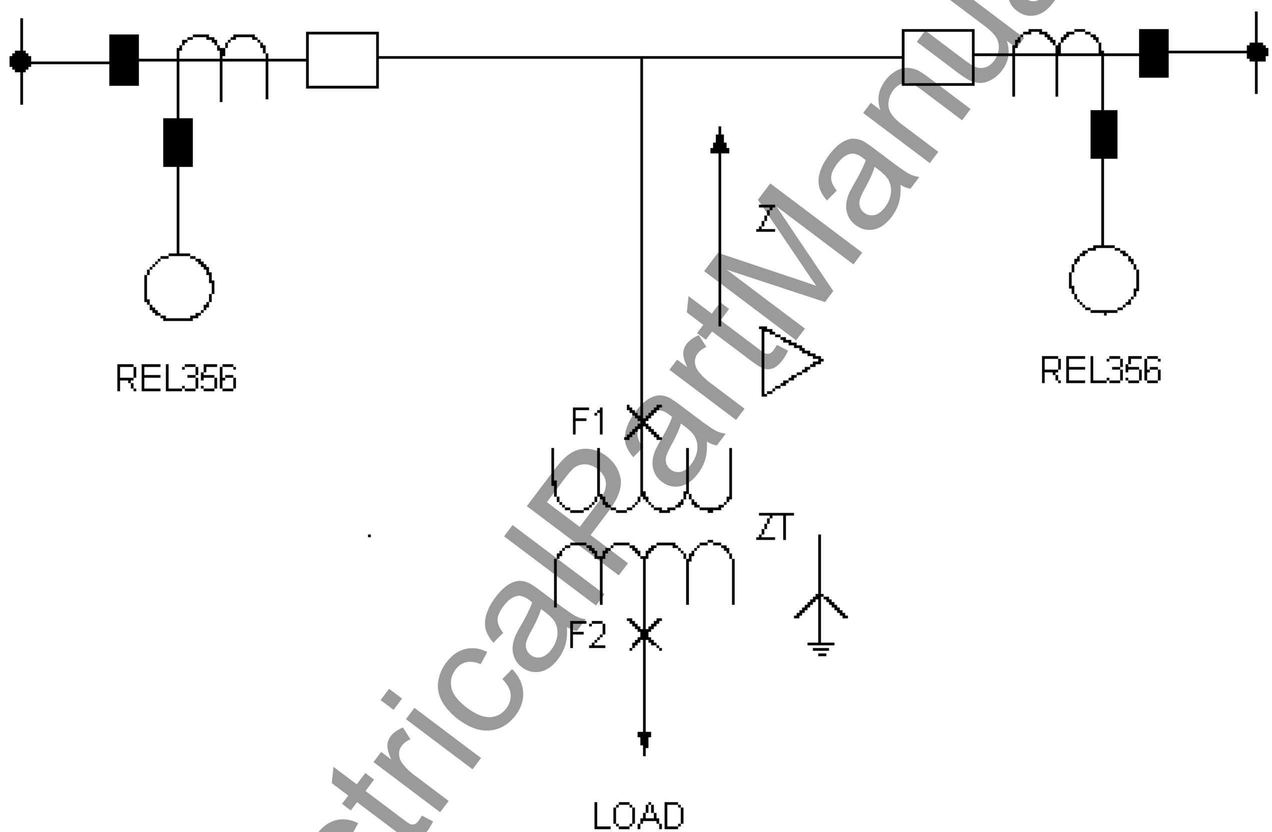
Application Note

Substation Automation and Protection Division

Current Differential Relay REL356 Tapped Load Applications

Introduction

This note discusses the use of REL356 current differential relay in tapped load applications.



Settings for Tapped Load Applications

The REL356 relay may be used where the line is protected as a two-terminal line but has a load tap in the zone of protection. In order to apply and set the relay properly in this environment, there must be a transformer at the load tap. If a transformer is not present, the relays can not be set to limit the zone of protection, and the power line must be treated as a three-terminal line.

An example of a load tapped two-terminal line is shown in Figure x-x. Careful consideration must be given to the settings that are applied to the relay to assure that all faults, up to and into the transformer, are recognized and all faults beyond the transformer are ignored. In Fig x-x, a delta-wye transformer is shown with the wye on the load side and with a grounded neutral. This is the most common application. The ZT in Fig 5-1 is the transformer impedance, and Z is the total equivalent impedance looking back into the system from the high voltage terminals of the transformer. What must be considered are the relay energy levels for faults on the line side of the transformer vs. that for faults on the load side.

The relay energy is affected by two things; the sequence network settings and the type of fault. The internal faults that produce the lowest network filter output current and the external faults which produces the highest filter output current must regulate the settings.

