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Protection of Distribution Network

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ABSTRACT:
In a typical electrical network, it is important to design a system complete with protection to prevent any abnormalities or fault occurrence to disturb the whole source of electrical to be shut down. Only a portion of effected part must be closed and fault duration at high current value should be carefully monitored. Overcurrent protection device discrimination play vital roles to ensure protective relay will react accordingly. In this paper introduces in practice some of protection concepts; it is based on real live problem which involves setting protection relays. The paper presents for the real problem carefully to identify the most important issues and then work suitable settings. The proposed algorithm has been tested to an 33/11kV Distribution Network. Some bus data have been tested and the tests result of the network was studied, analyzed and discussed. The algorithm has proven successfully fulfilled the discrimination requirement.
KEYWORDS: *Inverse definite minimum time, overcurrent relay, discrimination time interval, setting current and time multiplier setting.*

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I. INTRODUCTION:

The paper is to implement some of the protection concepts. It is based on real life problem, which involves specifying protection relays. Partial revision of protection is quite common in practice, as a network circuit and substations are transferred to or from one supply point to another because of system modifications. The paper identify the most important issues and suitable settings
The circuits for which settings are required are shown in diagram below.

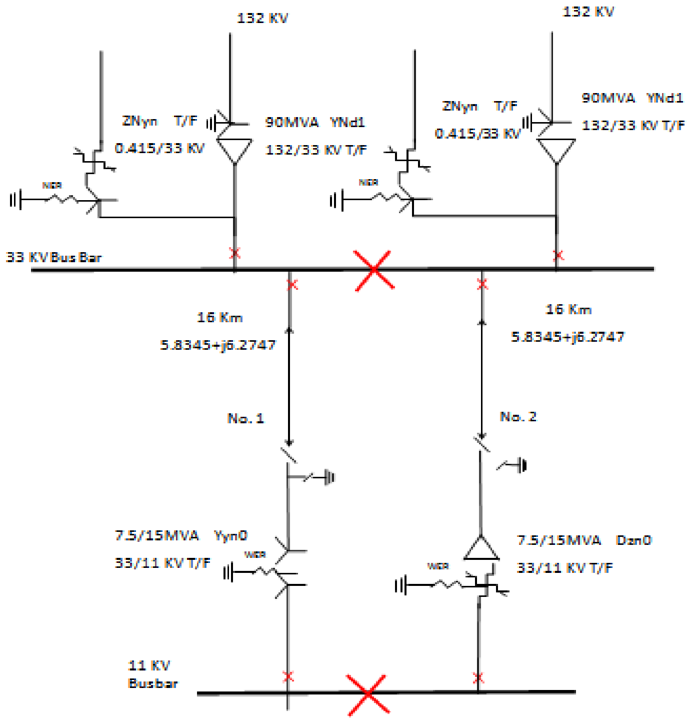


Fig.1.1 The power system diagram

An appreciation of how the main protection works is essential if setting up IMDT schemes as back up protection. In many ways setting IMDT relays so that they discriminate correctly is far more difficult than setting up a unit protection scheme. The reason of this is that under fault conditions the flow of fault current may:

- Be shared over two or more paths.
- Change paths during the fault, because of sequential breaker tripping.
- Alter in magnitude and direction of flow, because of pre-existing outages on parts of the power system.

On top of this several IDMT relays monitoring the actual fault flow path(s) will start to respond to the fault current, and the researcher job to see that they are set up to respond correctly; also, part of the research job is to determining a responsible compromise response. Hence it is essential to formally record the assumptions, system operating configuration, and design compromises made whilst calculating the setting.

Study Case

Work calculation of the IDMT overcurrent it's an Inverse definite minimum time overcurrent relay (IDMT) is type of over current relay which operates in inverse time fashion with the current in the protected system. Basically with increase in peak value of current there is an increase in time of operation and earth fault settings. Data for estimating fault levels is Setting to be the 132 kV fault level 3500MV, Impedance of each 132kV 90MVA transformer =0.25pu on 100MVA, Impedance of each 33/11kV transformer at,"E" =1%Z per MVA rating so, yielding 7.5%Z on 7.5MVA or 15%Z on 15MVA.

With the exception of the 33kV high-set overcurrent relay(I>>) the relay settings should be set setting of 50% to 200% of nominal by 25% increments for overcurrent relays and 20% to 80% by 10% increments for earth fault relays. The time multiplier (TM) wheel which can be set between 0.1 and 1.0 by 0.025 increments, to set some of relays a design fault level of 1000MVA at the 33kV busbar will be more appropriate than the actual fault level.

