# RELAY SETTING COORDINATION USING ETAP

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**Abstract**

*Relays and circuit breakers are the heart of the modern large interconnected power system. Proper coordination of relays is important to attenuate unnecessary outages. Usually electric circut is for protection. This paper presents shortcircuit analysis and relay coordination of overcurrent relays of a radial power grid of 1149.441MVasc capacity of an industrial powerplant using etap simulation and hand calculation and comparision of result by both the methods.*

**Index Terms**— *earth fault settings, Etap simulation, hand calculation, over current relay settings, radial system, relay coordination, short circuit analysis.*

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## 1 INTRODUCTION

In any power system network, protection should be designed such protective relays isolate the faulted portion of the network at the earliest, to prevent equipment damage, injury to operators and to make sure minimum system disruption enabling continuity of service to healthy portion of the network. In case of failure of primary relays, back up relays operate after sufficient time discrimination.

The protective relay should be able to discriminate between normal, abnormal and fault conditions. The term relay coordination covers concept of discrimination, selectivity and backup protection.

In modern era, the demand for electrical power generally is increasing at a faster rate in economically emerging countries. So the networks of electricity companies become very complicated. The exercise of load flow analysis, fault calculations and listing the first and back-up pairs are going to be very tedious and a number of other iterations would be required to calculate TMS of relays in order that minimum discrimination margin as needed is found between a relay and every one its back-up relays in large electrical system. This is possible only through computer programming. ETAP performs numerical calculations with tremendous speed, automatically applies industry accepted standards, and provides easy to follow output reports. ETAP, while capable of handling 1000 buses, contains a load schedule program which tracks up to 10,000,000 load items, and reports the voltage and short-circuit current at the terminals of each load item. 100% of the Top 10 electrical design firms relay on ETAP (ECM Magazine). This capability makes ETAP suitable for giant industrial facilities, also as utility systems. Thus our project includes smart implementation of relay coordination using ETAP and multifunction relays having combined definite time and inverse time characteristics.

## 2 SHORT CIRCUIT ANALYSIS

### 2.1 Calculation of Transformer fault current and circuit breaker capacity

For a 15000KVA ,33KV – 480Y/277V, first you will need to know the transformer Full Load Amperes

Full Load Ampere = KVA / 1.73 x L-L KV

FLA = 20000 / 1.732 x 33

FLA = 1202A

The 20000KVA 11V secondary full load ampere is 1,202A.The percent of impedance value is 12.17.

Therefore;

% Z =12.17%

This shows that if there was a 3-Phase Bolted fault on the secondary of the transformer then the utmost fault current that would flow through the transformer and therefore the FLA =1202A

Based on the infinite source method at the first of the transformer. A quick calculation for the utmost Fault Current at the transformer secondary terminals is

FC = FLA / %PU Z

FC = 1202 / 0.1217 = 9876.74A

This quick calculation can assist you determine the fault current on the secondary of a transformer for the aim of choosing the right overcurrent protective devices which will interrupt the available fault current. The main breaker that is to be installed in the circuit on the secondary of the transformer has to have a KA Interrupting Rating greater then 9876.74A. Be aware that feeder breakers should include the estimated motor contribution too. If the particular connected motors aren't known, then assume the contribution to be 4 x FLA of the transformer. Therefore, in this case the feeders would be sized at 9.876 + (4 x 1202) = 4817.876 Amps.

### 2.2 Assumptions

1. The reactance of all cables, circuit breakers, current transformers, and buses are neglected, as well as the resistance values of all the system components. The effect of these is usually small when compared to the effect of power company short circuit per-unit reactance and generator and transformer per-unit reactance.

2. All the faults are considered bolted, that is, the fault impedance is assumed to be zero.

3. Contribution of back emf of motors in feeding the fault current is neglected. The short-circuit currents calculated with the preceding assumptions will be slightly higher, on the conservative side, than if the neglected values were used in the calculations.

