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Application Settings for ABB REL352 Phase Comparison Protection

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APPLICATION SETTINGS FOR ABB REL352 PHASE COMPARISON PROTECTION

FOREWORD

REL352 is a phase comparison unit protection manufactured by ABB. It uses power line carrier for communication. Since there is no clear technical guidance in ABB's Manual for application of the settings, it is intended that this document will provide guidance on calculation of the relay settings for application in National Grid's 275 kV and 400 kV systems.

1 SCOPE

The report provides the technical guidance on setting calculations for relay REL352 (ver 1.12). It also provides recommended settings for the PLC equipment TC-10B. The settings recommended in this document only apply to two-ended circuits.

2 REFERENCES

- (i) REL352 User's Guide, ABB Power Automation and Protection Division, Florida 33065, USA, Manual Ref. 40-201.9B, ver1.12, February 1999.
- (ii) National Grid Document: Technical and Operational Characteristics of the National Grid Transmission System, Issue 1, June 1998.
- (iii) National Grid Document: TPS 2.6.2, Issue 3, December 1998.

3 DESCRIPTION OF REL352

REL352 is a microprocessor-based unit protection using a phase comparison technique. The protection scheme for National Grid's application uses ON/OFF PLC communication. The relay combines the phase current (Ia, Ib and Ic) measured into a single quantity. This quantity is an output of symmetrical component filter which is proportional to the weighted sum of the sequence components as below:

$$IT = C0 \times I0 + C2 \times I2 - C1 \times I1 \quad (1)$$

Where: C0, C1, C2 = Settings of symmetrical component coefficient.
I1, I2, I0 = Phasor of positive, negative and zero phase sequence current, secondary values.

The quantity IT is normally a sinusoidal waveform. The other settings associated with IT are:

- LP – A threshold that represents a phase of positive half-cycle of the IT signal at the local end. The local positive LP is defined as a logic "1" in the positive region of IT above the threshold LP.
- LN – A threshold that represents a phase of negative half-cycle of the IT signal at the local end. The local negative LN is defined as a logic "1" in the negative region of IT above the threshold LN. LN = - LP

IKEY – The IKEY level defines the threshold generating the square wave form to be sent to the remote terminal. The IKEY level is defined in the positive region of the IT signal. Above the threshold level, the local terminal will "key" a logic "1" to the remote terminal via the IKEY output signal.

With ON/OFF PLC communication, phase comparisons are performed only in the negative half-cycle of the IT signal. Trip occurs when IT is above the threshold LN for more than 4.8 ms and during which period no blocking signal is received from the remote end. In addition, a trip can only occur if phase current or residual current is above the setting IPL or IGL.

More detailed description for REL352 is in Reference (i).

4 APPLICATION OF REL352 SETTINGS

The REL352 for National Grid's Application does not have the distance backup protection module. Therefore the settings for the distance protection are not required.

4.1 Scheme and Link Settings

The scheme and link settings of REL352 were chosen for application of the relay in National Grid's systems. These settings are fixed for each application and shown in Appendix A.

4.2 Protection Settings

4.2.1 C1, C2, C0

C1, C2 and C0 are Symmetrical Component Coefficients shown in formula (1) above. The coefficients control relay sensitivity to earth faults, phase-phase faults and 3-phase faults. It is recommended to set the coefficients as follows for both 400 kV and 275 kV circuits:

$$C1 = 0.1, \quad C2 = 0.45, \quad C0 = 2.45.$$

4.2.2 IKEY

ABB stated that IKEY should be set to a value larger than 1.5 times the Line Charging Current multiplied by C1, and greater than 0.06 A (REL352 manual p. 64). It is recommended to set IKEY to a standard setting of 0.1 A for both 400 kV and 275 kV circuits:

$$IKEY = 0.1 \text{ A}$$

4.2.3 LP

For an out-zone fault, the relay at the local end should be blocked by the IKEY signal received from remote end when LN element picks up (LN = -LP). A margin is therefore required between IKEY and LP. ABB recommended to set LP to 2 times IKEY. So for both 400 kV and 275 kV circuits set:

$$LP = 2 \times IKEY = 2 \times 0.1 = 0.2 \text{ A}$$

For an in-zone fault, the minimum pulse width of LP signal needs to be 4.8 ms in order for the relay to trip. By mathematical analysis of a sinusoidal waveform, it can be derived that:

$$\text{If } \sqrt{2} \times ITP \times \sin(47^\circ) = 1.034 \times ITP > LP \quad (2)$$