1.1

$$S_{base} = 100MVA$$

$$Z_{base} = \frac{V_{base}{}^2}{VA_{base}} = \frac{(33 \times 10^3)^2}{100 \times 10^6} = 10.89\ \Omega$$

$$X_{T1} = X_{T2} = X_{p.u.} \times \frac{NewVA_{base}}{OldVA_{base}} = 0.075 \times \frac{100MVA}{7.5MVA} = j1\ \ p.u.$$

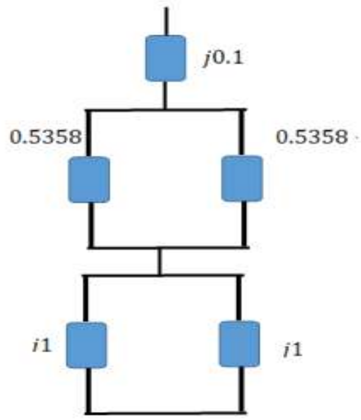
$$X_{T(parallel)} = \frac{1}{2} = j0.5$$

$$Z_{T.L.(p.u.)} = \frac{Z_{T.L.}}{Z_{base}} = \frac{5.8345 + j6.2747}{10.89} = 0.5358 + j0.5762\ \ p.u.$$

$$Z_{T.L.(parallel)} = \frac{0.5358 + j0.5762}{2} = 0.268 + j0.288$$

$$X_{33\ busbar} = X_{p.u.} \times \frac{NewVA_{base}}{OldVA_{base}} = 1 \times \frac{100MVA}{1000MVA} = j0.1\ \ p.u.$$

$$Z_{(Total)} = j0.5 + (0.268 + j0.288) + \ j0.1 = 0.268 + j0.888\ \ \ p.u.$$



Therefore,

$$the\ fault\ level = \frac{VA_{base}}{Net\ impedance} = \frac{100MVA}{0.268 + j0.888} = 107.81\ MVA$$

$$the\ fault\ current = \frac{the\ fault\ level}{\sqrt{3}V_{base}} = \frac{107.81MVA}{\sqrt{3} \times 11KV} = 5658.56\ \ A \qquad at\ the\ 11KV\ busbar$$

In section 1.1 shows that the 11KV circuits have a 400A rating, with switching rating (for few minutes) of 440A. Therefore, the correct reset properly when the PSM ≤ 0.9.

So:

440A ≤ 0.9 PSM.

Hence: 1 PSM ≥ (440/0.9) ≅ 488.9 A

So the relay setting current ≥ 488.9 to insure a safe margin for the cable feeder switching rating.

Now we can get the relay setting current from this formula, that we assume 125% a plug setting value.

$$relay\ setting\ current = \frac{400}{1} \times \left(1 \times \left[\frac{125}{100}\right]\right) = 500 \quad A$$

We can get MTS now from:

$$t_{op} = \frac{[0.14 \times TMS]}{[PSM^{0.02} - 1]}$$

$$\therefore MTS = \left(\frac{t_{op}}{0.14}\right) \times (PSM^{0.02} - 1) = \left(\frac{0.9}{0.14}\right) \times \left(\left(\frac{5658.56}{500}\right)^{0.02} - 1\right) = 0.31965 \quad A$$

Hence set $\boldsymbol{TMS} = 0.325$

The 132/33 90 MVA transformers have an impedance 0.25 p.u. on 100MVA and the source fault level is 3500MVA.

$$X_{source} = \frac{NewVA_{base}}{OldVA_{base}} = \frac{100MVA}{3500MVA} = j0.02857 \ \ p.u.$$

$$X_{33\ busbar} = \frac{0.25}{2} = j0.125 \ \ p.u.$$

The actual level fault and fault current is:

$$the\ fault\ level = \frac{VA_{base}}{Net\ impedance} = \frac{100MVA}{(j0.125 + j0.02857 + (0.268 + j0.288) + j0.5)}$$
$$= 102.15MVA$$

$$the\ fault\ current = \frac{the\ fault\ level}{\sqrt{3}V_{base}} = \frac{102.15MVA}{\sqrt{3} \times 11KV} = 5361.48 \ \ A \qquad at\ the\ 11KV\ busbar$$

Then the minimum time operation required is:

$$t_{op} = \frac{[0.14 \times TMS]}{[PSM^{0.02} - 1]} = \frac{[0.14 \times 0.325]}{\left[\left(\frac{5361.48}{500}\right)^{0.02} - 1\right]} = 0.9364 \quad second$$

