settings of its protection system.

The incorrect relay settings may lead to:

a) Inadvertent operation of circuit breaker/isolating device
b) Loss of production
c) Equipment failure
d) Damage to equipment and people
e) Loss of power to healthy system

This paper describes the criteria / philosophy for working out relay settings and coordination of electrical distribution system of a typical industrial plant. The paper describes relay setting criteria only for phase fault and ground fault protection relays. Setting criteria for other types of protection such as under voltage/over voltage protection, under frequency/over frequency protection, reverse power protection, unit protections etc. are not covered in this paper.

II. PROTECTION SYSTEM CHARACTERISTICS

Following are important characteristics of protection system:

a) Selectivity
Protection system should operate selectively, disconnecting only the faulty part of the network.

b) Safety
Protection system should not operate when not required. It should not operate during transient condition of the network. Protection relay must be set in such a manner that it does not cause undesired tripping.

c) Sensitivity
Protection system should be sensitive enough to detect minimum fault current (short circuit current).

d) Speed
Protection system should operate in a shortest possible time and clear the fault thereby minimizing damage to the system components/equipment.

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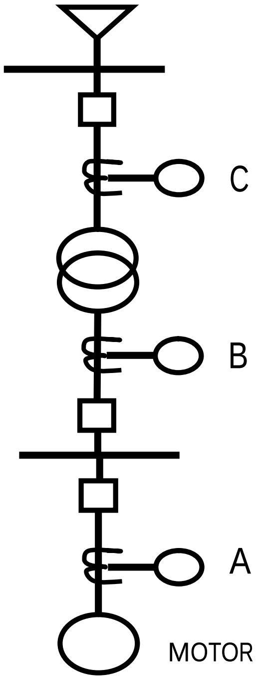
III. RELAY SETTINGS& COORDINATION CRITERIA

Given below are criteria for working out relay settings and coordination. It may be noted that criteria given are only for phase fault protection and ground fault protection relays. The setting criteria for other types of protection are not covered in this paper.

3.1 The relay settings shall be worked out starting from the downstream electrical system moving up.



For system shown above, the settings shall be worked out in following sequence.

Relay A, followed by Relay B, followed by Relay C.

3.2 The relay settings shall be worked out separately for phase fault protection relays and ground fault protectionrelays. The TCC (Time Coordination Curve) shall be plotted separately for phase fault and ground fault.

3.3 The relay settings and coordination study must be based on the calculated short circuit currents. The study should not be based on rated short circuit current values of the busbars. The short circuit study shall be performed to calculate actual phase and ground fault currents on each bus in the system under study. Following data of Utility system are required for calculating actual short circuit currents of the system under study:

3.3.1 Sending end (Utility Bus) actual short circuit current values (maximum and minimum) for phase fault and ground fault.

3.3.2 Impedance of Cable / transmission line between Utility Substation to plant incomer.

3.3.3 Number of transformers operating in parallel at Utility Substation bus which is feeding power to the plant.

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3.4 The relay settings shall be worked out for Normal Operating Configuration of the plant (Configuration which is available for >80% time in a year). For example Bus-coupler in 'Open' condition, Standby Generator is in 'Out of Service' condition, Standby load in 'Off' condition etc.

3.5 The relay settings shall be worked out such that fault at any location in the system is cleared within maximum one Second; to maintain system stability.

3.6 Work out relay settings such that primary protection and first back up protection clear the fault in maximum one second time maintaining the discrimination and selectivity. It is good if second back up protection also clear fault in one second.

3.7 Discrimination (time gradation) of about 200-250 ms shall be provided between two protections in series (example Outgoing feeder and Incoming feeder, Transformer secondary side relay and transformer primary side relay for secondary side fault). The discrimination time of 200-250 ms is considering following factors:
Opening time of Circuit Breaker: 60 ms
Inertia time of protections: 20 ms
Relay error: 60 ms
Safety margin: 50-100 ms

3.8 To reduce the fault clearance time of upstream protection system, discrimination shall not be provided between receiving end relay and sending end relay.

3.9 Protection system shall be reviewed before starting the relay setting and coordination exercise. Missing protection shall be added and extra protections provided if any shall be deleted.