Where: ITP is the r.m.s. value of IT signal.

Then the width of the square wave form of LP will be greater than 4.8 ms.

For a balanced 3-phase fault, assuming that the fault current is IFP (r.m.s. secondary value), then from formula (1):

$$ITP = C1 \times IFP \quad (3)$$

From equation (2) and (3) above, it can be derived that:

$$\text{If } 1.034 \times C1 \times IFP > LP \quad (4)$$

Then the width of the square wave form of LP will be greater than 4.8 ms.

Allow 20% margin for IFP, criterion (4) then becomes:

$$1.034 \times C1 \times IFP / 120\% = 0.86 \times C1 \times IFP > LP \quad (5)$$

If the fault current is fed from a weak end, it may not satisfy the criterion (5) above. The CB at the weak end has to rely on the relay at the strong end to send an intertrip to clear the fault.

For phase-phase and earth faults, the relay sensitivity is higher than that of a balanced 3-phase fault because C0 and C2 are set higher than C1. In order to minimise the affects of load current on relay sensitivity for high impedance earth faults, C1 should be set to a relatively low value, ABB recommended to set C1 to 0.1.

4.2.4 ITA1 (r.m.s. value)

ITA1 is a setting of IT signal for the first starter. IKEY can only be transmitted if the starter picks up. Therefore the ITA1 needs to be set to above maximum load current including unbalanced ZPS and NPS currents. Reference (ii) gives the following indicative values of maximum continuous sequence load current components on National Grid's 400 kV and 275 kV circuits:

	400 kV	275 kV
Maximum continuous NPS current	470 A	280 A
Maximum continuous ZPS current	165 A	100 A

It can be seen from above table that the ratio between ZPS and NPS current is approximately 1 to 3. The figures of 10% load current for maximum NPS current and 5% load current for maximum ZPS current had been used in relay settings in the past. Based on the recent values shown in above table, for REL352 setting calculation, it is reasonable to assume that the maximum NPS current would be 10% of maximum load, however the maximum ZPS current would only be 3.5% of maximum load.

It is difficult to predict the phase relationship between I1, I2 and I0, but in the worst case, the IT could be:

$$IT = (C1 + C2 \times 10\% + C0 \times 3.5\%) \times ILM$$

Where ILM is the maximum load current including overload, secondary value.

For the recommended setting: C1 = 0.1, C2 = 0.45, C0 = 2.45
The corresponding IT would be:

$$IT = (0.1 + 0.45 \times 0.1 + 2.45 \times 0.035) \times ILM \\ = 0.2308 \times ILM = 2.31 \times C1 \times ILM$$

So if ITA1 is set to $2.31 \times C1 \times ILM$, the relay will not "Key" the PLC equipment under the maximum overload condition, even if the maximum unbalanced current is present in the system under the worst phase angle combinations. So it is recommended to set:

$$ITA1 = 2.31 \times C1 \times ILM \quad (6)$$

The setting of ITA1 is displayed on the relay as a percentage of ITA2. The above setting equals to 80% of ITA2 (see below). Therefore set:

$$ITA1 = 80\%$$

When a fault occurs in the system, an increment starter (DITA1) will pick up if IT changes in level by 6% (The 6% is fixed in the relay).

In addition to the DITA1, the relay also includes a voltage increment starter ΔV to start the KEYING if there is a change in system voltage. This is why VT inputs are required.