1.2 Earth fault setting 16KV feeder IDMT relay settings:

From section 1.1, the short current phase to earth for 16KM $\leq 3 \times 1.8196 = 5.94588 \ A$ and for 24KM the short current phase to earth is $\leq 3 \times 2.7294 = 8.1882 \ A$, which is the virtual earth fault current for a fault on another feeder is: $400 \times (20\%) = 80 \ \ A > 8.1882A$.

$$TM \geq \left(\frac{t_{op.}}{0.14}\right) \times (PSM^{0.02} - 1) = \left(\frac{0.9}{0.14}\right) \times \left(\left(\frac{2000}{0.2 \times 400}\right)^{0.02} - 1\right) = 0.4275 \ \ second$$

Which is not acceptable, if a very low earth fault plug setting is chosen, the response is less sensitive than a little higher earth fault plug and the CTS would need to increase the voltage required to operate. So we will choose a minimum IDMT E/F relay setting of 30% of the current it may be correct (120).

$$TM \geq \left(\frac{t_{op.}}{0.14}\right) \times (PSM^{0.02} - 1) = \left(\frac{0.9}{0.14}\right) \times \left(\left(\frac{2000}{120}\right)^{0.02} - 1\right) = 0.372 \ \ second$$

∴ TM can be set as: 0.375 Seconds.

The time operation is:

$$t_{op} = \frac{[0.14 \times TMS]}{[PSM^{0.02} - 1]} = \frac{[0.14 \times 0.375]}{\left[\left(\frac{2000}{120}\right)^{0.02} - 1\right]} = 0.907 \quad second$$

1.3 Earth fault setting: 33 KV /11kv transformer 11KV standby earth fault relay at substation E:

The transformer standby earth fault relay setting of 30% of 600A required equal (180A).

So that:

$$t_{op} = \frac{[0.14 \times TMS]}{[PSM^{0.02} - 1]} = \frac{[0.14 \times 0.375]}{\left[\left(\frac{1000}{120}\right)^{0.02} - 1\right]} = 1.2119 \qquad Seconds$$

This maximum time for operating for the feeder IDMT E/F relay, and the time operating for standby earth fault relay (adding with timing margin between relays) should be: $= 1.212 + 0.4 = 1.612 \quad seconds$

$$t_{op} = \frac{[0.14 \times TMS]}{[PSM^{0.02} - 1]} = \frac{[0.14 \times 0.375]}{\left[\left(\frac{2000}{120}\right)^{0.02} - 1\right]} = 0.907 \quad second$$

That: $TM \geq \left(\frac{t_{op.}}{0.14}\right) \times (PSM^{0.02} - 1) = \left(\frac{1.612}{0.14}\right) \times \left(\left(\frac{1000}{180}\right)^{0.02} - 1\right) = 0.4017 \ second$

This will set as: (TM=0.425 Second).

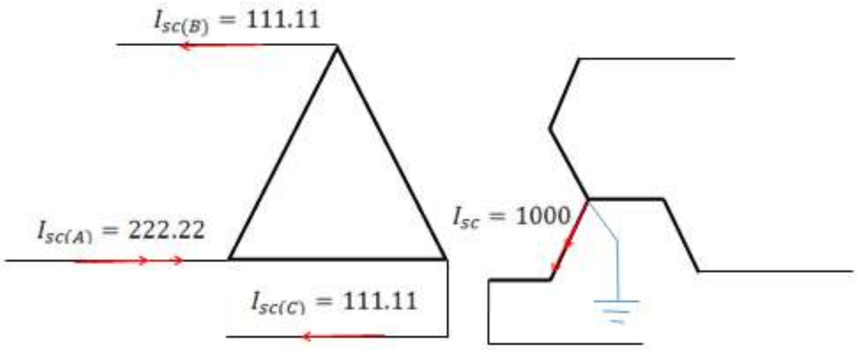
$$\therefore t_{op} = \frac{[0.14 \times TMS]}{[PSM^{0.02} - 1]} = \frac{[0.14 \times 0.425]}{\left[\left(\frac{1000}{180}\right)^{0.02} - 1\right]} = 1.705 \quad seconds$$

