T60 Percent Differential Calculations

GE Power Management No. GET-8425

INTRODUCTION

Since differential protection is the primary method of transformer protection, correct configuration of the T60 Percent Differential element is very important. The power system, transformer, and CTs all influence the application of the Percent Differential element.

The T60 Percent Differential element has trip/restrain characteristic defined through relay settings by a pickup, two slopes, and two associated breakpoints. The characteristic is shown in the following diagram and defined by the following settings:

- Minimum Pickup (in pu)
- Slope 1 (in %)
- Break 1 (in pu)
- Slope 2 (in %)
- Break 2 (in pu)

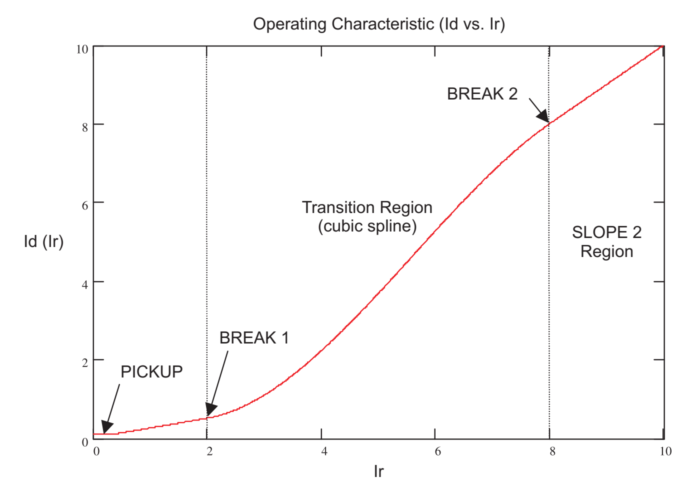

FIGURE 1. Percent Differential Characteristic

It is important for the user to understand the Slope 1 and 2 percentage settings and the Minimum Pickup, Break 1, and Break 2 per-unit values.

UNIT CT VALUE

A T60 Percent Differential element per unit value refers to setting scaled to the identified Unit CT. The Unit CT is the smallest ratio of CT primary rated to nominal winding-currents, for the transformer windings and their respective CTs.

For example, consider a transformer with the following characteristics: Dy30°, 100 MVA, 220 kV / 69 kV, CT 1 (500:1) on the Delta winding, and CT 2 (1000:1) on Wye winding. We have the nominal currents on the Delta and Wye windings as:

$$I_{nom(\text{Delta})} = \frac{100\text{ MVA}}{\sqrt{3} \times 220\text{ kV}} = 262.43\text{ A} \quad \text{(EQ 1)}$$

$$I_{nom(\text{Wye})} = \frac{100\text{ MVA}}{\sqrt{3} \times 69\text{ kV}} = 836.73\text{ A} \quad \text{(EQ 2)}$$

Dividing the primary current rating with nominal current, we have:

$$\frac{\text{CT 1}}{I_{nom(\text{Delta})}} = \frac{500\text{ A}}{262.43\text{ A}} = 1.9 \quad \text{(EQ 3)}$$

$$\frac{\text{CT 2}}{I_{nom(\text{Wye})}} = \frac{500\text{ A}}{836.73\text{ A}} = 1.195 \quad \text{(EQ 4)}$$

The calculated ratio for CT 2 is lower; therefore, the Unit CT value is 1000 A.

PER-UNIT SETTINGS (MIN PKP, BREAK 1 AND 2)

For this example, a Minimum Pickup setting of 0.1 pu is equal to 0.1 × 1000 A = 100 A differential current. This setting should be larger then the transformer magnetizing current and steady state CT errors during no load conditions.

The Break 1 setting is based on the previously defined pu value of the full load transformer current. The information for the different MVA transformer loads can be obtained from the transformer's nameplate.

The Break 2 setting is based on the saturation limit for each winding CT during external faults. The Break 2 is the minimum pu current causing CT saturation, for all CTs.

SLOPE SETTINGS (SLOPE 1 AND 2)

The Slope 1 and 2 settings express the slope of the operating characteristic as a function of differential current (I_d) and restraint current (I_r) shown below:

$$I_d = \overrightarrow{i_{1(\text{comp})}} + \overrightarrow{i_{2(\text{comp})}} \quad \text{(EQ 5)}$$

$$I_r = \max(|i_{1(\text{comp})}|, |i_{2(\text{comp})}|) \quad \text{(EQ 6)}$$

The slope is:

$$\text{Slope} = \frac{\Delta I_d}{\Delta I_r} \times 100\% \text{ (in pu)} \quad \text{(EQ 7)}$$

Slope 1 is the slope setting from pickup to Break 1, and is based on CT errors during normal load currents and from tap changes.

Slope 2 identifies the slope where the CT saturation are likely and maximum restraint is required. A recommended setting is 98%; this provides stability if one CT is partly saturated during an external fault. It implies that a large differential current is required for an differential operation.