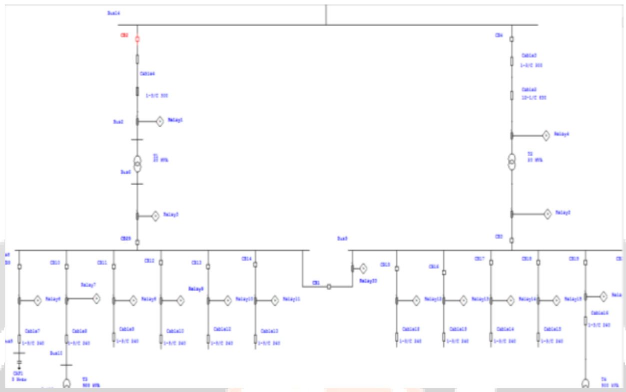
### 2.3 Steps for hand calculation of 3 phase and 1 phase short circuit current of single transformer in service

- 3 phase Fault current at local end (33KV side) = Base MVA/1.73*Base KV*Z(tot)
- 1 phase Fault current at local end = 1.73*Base MVA/Base kv*Z(tot)
- Z(tot)=total (source impedance + impedance in p.u )
  Source impedance = Rated Kv/1.73*3phase fault current
  Total impedance in per unit is calculated by the addition of +ve and –ve and zero sequence of cable and OHL. (Here the +ve and –ve sequence of the cable and OHL will be equal)
- Reflected fault current 33kv side of 33/11kv t/f(I2) = V2*I2/V1
- 3 phase Fault current at 0.415Kv side of 11/0.415 t/f= MVA/1.73*KV*Z(tot)
- 1 phase Fault current at 0.415Kv side of 33/11Kv t/f=1.73*MVA/KV*z(tot)

**2.4 System Model**

Here we have considered a part of 33 kV radial system of 1149.441 MVAsc capacity for relay coordination, which is as shown in fig. 1.

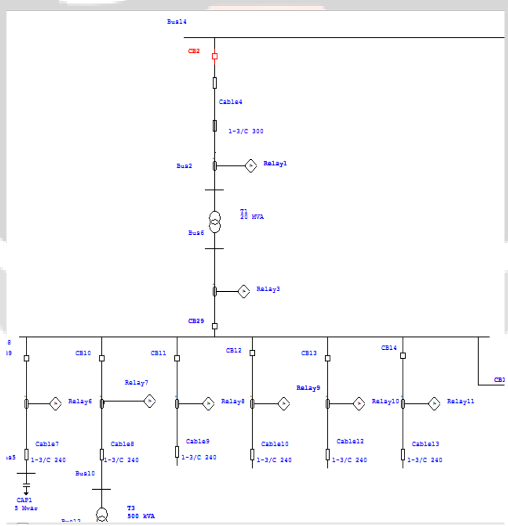
Figure 1



**2.5 Calculation of 3 phase short circuit current of single transformer in service**

Consider the single line diagram in fig.2 which shows the values of current in the diagram obtained by performing Short Circuit analysis when a 3 phase fault is inserted at load side in ETAP .

The fault current flows from grid through transformer (20MVA) & transformer (20MVA) (connected in parallel feeder).



**2.6 Tabulation of both 3 phase and 1 phase short circuit current**

| Location of the fault current created | By ETAP(ka) | Hand cal.(Ka) | Difference | By ETAP(ka) | Hand cal.(Ka) | Difference |
|---|---|---|---|---|---|---|
| Fault generated and reflected at 33kv side of 33/11kv t/f | 1.92 | 1.815 | 0.105 | - | - | - |
| Fault current contributed by 11kv incomer bays | 5.5 | 5.6346 | 0.1346 | 1.51 | 1.815 | 0.305 |
| Reflected fault generated at 11kv side of 11/0.415V | 0.517 | 0.508 | 0.009 | - | - | - |
| Fault generated at .415 side of 11/.415 kv | 13.77 | 13.48 | 0.29 | 14.32 | 13.89 | 0.43 |

## 3 RELAY COORDINATION

Stage 51:

It involves the inverse time characteristic stage, required for coordination of relays.

• Pickup

• Time Dial

Stage 50 allows us with:

o Instantaneous operation of relay

o Definite time operation of relay (delay)

• Pickup

• Delay

### 3.1 Stage 51 Setting

1) Curve type: IEC Normal Inverse

2) Pickup setting(Amp): For all relays, pickup for 51 = rated

current through the relay

3) Decide required time of operation for every relay:

First of all, we consider the PSM & TMS settings of GETCO Relay, provided by GETCO. We insert 3phase fault at load side & write its stage 51 tripping time. (We got 700ms).