The referred current of short circuits (φ-E) is (1000A) to operate relays further back in the supply system, and it is important to find the corresponding the short current (φ-E) for each transformers HV winding. In the case of transformer, The fault current phase to earth Dzn0 (7.5/15 MVA & 33/11 KV) is:

$$I_f = \frac{2}{3N} \times I_{sc.(\emptyset - E)}$$

$$I_f = \frac{2}{3 \times \frac{33000}{11000}} \times 1000 = 222.222 \ A \ldots\ldots\ldots\ldots\ldots\ldots 33KV \ side$$

$$I_B = \frac{222.222}{2} = 111.111 \ A = I_C$$

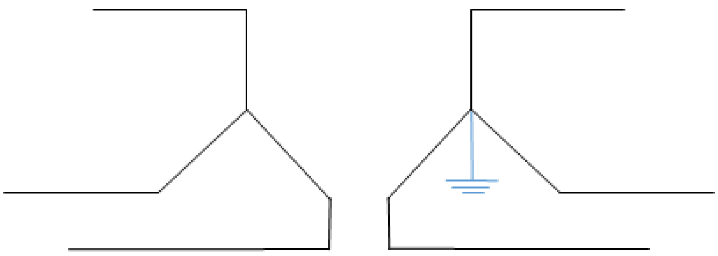


The fault current in case of transformer phase to earth Yyn0 (7.5/15 MVA & 33/11 KV) is:

$$I_f = \frac{2}{3N} \times I_{sc.(\emptyset - E)}$$

$$I_f = \frac{2}{3 \times \frac{33000}{11000}} \times 1000 = 222.222 \ A = I_B \ldots\ldots\ldots\ldots\ldots\ldots 33KV \ side$$

$$I_A = \frac{222.222}{2} = 111.111 \ A = I_C$$



It's clear that the relays further back in the supply system will not operate due to these referred currents because their value is small enough to be ignored by the HV side relays.

1.4 Transformer 33KV 2-stage IDMT overcurrent and earth fault:

The phase to phase fault current is:

$I_{sc(\phi-\phi)} = -j\sqrt{3}I_1$ …….. (1) $\qquad$ $I_1 = \frac{E}{Z_1+Z_2}$……….. (2)

$$I_{sc(\phi-\phi)p.u.} = -j\frac{\sqrt{3}}{(0.268+j1.1987)+(0.268+j1.1987)} = 0.7051\measuredangle - j167.39\ p.u.$$

$$I_{base} = \frac{MVA_{base}}{\sqrt{3}\times V_{base}} = \frac{100\times10^6}{\sqrt{3}\times 11\times 10^3} = 5248.6388\ A$$

$$I_{sc(\phi-\phi)actuale} = 5248.6388\times 0.7051\measuredangle - 167.39 = 3700.815\measuredangle - 167.39\ A$$

Now we have to calculate the three phase fault ($I_{sc(3\phi)}$) at 11KV:

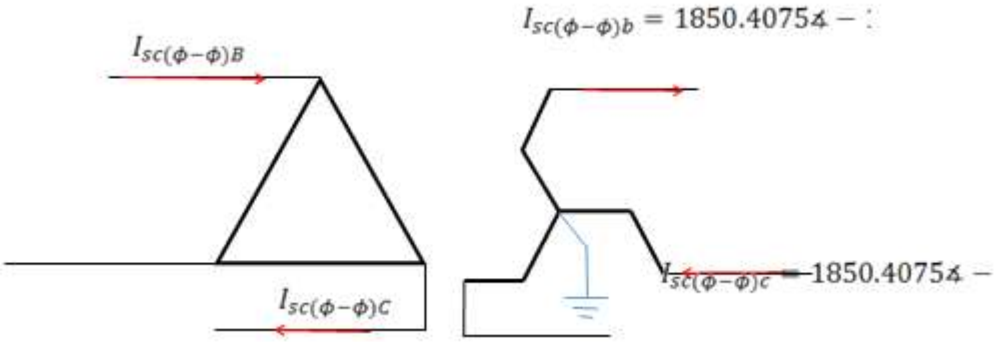
$$Fault\ level = \frac{100\ MVA}{Net\ Imp.} = \frac{100\times10^6}{0.268+j1.1987} = 81.41\ \ MVA$$

$$I_{sc(3\phi)} = \frac{81.41\times10^6}{\sqrt{3}\times 11\times10^3} = 4272.91\ \ A$$

The referred current ($I_{sc(\phi-\phi)}$) at transformer 33/11KV Dzn0 is:

$$I_{sc(\phi-\phi)} = \frac{3700.815\measuredangle - 167.39}{2} = 1850.4075\measuredangle - 167.39\ \ A$$