3.10 Instantaneous overcurrent protection (50) and Instantaneous ground fault protection (50N) should not be provided on Incoming Feeder to a switchgear or MCC; as these protections if provided, will operate instantaneously for fault on any outgoing feeder thereby disconnecting power supply to healthy downstream system. However, 50 and 50N can be provided on Incoming Feeder for auto transfer scheme and Zone Selective Interlock purpose.

3.11 Following are criteria for selecting IEC type IDMT (Inverse Definite Minimum Time) characteristics for Phase and ground overcurrent protections.

- Extremely Inverse (EI) Characteristic shall be used as a back up to fuse as the EI characteristic curve slope is similar to fuse characteristic curve slope. Hence, for fault on feeder having Fuse, relay will allow fuse to operate first as a primary protection for bolted fault of higher magnitudeand also for the arcing fault (with resistance at the point of fault) of lower magnitude.
- Very Inverse (VI) Characteristic shall be used for IDMT phase fault protection (51) on primary side of transformer. The51 protection with VI characteristic will take a longer time to operate for phase fault on the transformer secondary side system thereby acting as a backup protection to the secondary side 51 relay. However, for the fault on transformer primary side, the 51 relay with VI characteristic will operate much faster to clear the fault as a backup protection to 50 relay.
- Normal Inverse (NI) Characteristic shall be generally used for the Switchgear or MCC Incoming feeder.
- Long Time Inverse (LTI) Characteristic shall be generally used for protection of Neutral Grounding Resistor during ground fault.
- Refer following figure showing IDMT characteristic selection for a typical network.

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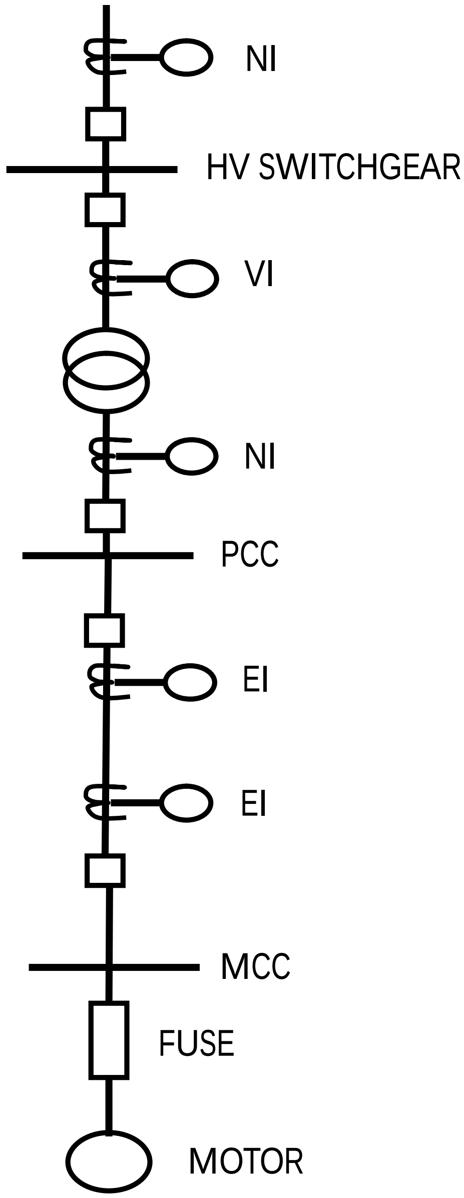

3.12Delta-Star (with grounded neutral)transformer with vector group Dyn11/Dyn1 shall be provided with 50, 51 and 50N protections on its primary side (Refer figure below):

- 50is used as a primary protection for phase fault on transformer primary side.
- 50N is used as a primary protection for ground fault on transformer primary. 50N do not operate for any ground faults on Star side system, as Delta provides a natural isolation from the ground faults on transformer secondary side.
- 51is used as a backup protection to phase faults on transformer secondary side.

