Sample Project and Settings for DEMA MCR 310

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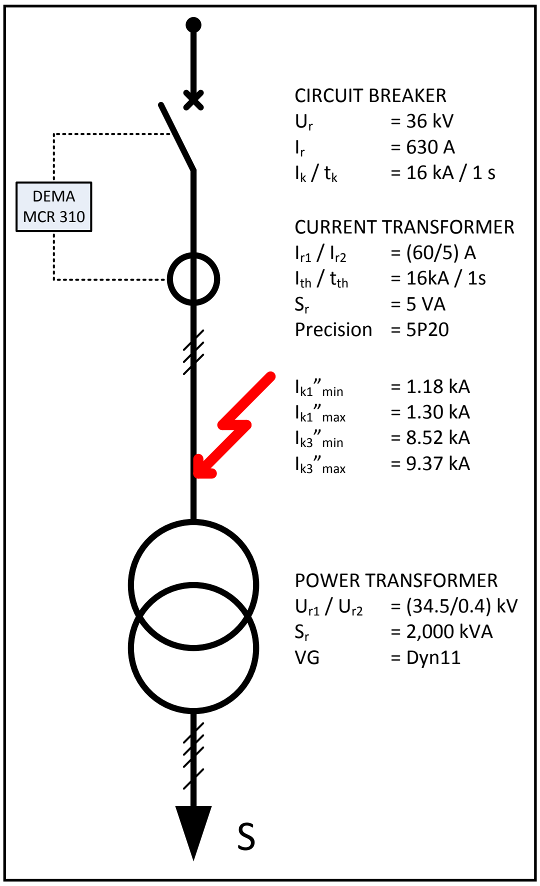


Sample Project & Single Line Diagram

This article is intended to act as a guide for basic calculations of secondary protection practices and setting procedure for DEMA MCR 310 Electronic Overcurrent Protection Relay.

To form a basis for the calculations, a sample project with the single line diagram on the left is created. When evaluating the project, it must be noted that;

- The project and single line diagram is completely fiction,
- The component ratings are given as sample values and may not necessarily represent any component ratings in the market,
- The component selections are not based on engineering fundamentals thus must not be translated as selection suggestions or templates.

The following calculations, estimations and graphics show the fundamentals of providing protection for a power transformer by using DEMA MCR 310 Electronic Overcurrent Protection Relay.

1. **Deciding the phase "I_s": Phase Overcurrent Protection Threshold**

The phase windings of the power transformer must be protected against overloading. In order to set a protection threshold current, we must first calculate the rated current of the protected device.

The rated primary current of the power transformer is calculated as:

$$I_{r1TR} = S_r \div \left(\sqrt{3} \times U_{r1}\right) = 2{,}000\ kVA \div \left(\sqrt{3} \times 34.5\ kV\right) \cong\ 33.47\ A$$

At the secondary circuit, the rated current of the power transformer is seen as:

$$I'_{r1TR} = I_{r1TR} \times CTR^{1} = 33.47\ A \times (5/60) = 2.79A$$

For MCR 310 protection relay, we have the option to set overcurrent protection threshold "I_s" to 2.75 A or 3.00 A, which are the closest possible setting values to I_{r1TR}'.

If we set the I_s value to 3.00 A, the power transformer can be overloaded 7.5% of S_{rTR} without the interruption of the protecting unit; which, we assume, is not allowed by the power transformer manufacturer.

<u>Knowing this, we decide to set the I_s' to 2.75 A for phase protection.</u>

[1] CTR: Current Transformer Ratio; equals to rated secondary current devided by rated primary current of a current transformer.

2. Deciding the phase "xt" and "mode": Phase Overcurrent Protection Tripping Characteristics

Once we decided and set the I_s value, we must characterize the behavior of the protection unit for the case that the phase current exceeds the threshold current I_s, or by other words, decide the trip delay characteristics - which is expressed by the setting zones "xt" and "mode" on MCR 310 units.

The factors that will determine the ideal trip delay characteristics of the protection relay in our project are various:

- the characteristics of the power transformer load (the secondary load),
- the characteristics of the power network protection scheme,
- the characteristics of the power network supply quality, and
- The loading guide provided by the power transformer manufacturer – if available.

Knowing that, two points must be taken into consideration:

- it is (for most of the cases) practically impossible to determine the characteristics of the load and the power network, and
- Power transformer manufacturers do not provide loading guides for their products.