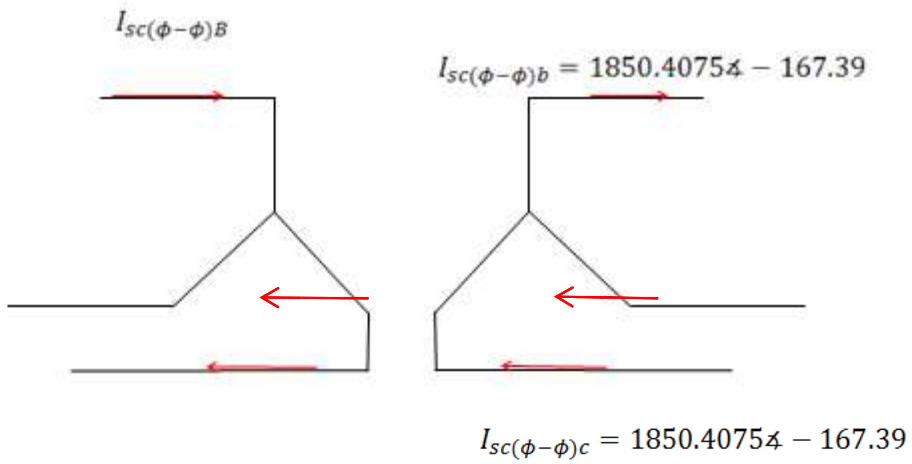
$$I_{sc(\phi-\phi)C} = \frac{18504.075\measuredangle - 167.39}{5} = 370.0815\measuredangle - 167.39\ \ A = I_{sc(\phi-\phi)B}$$



The referred current ($I_{sc(\phi-\phi)}$) at transformer 33/11KV Yyn0 is:

$$I_{sc(\phi-\phi)} = \frac{3700.815\measuredangle - 167.39}{2} = 1850.4075\measuredangle - 167.39\ \ A$$

$$I_{sc(\phi-\phi)C} = \frac{1850.4075\measuredangle - 167.39}{5} = 370.0815\measuredangle - 167.39\ \ A = I_{sc(\phi-\phi)B}$$



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The referred current ($I_{sc(3\phi)}$) at transformer 33/11KV Yyn0 and Dzn0 is:

$$I_{sc(\phi-\phi)} = \frac{4272.91}{2} = 2136.455\ A$$

$$I_{sc(\phi-\phi)T1,T2} = \frac{4272.91}{5} = 854.582\ A$$

The calculation shows that the ($I_{sc(3\phi)}$) and ($I_{sc(\phi-\phi)}$) are not equal, which is the ($I_{sc(3\phi)}$) for transformer tow stage overcurrent grading. Furthermore, this the best time running of the relays and the operating time reducing on either side of the transformer. Also, its need to calculate the (MVA_{input}) because the value of the input current may it could be higher than the (MVA_{output}) expected to reactive and resistive losses.

From the (2.3) given, we assume that $V_{receive} = 1.0\ p.u.$ at the transformer`s 33KV terminals.

MW	MVAR	MVA	P.F.	comment
14.25	4.68374	15	0.95	Assume PF=0.95,on 11KV
	2.25			transformer I^2X loss for 15%X on 15MVA $(= I^2 \times 0.15 \times 15)$
14.25	6.93374	15.8473	0.899	On 33KV

The voltage drop on 33KV will be, and we use the MVA base 100MVA per unit:

$$S_{received} = \frac{14.25 \times 10^6 - j6.93374 \times 10^6}{100 \times 10^6} = 0.1425 - j0.0693374\ p.u.$$

And the impedance bass calculated by:

$$Z_{bass} = \frac{(33 \times 10^3)^2}{100 \times 10^6} = 10.89\ \Omega$$

$$Z_{TL.pu} = \frac{5.8345 + j6.2747}{10.89} = 0.53577 + j0.5762\ \ p.u.$$

Right now, we can calculate ($V_{sending}$) by this formula:

$$V_{seding} = V_{receiving} + (Z_{TL} \times I)$$

Which,

$$I = \frac{\bar{S}_{receiving}}{\bar{V}_{receiving}}$$

Therefore,

$$V_{sending} = V_{receiving} + (Z_{TL} \times I) = 1 + \left[(0.53577 + j0.5762) \times \left(\frac{0.1425 - j0.0693374}{1}\right)\right]$$

$$= 1.0432\measuredangle 6.564\ \ p.u.$$

$$V_{receiving} = \frac{1}{1.0432} = 0.9586\ p.u.$$

$$\therefore V_{rec.(actual)} = 0.9586\ \times 33 \times 10^3 = 31633.436\ volt$$

The maximum load calculate by on 33KV circuit:

$$I_{max} = \frac{S_{rec.}}{\sqrt{3} \times V_{rec.}} = \frac{15.8473 \times 10^6}{\sqrt{3} \times 31633.436} = 289.233\ A$$

Of note, this load current essentially matches 311A line rating.

To reset of the 33KV two stage IDMT overcurrent relay:

$300 \leq 0.9PSM$

$333.33 \leq PSM$ The relay setting current.