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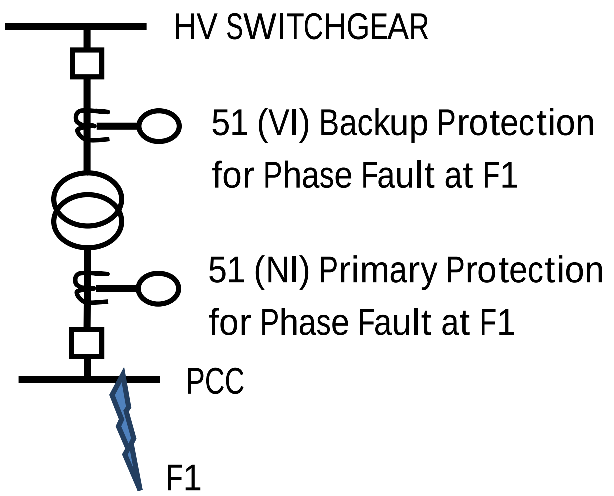
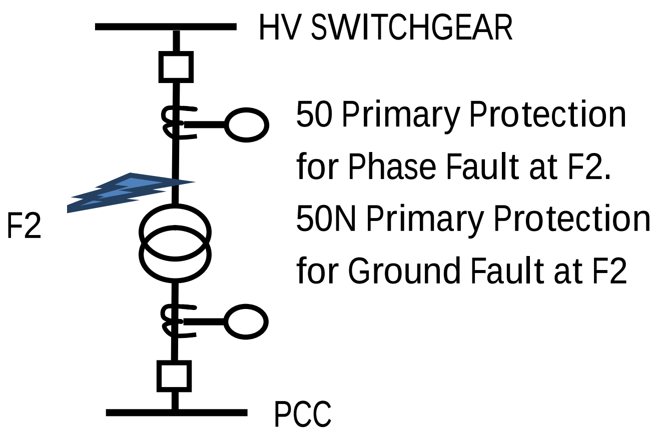
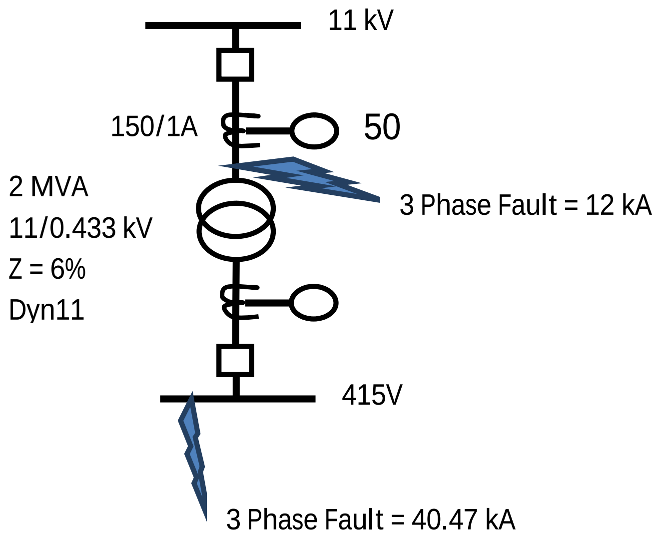




3.13Criteria for setting 50 (Instantaneous Overcurrent Protection) provided on transformer primary

Case study: In one of the plant having 2 MVA transformer as shown below, the 50 relay setting was 9A. This unit operated for a 3 phase fault on one of the outgoing feeder as setting was incorrect.



For a 3 phase fault on outgoing feeder, the current seen by relay = (40470 x 433/11000) x (1/150) = 10.62A which is above pick up setting of 9A. Hence relay operated instantaneously and tripped transformer HV breaker.

Solution: 50 unit should not operate for Low Voltage (LV) side phase faults and during transformer charging. Transformer charging current is maximum 12 times its full load current. To comply with these two conditions, set pickup setting of 50 relay for 1.3 times reflected LV phase fault current.