At this point, it is generally the best way to examine and follow the common practices in your local network.

a. We must first decide the trip delay mode among the options: IEC Standard (Normal) Inverse, IEC Very Inverse, IEC Extremely Inverse, IEC Long Time Inverse or definite time delays. The trip delay mode is mostly decided by the power network protection scheme to provide selectivity between protection points. For this project, we will assume that the power network protection scheme is IEC Standard (Normal) Inverse; therefore, the trip delay mode for the power transformer is decided as IEC Standard (Normal) Inverse. Looking at the table below, it can be seen that the mode switches should be set to "111" to obtain IEC SI delay characteristic.

b. For IEC Standard (Normal) Inverse delay characteristics, setting the "xt" tripping delay coefficient between 0.30 and 0.50 usually results in stable operation conditions for power transformer protection. At these values, power transformers are well-protected against overloading, while the protection is flexible enough for preventing unnecessary tripping of the circuit breaker by momentary overloads.

   Taking into account the characteristics of the load and the local practices, we assume and decide that the tripping delay coefficient "xt" should be set to 0.40 to provide optimum trip delay characteristics.

Delay Mode Legend							
IEC SI	**IEC VI**	**IEC EI**	**IEC LTI**	**D1 (1 s)**	**D10 (10 s)**	**D50 (50 s)**	**LED Test**
1	**1**	**1**	**1**	**0**	**0**	**0**	**0**
1	**0**	**1**	**0**	**0**	**1**	**1**	**0**
1	**1**	**0**	**0**	**1**	**0**	**1**	**0**

3. Deciding the phase “I>>”: Phase Instantaneous Tripping Threshold

It’s now time to decide the current threshold for the instantaneous tripping “I>>”, from which point further the circuit will be broken and current will not be allowed to flow, due to extreme conditions (possibly a short-circuit) downstream the circuit.

When deciding the instantaneous tripping threshold (I>>) for phases, the following parameters must be taken into account:

- I>> must never exceed the I_{k1}” phase-to-earth short circuit current[2], which is statistically the most common of all faults and which is usually strong enough to destroy the system components within a short duration.

  Therefore, for our case, I>> should be set below:

  Formula below shows the calculation of the higher limit of I>> in secondary values.

  $$(I \gg)' \leq I''_{k1,min} \times CTR = 1.18\,kA \times (5/60) = 98.3\,A$$

- Most of the loads require high current feed at the pick-up momentarily. I>> setting must be high enough to let the initial / inrush current not be interrupted. Setting I>> value to very low value may result failure to energize the load.

  For our case, the load is a power transformer, which is known to have inrush current as high as 8 times of its rated current. Therefore, I>> should be set above:

  Formula below shows the calculation of the lower limit of I>> in secondary values.

  $$8 \times I_{r1TR} \times CTR = 8 \times 33.47\,A \times (5/60) = 22.32\,A$$

The calculations above show that the setting I>> should be within the range:

I>> setting zone expressed in secondary values

$$22.32\,A < (I \gg) < 98.3\,A$$

For most cases, there are no advantages in setting the I>> far above its minimum permissible limit, therefore we should set the I>> at the nearest setting point above 22.32 A.

The I>> setting on MCR 310 units are done in multipliers of I_s overcurrent threshold. If the multipliers of the I_s is examined, we see that;

$7 \times I_s = 7 \times 2.75\,A = 19.25\,A$ $(Lower\ than\ 22.32\,A, therefore\ not\ suitable)$,
$8 \times I_s = 8 \times 2.75\,A = 22.00\,A$ $(Lower\ than\ 22.32\,A, therefore\ not\ suitable)$,
$9 \times I_s = 9 \times 2.75\,A = 24.75\,A$ $(Higher\ than\ 22.32\,A, so\ suitable)$.

<u>We decide to set the I>> instantaneous tripping threshold to 9 x I_s.</u>

[2] This statement is valid for systems with neutral points solidly earthed, or systems where neutral point is earthed over a relatively low impedence. For other systems, special rules apply.

4. Deciding the earth "I_s": Earth Overcurrent Protection Threshold

Earth overcurrent protection in earthed neutral systems is essential for the following reasons:

- The neutral conductor of the power transformer must be protected against overloading,
- Phase to earth leakages must be sensed and insulated to prevent human and material safety and to prevent unnecessary power loss.

In a 3-wire medium voltage system with its neutral point earthed, no earth current due to load unbalance is expected; so, at the first glance, setting the I_s of the earth overcurrent protection threshold to lowest values possible may make sense. However, setting the I_s to values approximate to zero may result in supply discontinuity and constant tripping because of the following reasons:

- Current transformers on the phases may not transduce the phase current values perfectly, which will result earth current on the secondary circuit,
- Harmonic current in the 3rd order and its multipliers flowing through the current transformers sum up at the secondary circuit and flow through the earthing conductor. Practically, depending on the harmonic components on the lines, earth current will continuously flow on the secondary circuit.