Then the 125% setting has been chosen (375 A relay setting > 333.33 A), that was known from section 1.1, the relay current setting should be set to 50% to 200% by 25% increments for O/C relays.

$$\therefore Fault\ Level = \frac{100 \times 10^6}{[\left(j\frac{100}{1000}\right) + (0.5358 + j0.5762\ ) + j1]} = 56.826\ MVA$$

$$I_f = I_{sc} = \frac{56.826 \times 10^6}{\sqrt{3} \times 33 \times 10^3} = 994.1971\ A\ at\ 33KV$$

$I_f = I_{sc} = \frac{56.826\times10^6}{\sqrt{3}\times33\times10^3} = 994.1971\ A\ at\ 33KV$ (S.C. current for three phase)
And,

$$I_{s.c.(\emptyset-\emptyset} = \frac{\sqrt{3}}{2} I_{s.c.(3\emptyset)} \times N = \frac{\sqrt{3}}{2} \times 994.1971 \times 3 = 2582.99 \cong 2583\ A$$

The IDMT overcurrent relay operating time (top) is:

$$t_{op} = \frac{0.14 \times 0.375}{\left(\left(\frac{2583}{500}\right)^{0.02} - 1\right)} = 1.36279\ \ second$$

$$\therefore t_{op} \geq (1.36279 + 0.4) = 1.763\ second$$

$$TM \geq \left(\frac{t_{op}}{0.14}\right) \times (PSM^{0.02} - 1) = \left(\frac{1.763}{0.14}\right) \times \left(\left(\frac{994.1971}{375}\right)^{0.02} - 1\right) = 0.2366$$

That, time multiplier will set as: TM=0.25, and now we calculate the time operation by:

$$t_{op} = \left(\frac{0.14 \times 0.25}{\left(\frac{994.1971}{300}\right)^{0.02} - 1}\right) = 0.248\ second$$

This will set as: **(TM=0.25 Second)** for the 33KV 2-stage IDMT overcurrent relay

1.5 sitting IDMT 33KV feeder overcurrent protection:

As shown on table, absolutely needed to obtain the load that can be found on the 33KV feeder to set the protection:

MW	MVAR	MVA	P.F.	comment
14.25	4.68374	15	0.95	Assume PF=0.95,on 11KV
	2.25			transformer I^2X loss for 15%X on 15MVA $(= I^2 \times 0.15 \times 15)$
14.25	6.93374	15.8473	0.899	On 33KV

Now we calculate the load current on 33KV:

$$I_{load} = \frac{15.8473 \times 10^6}{\sqrt{3} \times 33 \times 10^3} = 277.2558\ \ A$$

To reset of the 33KV two stage IDMT overcurrent relay:

$277.2558 \leq 0.9PSM$

$308.062 \leq PSM$ (The relay setting current).

That we chose 75% setting (450 relay setting current), because the 33KV feeder protection CTs are 600/1A and the relay current setting must be set to 50% to 200% by 25% increments for O/C relays.
To use 100MVA per unit base (the 33KV design fault level of 1000MVA), we have calculate:

$$Fault\ Level = \frac{100 \times 10^6}{[\left(j\frac{100}{1000}\right) + (0.5358 + j0.5762\ ) + j1]} = 56.826\ \ MVA$$

$I_f = I_{sc} = \frac{56.826\times10^6}{\sqrt{3}\times33\times10^3} = 994.1971\ A\ at\ 33KV$ (S.C. current for three phase)
And,

$$I_{s.c.(\emptyset-\emptyset} = \frac{\sqrt{3}}{2} I_{s.c.(3\emptyset)} \times N = \frac{\sqrt{3}}{2} \times 994.1971 \times 3 = 2582.99 \cong 2583\ A$$

In this, the time operation for the 33KV 2-stage IDMT overcurrent relay associated with the 33/11KV transformer is:

$$t_{op} = \left(\frac{0.14 \times 0.325}{\left(\frac{2583}{500}\right)^{0.02} - 1}\right) = 1.36279\ \ second$$

Thus, $t_{op} \geq (1.363 + 0.4) = 1.763$.
And the TM calculated by:

$$TM \geq \left(\frac{t_{op}}{0.14}\right) \times (PSM^{0.02} - 1) = \left(\frac{1.763}{0.14}\right) \times \left(\left(\frac{994.1971}{375}\right)^{0.02} - 1\right) = 0.2366$$

That, time multiplier will set as: TM=0.25, and now we calculate the time operation by:

$$t_{op} = \left(\frac{0.14 \times 0.25}{\left(\frac{994.1971}{300}\right)^{0.02} - 1}\right) = 0.248\ second$$