If the relay is set to have a negative sequence response, the type of internal phase fault that will produce the lowest sequence network current will be a CA or AB fault. This minimum internal fault is assumed to occur at the transformer high terminals (F1). If the relay is set to have no negative sequence response (C2 = 0), then all combinations of phase-to-phase faults produce a low energy level in the relay. For this phase-to-phase fault, the positive sequence portion of the current is all that will affect the filter output response, and that current level is equal to $V_{LN}/(2ZR_C)$ where V_{LN} is the line to neutral voltage and R_C is the current transformer ratio.

The type of external faults that produce the highest sequence network output for faults on the load side of the transformer must be considered. Ground faults do not produce any zero sequence current in the relays because of the presence of the transformer delta, and therefore, only the positive and negative sequence response need to be considered. If the relay is set for no negative sequence response, it is clearly seen that a three-phase fault on the load side will produce the highest network current output at the relay location. The fault current, in this case, will be $V_{LN}/[(Z+ZT)R_C]$.

The case where the relay is set to have a negative sequence response (C2≠0), presents a more difficult analysis. Due to the fact that the positive sequence constant (C1) is opposite in sign to the negative sequence constant (C2), and considering the fact that the high side positive sequence current will lead the low side current by 30 degrees, and the high side negative sequence current will lag the low side current by 30 degrees for a standard transformer, it can be shown that a phase B-to-C fault or a phase C-to-A fault will produce the highest sequence output of all the low voltage phase faults. A C-to-G fault will produce the highest filter output current for phase-to-ground faults on the low voltage side of the transformer. It depends on the values of Z and ZT as to whether the phase-to-phase or phase-to-ground fault produces the larger output. Therefore both must be considered.

For a phase B-to-C fault, the positive sequence "A=phase" current is $V_{LN}/[2(Z+Z_T)R_C$. The negative sequence "A-phase" current is equal in magnitude to the positive sequence current and is 120 degrees out of phase with it. For a phase C-to-G fault, the positive sequence current "A-phase" current is $V_{LN}/[(2Z+3ZT)R_{C,}$ and the negative sequence "A-phase" current is equal in magnitude but 180 degrees out of phase with it. It must remembered that these phase relationships are on the hgih-side of the transformer, and the fault is on the low side. Examination will show that the low-side CG case produces a higher filter output voltage than either of the phase-to-phase faults if Z/ZT > 3, and a phase-to-phase fault produces a higher value if Z/ZT < 3 (based on C1=0.1 and C2=0.7).

Settings for OTH, C0, C1 and C2 for Tapped Load Applications

The relay setting OTH and the sequence filter constants, C1, C2 and C0, should be first selected according to normal conditions following the recommendations in Sections 5.5.2 and 5.5.3:

C2 = 0

When no negative sequence response is used (C2 = 0) the relay should be set to fulfill both conditions (1) and (2)

- (1) trip for a phase-to-phase fault on the high side of the transformer

$$OTH < 0.3 \cdot C_1 \cdot \frac{V_{LN}}{2 \cdot |Z| \cdot R_C}$$

- (2) not trip for a three phase fault on the low side of the transformer

$$OTH > 0.3 \cdot C_1 \cdot \frac{V_{LN}}{\left|Z + Z_T\right| \cdot R_C}$$

C2 ¹ 0 and Z/ZT < 3

When negative sequence response is used (C2≠0) and Z/ZT < 3 the relay should be set to fulfill conditions (3), (4), *and* (5):

- *(3) trip for a three phase falt on the high side of the transfomer*

$$OTH < 0.3 \cdot C_1 \cdot \frac{V_{LN}}{\left|Z\right| \cdot R_C}$$

- *(4) trip for a phase-to-phase fault on the high side of the transformer*

$$OTH < 0.3 \cdot \left|-C_1 + C_2 e^{-j60^\circ}\right| \cdot \frac{V_{LN}}{2 \cdot \left|Z\right| \cdot R_C}$$

- *(5) not trip for a phase-to-phase fault on the low side of the transformer*

$$OTH > 0.3 \cdot \left|-C_1 + C_2 e^{j120^\circ}\right| \cdot \frac{V_{LN}}{2 \cdot \left|Z + Z_T\right| \cdot R_C}$$

C2 ¹ 0 and Z/ZT > 3

When negative sequence response is used (C2¹0) and Z/ZT > 3 the relay should be set to fulfill conditions (6) and *(7):*

- *(6) trip for a three phase falt on the high side of the transfomer*

$$OTH < 0.3 \cdot C_1 \cdot \frac{V_{LN}}{\left|Z\right| \cdot R_C}$$

- *(7) not trip for a phase-C-to-ground fault on the low side of the transformer*

$$OTH > 0.3 \cdot \left|-C_1 + C_2\right| \cdot \frac{V_{LN}}{\left|2 \cdot Z + 3 \cdot Z_T\right| \cdot R_C}$$

where

V_{LN} is the line-to-neutral voltage,

R_c is the CT ratio,

Z is the total equivalent system impedance looking back into the system from the transformer bank, in high side ohms

Z_T is the transformer impedance, in high side ohms

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