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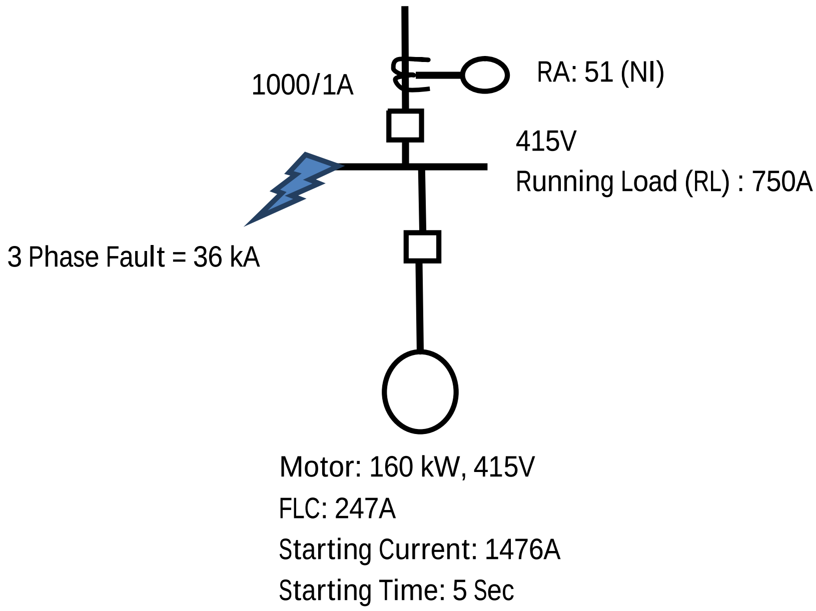
Transformer charging current = 12 x Transformer Full Load Current = 12 x 105 = 1260A. Pick up > 1260/150.
Pickup > 8.4A, as per transformer charging current criteria.
Pickup Setting of 50 unit = 1.3 x Reflected 415V Phase Fault Current / CT Ratio
1.3 is a safety margin to take care of transients, CT error, relay error etc.
Pickup setting = 1.3 x (40470 x 433/11000) x (1/150) = 13.80
Set Pickup = 14 A
With Pickup setting of 14A, relay will not operate for 415V side phase fault as well as during transformer charging.
Phase fault on transformer 11 kV winding = 12kA.
Relay primary operating current = Pickup setting x CT Ratio = 14 x 150/1 = 2100A
Phase Fault current = 12000A. Hence 50 unit will operate instantaneously for 11 kV side fault.

The setting of 50 Unit was revised to 14A.

3.14Criteria for setting 51 (IDMT Overcurrent Protection)
Case study: In one of the plant the setting of 51 (IDMT Overcurrent protection) protection provided on Incoming feeder to MCC was set as per overload criteria for the system as shown below.



415V bus has maximum running load of 750A. The largest motor connected to this bus is 160 kW, DOL start motor.

As per overload criteria the pick-up setting = (1.1 x Running Load) / CT Ratio = (1.1 x 750) / 1000 = 0.825A
Adopted setting PS = 0.83A. Considering NI characteristic and relay OT of 0.3 sec for 3 phase fault, the TMS setting = 0.14

With above settings, during 160 kW motor starting, the current from relay is as given below

PSM = (Running Load – Motor Full load current + Motor starting current) / CT Ratio
PSM = (750-247+1476) / 1000 = 2.38
For PSM=2.38 and TMS = 0.14, for NI characteristics, the relay operating time = 1.12 Sec.

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As motor starting time (5 sec) > Relay operating time (1.12 sec), the relay operated during starting of largest motor with all other load operating.

Solution: 51 (IDMT Overcurrent protection) protection provided on Incoming feeder to any switchgear shall not be set for Overload Protection. The IDMT relay IEC characteristics curves operating time ranges from few milliseconds to maximum 300 seconds. Whereas transformers thermal withstand capacities are in hours. Moreover if set as overload protection, the incomer relay may operate inadvertently during starting of large DOL start motor as shown in above example. Given below are criteria for setting 51 protection.

Setting of Relay: Relay shall be set such that it should not operate during starting of largest motor connected to the bus with all other loads operating.

Pickup Setting = (RL – FLC of 160kW motor + Starting Current of 160 kW motor)/CT Ratio
Pickup Setting = (750-247+1476) / 1000
Pickup Setting = 1.979
Set Pickup = 2.0A

Select NI Characteristic for this relay. Relay shall operate in 300 ms; considering downstream motor protection operating time of 50 ms for fault on motor terminal and 250 ms as discrimination time.
Time Multiplier Setting (TMS) = 0.13

With above setting, relay actual operating time for 3 phase fault on 415V Bus = 0.3 second.
With above settings, the relay operation during motor starting is prevented.

3.15By changing Pickup setting, the IDMT curve can be moved horizontally and by changing TMS setting, the curve can be moved vertically.