Now taking this point as reference , we decide the tripping times for the remainder keeping 150ms difference as follows:

- R33 should trip at 140 ms (bus coupler).
- R6&R17 both should trip at 240ms(capacitor bank feeder)
- R7 & R16 both should trip at 360 ms (as there is no other feeder or bus connected between them).
- R8 & R15 both should trip at 240 ms.

4) Time Dial (TSM):

Insert a 3 phase fault between MDB3 & CB69 and note down reflected currents through all the relays for 51 stage calculation:

R7 Setting (360ms) ( CT Ratio-100/1):

Pickup: RelayPickup=120% of t/f FLA*FLA/CT ratio

= (1.2*26.27)/(100/1)

- Reflected current at R7 due to 3 phase fault on load side(2 t/f in service) = 12.326 kA
- Reflected current at R7 due to 3 phase fault on load side(1 t/f in service)=6.741kA
- With TMS=1,

$operating\ time$= 0.14/($16.69^{0.02}$-1 )

= 2.41 sec

- For$T$ime of operation = 0.4s ;

TMS=0.4/2.41=0.165

Similarly we calculated pickup & TMS for rest of the relays as Shown below:

| STAGE 51 | | | |
|---|---|---|---|
| Relay | Pickup | TMS | Expected |
| R6 | 1 | 0.1 | 240 |
| R7 | 0.32 | 0.145 | 360 |
| R8 | 1 | 0.1 | 240 |
| R15 | 1 | 0.1 | 240 |
| R16 | 0.32 | 0.145 | 360 |
| R17 | 1 | 0.1 | 240 |
| R33 | 0.9 | 0.14 | 557 |

**3.2 Stage 50 Setting (Instantaneous or definite time)**

**1) Pickup setting(Amp):**

- For all outgoing feeder relays, we insert a 3 phase fault on LT side of transformer & note down reflected fault current on HT side through the relay.

Pickup= 1.3 ∗ reflected primary fault current on HT side of transformer/ CT ratio

- For all incomer relays,

$$PICKUP = \frac{1.3 * PRIMARY\ PICKUP\ OF\ IMMEDIATE\ DOWN\ RELAY}{\text{CT RATIO}}$$

The factor of 1.3 is multiplied so as to avoid pickup of the re-lay for fault on LT side of transformer i.e. for a fault out of its voltage level reach.

- For all incomer relays,

$$PICKUP = \frac{1.3 * PRIMARY\ PICKUP\ OF\ IMMEDIATE\ DOWN\ RELAY}{\text{CT RATIO}}$$

The factor of 1.3 is multiplied so that the settings must be high enough to avoid relay operation with the maximum probable load, a suitable margin being allowed for large motor starting currents or transformer inrush transients.

**2) Delay setting (sec):**

- For all feeder relays,

Delay= 0 sec (instantaneous) or (0.04 to 0.06 s)

- For all incomer relays,

Delay=0.2 sec (to allow feeder relay to trip first)

Going from load side to upstream and applying above two points,

- For **R7 & R16** (load side relays) , time delay 0 ms , as we want the relays to trip in 360ms or less anyways for a fault at loadside.

**R8&R15(outgoing feeder relay) (CT Ratio-400:1):**

Pickup:

- Reflected fault current on HT side of transformer=1.92 kA
- Primary Pickup = 1.3 * 1.92 = 2.496 kA
- Pickup= 2496/400 =**6.24 A**

Delay: 0 sec (instantaneous)

R1(incomer relay) (CT Ratio-100:1):

Pickup:

- Primary pickup of immediate down relay = 1.92 kA

- Pickup = 1.3 * 2496 / 100 = 32.4 A

Delay: 0.2 sec

| STAGE 51 | | |
|---|---|---|
| Relay | Pickup | Delay(s) |
| R7 | 7 | 0 |
| R16 | 7 | 0 |
| R1 | 32.4 | 0.2 |

**3.4 Comparision of stage 51**

| **Relay** | **Expected time obtained by handcalculation** | **Time obtainedin etap(ms)** |
|---|---|---|
| **R6** | **240** | **232** |
| **R7** | **360** | **353** |
| **R8** | **241** | **234** |

| | | |
|---|---|---|
| **R15** | **241** | **234** |
| **R16** | **360** | **353** |
| **R17** | **240** | **232** |
| **R33** | **557** | **550** |

### 3.5 Methodology for Earth Fault Setting

The pickup and time settings for both 51 and 50 stage for earth fault, can be calculated in a similar way as we calculated for over current relay, except the following differences :-

• Pickup: The overcurrent relay pickup are set at rated current while the overcurrent earth fault relay pickup is set at 0.2 times of rated current in IDMT stage (51 ) , while

pickup=0.4*rated current in high set stage (50).