Knowing these, an earth overcurrent protection threshold must be decided that will neglect the mentioned earth current, however, that will never allow the neutral conductor to be overloaded. Let's assume that the normal load characteristic on this project may result in 0.20 of the nominal phase current and the neutral conductor of the circuit can carry 800 A. The threshold should be within the range:

Values below belong to the primary circuit.

$$(0.20\ \times I_{r1TR})\ A\ < (I_s) < 800\ A$$
$$(0.20\ \times 33.47\ A) = 5.02\ A$$
$$6.69\ A\ < (I_s) < 800\ A$$

There is no benefit in setting the I_s far above the minimum permissible value.

Formula below shows the calculation of the permissible secondary earth current.

$$6.69\ A\ \times CTR = 6.69\ A \times (5/60) = 0.56\ A$$

<u>We decide the earth overcurrent protection threshold I_s' = 0.60 A</u>, which is the next bigger value available to set.

5. Deciding the earth "xt" and "mode": Earth Overcurrent Protection Tripping Characteristics

Once we decided and set the I_s value, we must characterize the behavior of the protection unit for the case that the earth current exceeds the threshold current I_s, or by other words, decide the trip delay characteristics - which are expressed by the setting zones "xt" and "mode" on MCR 310 units.

Let's first decide the "mode", or in other words, the characteristic for the tripping delay.

- For earth overcurrent protection, using definite time (DMT) tripping characteristics is common in most applications, because earth overcurrent and faults are usually continuous and needs corrective actions to be taken to be subsided,
- Earth conductors in three-wire systems are not intended to be loaded but to provide security and tracking of insulation of phases. Inverse time delay characteristics are designed to provide maximum continuity for phase loading; therefore, are not suitable for earth protection schemes,
- Additionally, most power network systems have definite time tripping characteristics for earth fault protection at their protection points, so, it is not usually possible to use other protection characteristics for an individual project due to selectivity issues.

Therefore, for most cases, it's the best way to decide a definite time delay for earth overcurrent protection. <u>We decide the earth protection delay mode to be DMT</u> (D1, D10 or D50; which will be decided below).

The "xt" parameter that sets the length of the delay is mostly limited:

- in the highest value by the selectivity scheme that is applied on the upstream protection point,
- And the lowest value by the high pick-up earth current duration drawn by the load, a power transformer in this case.

We assume that the network allows us a highest delay value of 1.00 s, which will not violate the selectivity scheme, and the load pick-up earth current that is above the I_s threshold is drawn from the network for a duration below 300 ms.

Therefore we can set the "xt" parameter within the range:

$$300\ ms\ \leq xt \leq 1\ s$$

High value earth faults will be protected by the instantaneous tripping function "I>>", so setting the "xt" value for earth overcurrent protection with some reserve will be suitable.

<u>We decide "xt" as 0.5 s.</u> Since the decided "xt" value is below 1 s, setting the mode to "D1" is suitable. Looking at the table below, it can be seen that the mode switches should be set to "001" to obtain D1 delay characteristic.

Delay Mode Legend							
IEC SI	**IEC VI**	**IEC EI**	**IEC LTI**	**D1 (1 s)**	**D10 (10 s)**	**D50 (50 s)**	**LED Test**
1	1	1	1	0	0	0	0
1	0	1	0	0	1	1	0
1	1	0	0	1	0	1	0

6. Deciding the earth "I>>": Earth Instantaneous Tripping Threshold

It's now time to decide the current threshold for the instantaneous tripping "I>>", from which point further the circuit will be broken and current will not be allowed to flow, due to extreme conditions (possibly a phase-to-earth short-circuit) downstream the circuit.

When deciding the instantaneous tripping threshold (I>>) for earth, the following parameters must be taken into account:

- Power transformers and some loads like powerful motors draw harmonic current in the 3rd order and its multipliers for a short time during energization, which may rise up to 0.6 times of nominal phase current value. To prevent instantaneous tripping just after the making of the circuit breaker, I>> threshold for earth fault protection must be set above this value.

  So the minimum I>> value for our project should be:

  Values below belong to the primary circuit.

  $$(I \gg) > (0.60 \times 33.47\ A)$$
  $$(I \gg) > 20.08\ A$$

  Formula below shows the calculation of the lower limit of I>> in secondary value.

  $$(I \gg)' > [20.08\ A \times (5/60)]$$
  $$(I \gg)' > 1.68\ A$$

- The I>> threshold for earth fault protection may never exceed the calculated minimum phase-to-earth current, which is 1.18 kA for our project. Converting the value to secondary terms;

  Formula below shows the calculation of the higher limit of I>> in secondary value.

  $$(I \gg)' < [1{,}180\ A \times (5/60)]$$
  $$(I \gg)' < 98.3\ A$$

Taking these concerns into account, the I>> should always be set within the range:

$$1.68\ A < (I \gg)' < 98.3\ A$$

At that point, we must note that phase-to-earth fault current values may go well below the calculated minimum earth fault current ($I_{k1,min}$") when the fault current flows over a relatively high impedance, like a branch of a tree. Therefore, it is most wise to set the I>> value as close as possible to the lower limit.