This will set as: **(TM=0.25 Second)** @ substation "E" for the 33KV 2-stage IDMT overcurrent relay

1.6 The 33KV fault level and the fault current for the normal case of the three phase fault at 33KV is:

$$level\ fault = \frac{100 \times 10^6}{((j0.02857) + (j0.125) + (0.268 + j0.288) + (j0.5))} = 102.148\ MVA$$

$$I_f = \frac{102.148 \times 10^6}{\sqrt{3} \times 33 \times 10^3} = 1787.13\ A$$

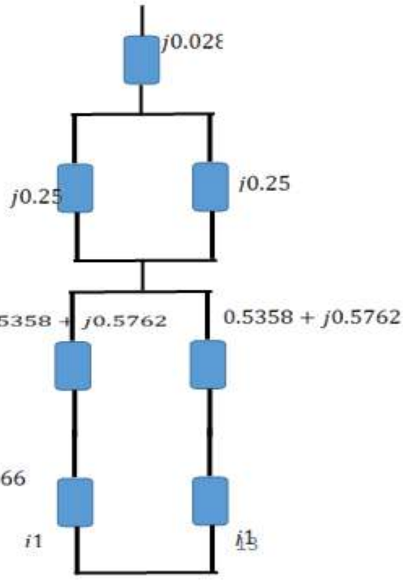
Then, the operation time related to this fault is:

$$t_{op} = \left(\frac{0.14 \times 0.25}{\left(\frac{893.56}{375}\right)^{0.02} - 1}\right) = 1.998\ seconds$$

$\therefore$ The time operation equal: $t_{op} \geq (1.998 + 0.4) = 2.398\ seond$

for the 33KV IDMT feeder protection

$$TM \geq \left(\frac{t_{op}}{0.14}\right) \times (PSM^{0.02} - 1) = \left(\frac{2.398}{0.14}\right) \times \left(\left(\frac{893.56}{450}\right)^{0.02} - 1\right) = 0.2366$$



This will set as: **(TM=0.25 Second)**

Otherwise, the three phase fault level close to 132/33 KV substation calculated by:

$$fault\ level = \frac{100 \times 10^6}{j0.125 + j0.02857} = 717.875\ MVA$$

And,

$I_f = \frac{717.875 \times 10^6}{\sqrt{3} \times 33 \times 10^3} = 12559.55\ A$ At busbars 33K

Then, the operation time related to this fault is:

$$t_{op} = \left(\frac{0.14 \times 0.25}{\left(\frac{12559.55}{450}\right)^{0.02} - 1}\right) = 0.508 \cong 0.51\ seconds$$

The adiabatic withstand for 12559.55 Amp. is 0.5, that 8900A for one second, so:

$$\left(\frac{(8900)^2}{(12559.55)^2}\right) = 0.5\ second$$

On the other hand, to clean this fault of three phase fault current at transformer 33KV side. We calculate the level fault:

$$level\ fault = \frac{100 \times 10^6}{((j0.02857) + (j0.125) + (0.268 + j0.288) + (j0.5))} = 102.148\ MVA$$

$$I_f = \frac{102.148 \times 10^6}{\sqrt{3} \times 33 \times 10^3} = 1787.13\ A$$

$$\left(\frac{HSO}{C} \equiv I \gg\right) = 3.5 \times 600 = 2100\ A$$

311A ≤ 0.9 PSM=345.55 A (the 311 A is the maximum rating of the overhead line circuit).
Then, we Can set ($I \gg$) from 0.4 – 2.4× $In\ with\ 0.01\ increments$. So, ($I \gg$) will be: 360 A and will set as: **(TM=0.25 Second)**.

The operating time (t_{op}) is:

$$t_{op} = \left(\frac{0.14 \times 0.25}{\left(\frac{2100}{360}\right)^{0.02} - 1} \right) = 0.9489 \cong 0.97 seconds$$

In the same time, adiabatic limit of the overhead line participating by: $\left(\frac{(8900)^2}{(2100)^2}\right) = 17.96\ second.$

That mean is high set overcurrent protection is **fine**, because one fault$(1 \times 0.975) \leq 17.96 second.$