• Transformer connection : The 51 stage time setting of earth fault relay is increased upstream in the same way as 51 stage setting of overcurrent. But if the transformer is deltastar (neutral grounded) connected, the fault at star side does not reflect any unbalance in line current of delta side . So 0 instead of continuing the increase in time moving upstream (along the line) , we start again from instantaneous tripping from delta side. And go on increasing the time upstream till next such delta star transformer is encountered ( that is when unbalance in line currents due to fault current is not reflected on the other side).

Project: ETAP 12.6.0H Page: 11
Location: Date: 22-03-2020
Contract: SN:
Engineer: Study Case: SC Revision: Base
Filename: OMAN RITAJ Config.: Normal

Momentary Duty Summary Report

3-Phase Fault Currents: (Prefault Voltage = 100 % of the Bus Nominal Voltage)

| Bus | | Device | | Momentary Duty | | | | | Device Capability | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ID | kV | ID | Type | Symm. kA rms | X/R Ratio | M.F. | Asymm. kA rms | Asymm. kA Peak | Symm. kA rms | Asymm. kA rms | Asymm. kA Peak |
| Bus6 | 11.000 | Bus6 | Bus | 10.657 | 14.6 | 1.517 | 16.162 | 27.222 | | | |
| Bus8 | 11.000 | Bus8 | Switchgear | 10.657 | 14.6 | 1.517 | 16.162 | 27.222 | | | |
| Bus12 | 0.433 | Bus12 | Bus | 14.607 | 1.6 | 1.019 | 14.880 | 23.494 | | | |

## 4 CONCLUSION

Thus, during this report, we've presented methodology of hand calculation and results of short analysis and relay coordination of a neighborhood of 33kV electrical system of 1149.441 MVAsc capacity industrial plant.

The short analysis methodology presented here is that the method used generally in industries with regard to ect 158 of Schneider Electric. The relay coordination methodology used in this report, is based on industrial guides (Alstom protection guide) and IEEE papers. Simulation results are obtained using Electrical Transient Analyzer Program (ETAP).

The overcurrent relays (phase and earth fault) are the main protection devices during a distribution system. The overcurrent relay coordination in radial network is very constrained optimization problem. The relays within the power grid are to be coordinated properly so on provide primary also as copy protection, and at an equivalent time avoid mal function and hence avoid the unnecessary outage of healthy part of system.

In this paper, hand calculation of relay settings is presented. But, if the network is very large and complicated and the calculations need to be performed again and again to get best coordination, then it becomes very tedious so using software like ETAP is useful to scale back the probabilities of malfunction and increase the speed. Thus ETAP software provides efficient tool to solve the coordination problem of overcurrent relays in radial system. Thus it can be concluded that the results obtained by both the methods i.e. hand calculation and simulation are almost same., in this report, we have presented methodology of hand calculation and results of short circuit analysis and relay coordination of a part of 33kV electrical system of 1149.441 MVAsc capacity industrial plant.

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The overcurrent relays (phase and earth fault) are the major protection devices in a distribution system. The overcurrent relay coordination in radial network is highly constrained optimization problem. The relays in the power system are to be coordinated properly so as to provide primary as well as back up protection, and at the same time avoid mal function and hence avoid the unnecessary outage of healthy part of system.

In this paper, hand calculation of relay settings is presented. But, if the network is very large and complicated and the calculations need to be performed again and again to get best coordination, then it becomes very tedious so using software like ETAP is helpful to reduce the chances of malfunction and increase the speed. Thus ETAP software provides efficient tool to solve the coordination problem of overcurrent relays in radial system. Thus it can be concluded that the results obtained by both the methods i.e. hand calculation and simulation are almost same.

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