The I>> setting on MCR 310 units are done in multipliers of I_s overcurrent threshold. If the multipliers of the I_s is examined, we see that;

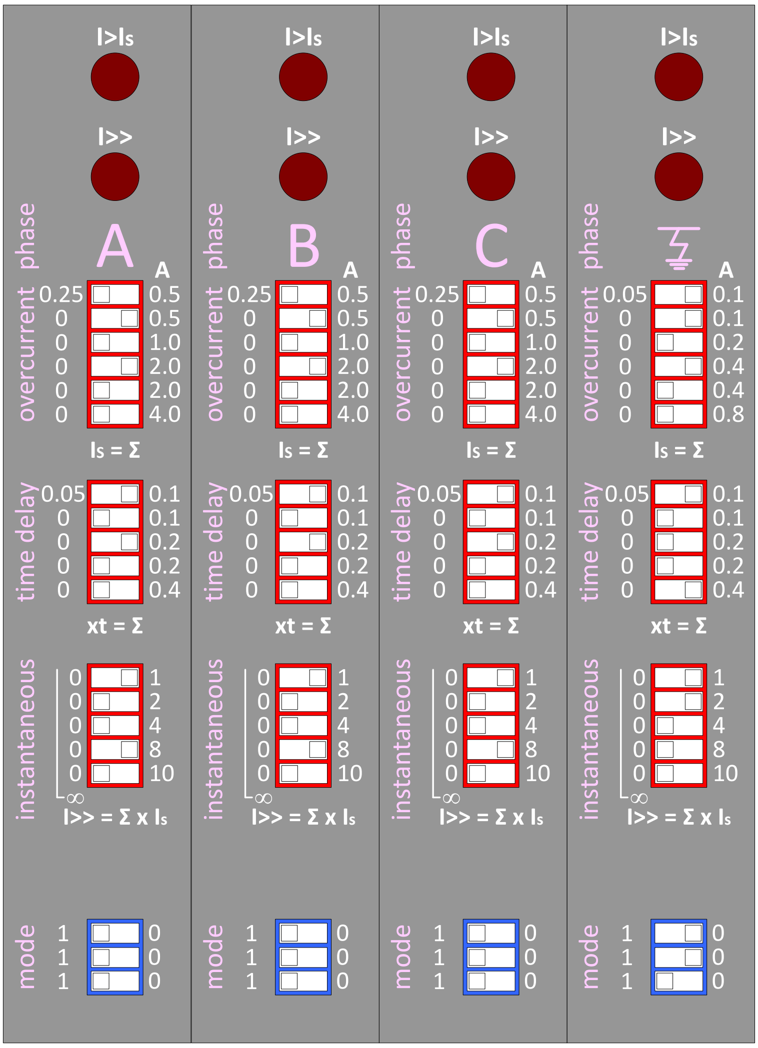
$1 \times I_s = 1 \times 0.60\ A = 0.60\ A\ (Lower\ than\ 1.68\ A, therefore\ not\ suitable)$,
$2 \times I_s = 2 \times 0.60\ A = 1.20\ A\ (Lower\ than\ 1.68\ A, therefore\ not\ suitable)$,
$3 \times I_s = 3 \times 0.60\ A = 1.80\ A\ (Higher\ than\ 1.68\ A, so\ suitable)$.

We decide to set the I>> instantaneous tripping threshold to 3 x I_s.

7. Table of settings and graphics of the set MCR 310 unit

The table below summarizes the settings we decided throughout our evaluations from the beginning of this document. The graphic below the table shows the settings applied on the units. For further information on the usage of the MCR 310 units, please refer to the unit technical guide.

Setting Zone	Phases (Unit A, B and C)	Earth (Unit D)
I_s (Overcurrent Protection Threshold)	2.75 A	0.60A
xt (Trip Delay Coefficient)	0.30	0.5 s
I>> (Instantaneous Tripping Threshold)	9 x I_s	3 x I_s
Mode (Trip Delay Characteristic)	IEC Standard Inverse	Definite Time D1 (Multiplier: 1 s)



A DEMA MCR 310 unit, set to provide optimal protection for the sample project.

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