1.7 The 33/11KV transformer directional IDMT O/C protection relay at Substation "E":

a) Calculate the fault close to busbar 33KV:

$$level\, fault = \frac{100 \times 10^6}{(j0.05 + j0.25 + 2(0.5358 + j0.5762) + 2(j1))} = 27.66 \quad MVA$$

$$I_f = \frac{27.66 \times 10^6}{\sqrt{3} \times 11 \times 10^3} = 1451.77 \quad A$$

$$I_{sc\,(\emptyset-\emptyset)} = \frac{\sqrt{3}}{2} \times \frac{I_f}{N} = \frac{\sqrt{3} \times 1451.77}{6} = 419.0899 \quad A$$

In section (1.1) at bullet 6, the 11kV DO/C protection relay is fitted, using 800/1A CTs, on the other hand has setting range of (50% to 200% by 25%) increment. So setting has chosen (75%).

b) Calculate the fault @ busbar 11KV:

$$level\, fault = \frac{100 \times 10^6}{(j0.0286 + j0.125 + 2(0.5358 + j0.5762) + 2(j1))} = 28.774 \quad MVA$$

$I_f = \frac{28.774 \times 10^6}{\sqrt{3 \times 11 \times 10^3}} = 1511.61 \quad A$ At B.B. 11KV

$$t_{op} \geq (0.15 + 0.4) = 0.55 \quad second$$

$$\therefore TM \geq \left(\frac{t_{op}}{0.14}\right) \times (PSM^{0.02} - 1) = \left(\frac{0.55}{0.14}\right) \times \left(\left(\frac{1511.61}{600}\right)^{0.02} - 1\right) = 0.0733$$

Will set as: **(TM=0.1 Second)**.

1.8 Earth fault setting feeder relay for 33KV:

$$t_{op} \geq (0.1 + 0.4) = 0.5 \quad second$$

$$\therefore TM \geq \left(\frac{t_{op}}{0.14}\right) \times (PSM^{0.02} - 1) = \left(\frac{0.5}{0.14}\right) \times \left(\left(\frac{2000}{180}\right)^{0.02} - 1\right) = 0.176$$

Will set as: **(TM=0.2 Second)**.

CIRCUIT NAME: **11KV side, feeder**											
Protection Type	Relay	Serial No.	CT Ratio	Range of Setting			Setting in use				Remarks
				100%	Amp. or volt	Time	CT Ratio	Amp. or Volt	Time	Resistance	
IDMT NER E/F			400/1	1A	50%-200%	0.1 – 1TM	400/1	125%	0.325		IDMT O/C (1.2)
			400/1	1A	20%-80%	0.1 – 1TM	400/1	30%	0.375		IDMT E/F (1.3)

Remarks	Standard Inverse IDMT curves	Calculated by: Adel Ali	Date:
Substation: **Substation "E"**		Voltage: **11KV**	Sheet no.: **1**

CIRCUIT NAME: **11KV side, feeder**											
Protection Type	Relay	Serial No.	CT Ratio	Range of Setting			Setting in use				Remarks
				100%	Amp. or volt	Time	CT Ratio	Amp. or Volt	Time	Resistance	
IDMT NER E/F			600/1	1A	20%-80%	0.1 – 1TM	600/1	30%	0.425		IDMT E/F
DO/C IDMT			800/1	1A	50%-200%	0.1 – 1TM	800/1	75%	1		IDMT O/C
Remarks	Standard Inverse IDMT curves						Calculated by: Adel Ali		Date:		
Substation: **Substation "E"**							Voltage: **11KV**		Sheet no.: **2**		

CIRCUIT NAME: **33KV side, 33/11KV transformer**											
Protection Type	Relay	Serial No.	CT Ratio	Range of Setting			Setting in use				Remarks
				100%	Amp. or volt	Time	CT Ratio	Amp. or Volt	Time	Resistance	
Two Stage IDMT O/C			300/1	1A	50%-200%	0.1 – 1TM	300/1	125%	0. 25		Stage one 11KV
							Stage tow=Stage one + 0.4				Stage two 33KV
Remarks	Standard Inverse IDMT curves						Calculated by: Adel Ali		Date:		
Substation: **Substation "E"**							Voltage: **33KV**		Sheet no.: **3**		

CIRCUIT NAME: **33KV feeder**											
Protection Type	Relay	Serial No.	CT Ratio	Range of Setting			Setting in use				Remarks
				100%	Amp. or volt	Time	CT Ratio	Amp. or Volt	Time	Resistance	
IDMT O/C & E/F			600/1	1A	50%-200%	0.1 – 1TM	600/1	75%	0.25		IDMT O/C
			600/1	1A	20%-80%	0.1 – 1TM	600/1	30%	0.2		IDMT E/F
Remarks	Standard Inverse IDMT curves						Calculated by: Adel Ali		Date:		
Substation: **Substation "E"**							Voltage: **33KV**		Sheet no.: **4**		

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