3.16Criteria for setting 51N (IDMT Ground Fault Protection)

- Set Pickup setting of 51N on higher side for the Solidly Grounded system as the fault current magnitude is high so even if Pickup setting is high, the Plug Setting Multiplier (PSM) will be more than 20 and IDMT characteristic will operate in the same time (Definite Time) for all PSM values greater than 20.
  Example: Solidly grounded system, Ground Fault Current = 42.29 kA
  For a feeder with CT Ratio = 1600/1A
  Pick up setting = 0.8
  PSM = 42290/ (1600 x 0.8) = 33.03
  PSM for arcing fault with 70% of ground fault magnitude = 33.03 x 0.7 = 23.12
  As PSM for Arcing Fault is >20; the relay operating time of IDMT characteristic for arcing fault is same as that of bolted fault.

- Set Pickup setting of 51N as 10% for resistance grounded system. In the resistance grounded system the ground fault magnitude is low (typically 200A to 400A as per NGR rating). Hence to get higher sensitivity, 51N relay Pickup setting shall be low (10%).

3.17Relay 51NE (Transformer Neutral Ground Fault Protection) and 64R (Restricted Ground Fault Protection) shall be wired to trip transformer primary side circuit breaker.

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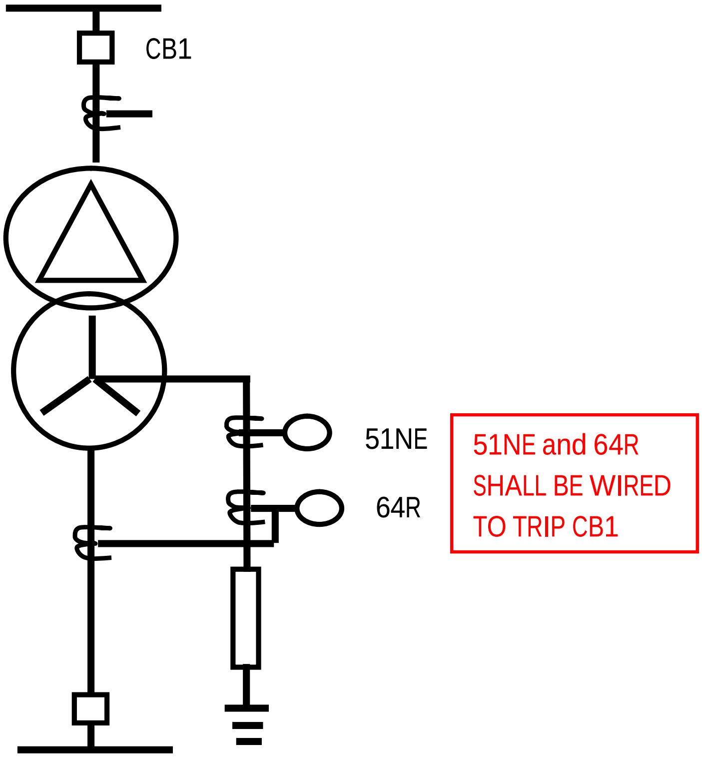

3.18 Criteria for setting 50N (Instantaneous Ground Fault Protection)

- For low impedance type of protection set Pickup setting of 50N above the charging current of transformer to avoid spurious operation of 50N during transformer charging due to CT saturation. Typically transformer charging current is between 8 to 12 times Transformer full load current. Hence set Pickup = 13 x Transformer Full Load Current/ CT Ratio. The magnitude of ground fault current on transformer primary side is much higher (in Kilo-amps) to operate 50N and clear fault instantaneously.
- For High impedance type of protection the stabilizing resistor is set to avoid operation of relay during transformer charging.

3.19Modern digital and microprocessor based relays have number of protections built in one relay. It is necessary to set required protection units and disable the extra protection units by configuring relay; otherwise relay may operate inadvertently.

IV.CONCLUSION

Various criteria described in this paper shall be used to workout relay settings and coordination of electrical network. The protection system is really only such if the protection functions necessary are provided and these are suitably set. Particular attention must be paid in the relay coordination study to verifying that the protections do not cause unwanted trips. Modern digital and microprocessor based relays may have number of protections built in one relay. While configuring these relays, it is necessary to set only desired protection units and disable the undesirable protection units otherwise, relay may operate inadvertently.

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DISCLAIMER

Protection relay setting is not only science, but it is also an art. Network parameter values are based on an example operating system and are for education purpose only. User is advised to use his/her discretion before using the same. The paper describes relay setting criteria only for phase fault and ground fault protection relays. Setting criteria for other types of protection such as under voltage/over voltage protection, under frequency/over frequency protection, reverse power protection, unit protections etc. are not covered in this paper.

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