Transformer Event Analysis

Exercise 1: SEL-787 Trips on Load

Introduction

A utility installed a new 30 MVA, 69/12.47 kV, DABY distribution transformer and slowly transferred feeder load onto it. A week after the initial energization, the SEL-787 Transformer Protection Relay tripped when no fault was on the system. The utility decided to raise the minimum operate current setting from 0.2 pu to 0.25 pu. Another week later, the relay tripped again. See Figure 1 for a drawing of the installation.

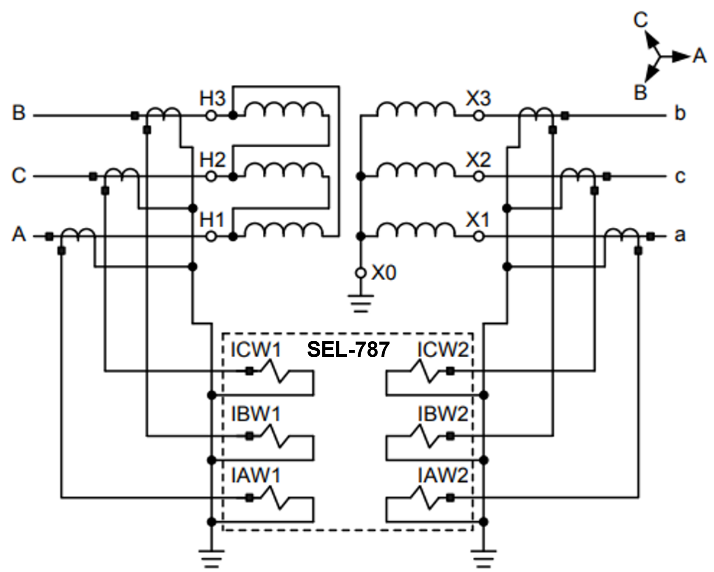

Figure 1 Transformer Installation

Resources available for this example:

- Event reports (Exercise 1 Filtered.CEV and Exercise 1 Differential.CEV)
- SEL-5601-2 SYNCHROWAVE® Event Software
- SEL-787 instruction manual
- "Using Custom Calculations in SYNCHROWAVE Event to Apply Transformer Compensation Matrices" (AG2015-26) application guide
- "Beyond the Nameplate – Selecting Transformer Compensation Settings for Secure Differential Protection" technical paper

Questions and Answers

1. Open Exercise 1 Filtered.CEV. Is this a fault? Did the relay trip?

If we plot the W1 and W2 signals, we can see that the currents look like load on the system rather than a fault. We can see from the digital signals that the relay tripped on percentage restrained differential (87R).

2. What operating characteristic does the 87R element use in the SEL-787? What signals are necessary to determine if the relay operated correctly based on this characteristic? What settings will we need, and what are they set to in the relay?

See Figure 2. The SEL-787 uses a percentage restrained differential element that asserts if the operate current falls above the O87P setting and also falls above the slope line (IOP/IRT > SLP). This is done for each phase independently.

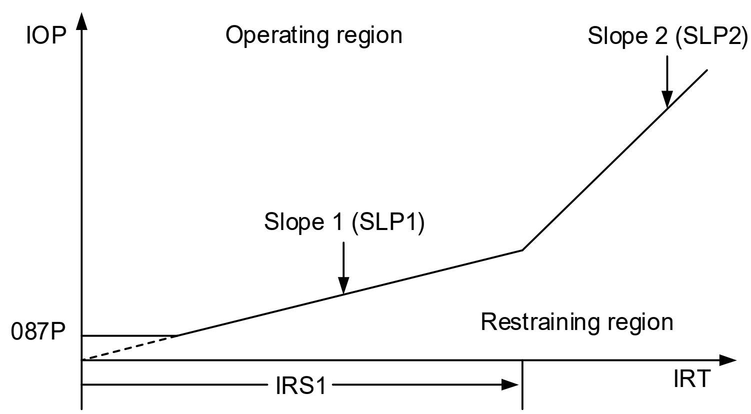

Figure 2 Example 87R Operating Characteristic

To determine if the relay operated correctly, we need to know which slope was active as well as the operate and restraint currents for each phase. We will also need to know the settings for O87P (0.25), SLP1 (25%), SLP2 (60%), and IRS1 (3).

3. Notice that the OP and RT quantities are not available in the filtered (winding) event report. Open the Exercise 1 Differential.CEV file to obtain the necessary quantities. Based on the RT quantities, what slope was the relay using?

Since the restraint values are all below the IRS1 setting of 3, we know that the relay was using SLP1 (25%) when the trip occurred.

4. Plot and compare the operate and restraint quantities for each phase. Does the operation of 87R make sense?

Figure 3 shows the operate and restraint quantities for each phase.

Figure 3 Operate and Restraint Quantities for Each Phase

For an 87R element to assert, two things must be true:

1. IOP needs to be above the O87P setting (0.25)
2. IOP/IRT must be greater than the SLP1 setting (25%)

As seen in Figure 3, IOP1 and IOP2 do not meet Condition 1, since they fall below the O87P threshold of 0.25. Thus, 87HR1 (A-phase) and 87HR2 (B-phase) remained deasserted.

If we look at the two conditions for C-phase:

1. IOP3 is 0.253, which is greater than the O87P threshold of 0.25
2. IOP3/IRT3 = 0.253 / 0.459 = 55%, which is above the SLP1 setting of 25%

Therefore, 87HR3 (C-phase) asserted. The operation makes sense, based on the signals that the relay saw.

5. Do the OP and RT quantities look correct for load conditions?

No, the presence of significant OP current is not correct for load conditions. There should never be significant OP current during load or pre-fault conditions.

6. The customer is unsure if their winding compensation settings are correct for their installation. What compensation settings were in the relay at the time of the event? Are they correct? If not, what do you propose they should be?

The compensation settings for this event are shown in Figure 4. Matrix 0 is used for the delta side, and Matrix 1 for the wye side. This is correct for a standard DABY transformer installation when applied to a system with ABC phase sequence.

W1CT	:= WYE	W2CT	:= WYE				
CTR1	:= 80	CTR2	:= 400	MVA	:= 30.0	ICOM	:= Y
W1CTC	:= 0	W2CTC	:= 1	VWDG1	:= 69.00	VWDG2	:= 12.47
CTRN1	:= 160	PTR	:= 60.00	VNOM	:= 12.47	DELTA_Y	:= WYE

Figure 4 Compensation Settings

However, this is not a standard installation. Based on Figure 1, the phase-to-bushing connections are not standard. We can derive the phase shift for this installation, as shown in Section IV of the “Beyond the Nameplate” technical paper. With this installation, we will find that the high side actually lags the low side by 30 degrees. This derivation is shown in Figure 5 and Figure 6.

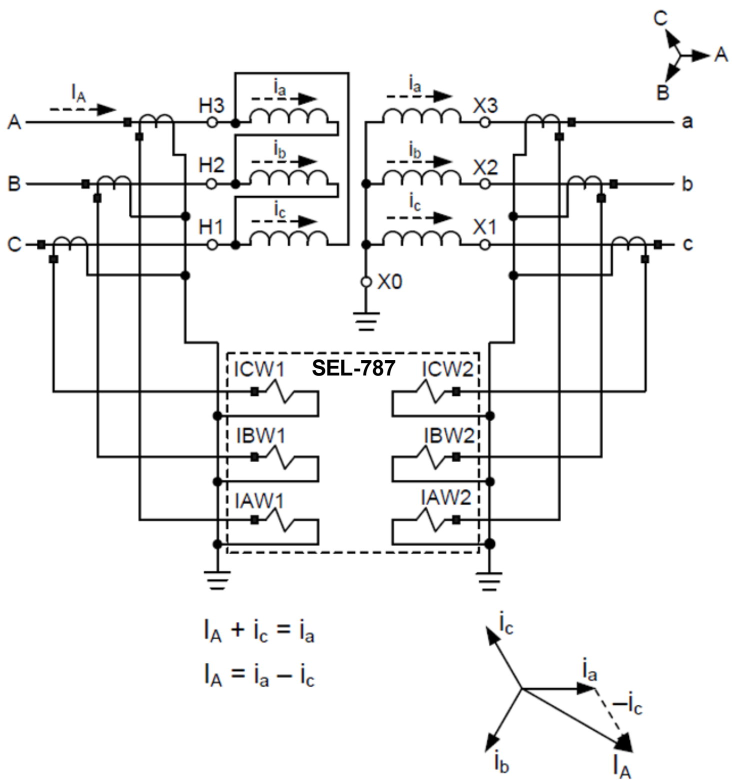

Figure 5 Deriving the Phase Shift at the Relay

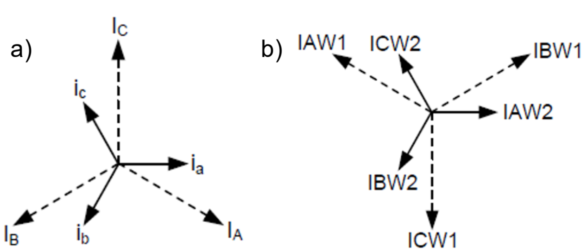

Figure 6 Phase Currents (a) on the System and (b) at the Relay

Using the rules in Section V of the "Beyond the Nameplate" technical paper, we can conclude that the correct compensation settings for this installation should be: W1CTC = 0 and W2CTC = 11.

7. Use the custom calculations in AG2015-26 to verify your answer. The calculations use the filtered (winding) event report signals and calculate new OP and RT quantities using your selected compensation settings. Are your proposed compensation settings correct?

A plot of the OP and RT signals from the custom calculations is shown in Figure 7. The OP currents drop to 0 when the compensation settings are changed. This verifies that our proposed compensation settings of W1CTC = 0 and W2CTC = 11 are correct.

Figure 7 Calculated OP and RT with W1CTC = 0 and W2CTC = 11

8. Other than proving incorrect compensation settings, can you think of any other uses for the calculations in AG2015-26?

These calculations can be used if an event needs to be analyzed and only the filtered (winding) event report was downloaded. The calculations will give you the OP and RT currents that are only available in the differential report. We can also simulate adjustments to the incoming signals (e.g., changing polarity, scaling due to a different CT ratio, etc.) and see what the relay would calculate for OP and RT.