Implementation of Transformer Protection by Intelligent Electronic Device for Different Faults

Y V Aruna, Beena S
(Asst. Professors, Department of EEE, Cambridge Institute of Technology, Bangalore-36)

ABSTRACT
Protection of power system equipment was traditionally done by using electromagnetic relay, static relays, and numerical relays. At present the microprocessor based relays are replacing the old Electromagnetic relays because of their high level accuracy and fast operation. RET670 (Transformer protection relay), an IED (INTELLIGENT ELECTRONIC DEVICE) provides fast and selective protection, monitoring, and control of all types of transformer. The configured IED is tested under different fault conditions simulated by using mobile test kit to ensure IED’s reliable operation on site. With preconfigured algorithms, the IED will automatically reconfigure the network in case of a fault, and a service restoration is carried out within milliseconds by giving trip signal to the corresponding Circuit breakers. On receiving the trip signal the circuit breaker operates providing quicker isolation of transformers under the fault condition. This enables to have a complete and an adequate protection to the specified power transformer.

Keywords – Transformer protection, IED, RET670

1. INTRODUCTION

An Intelligent Electronic Device (IED) is a term used in the electric power industry to describe microprocessor-based controllers of power system equipment, such as circuit breakers and transformers.

1. RET670 Introduction

RET670 provides fast and selective protection, monitoring and control for two- and three-winding transformers, autotransformers, generator-transformer units, phase shifting transformers, special railway transformers and shunt reactors. The transformer IED is designed to operate correctly over a wide frequency range in order to accommodate power system frequency variations during disturbances and generator start-up and shut-down as in Fig.1

A very fast differential protection function with settable CT ratio matching and vector group compensation makes this IED the ideal solution even for the most demanding applications. Since RET670 has very low requirements on the main CTs, no interposing CTs are required. It is suitable for differential applications with multi-breaker arrangements with up to six restraint CT inputs. The differential protection function is provided with 2nd harmonic and wave-block restraint features to avoid tripping for magnetizing inrush current, and 5th harmonic restraint to avoid tripping for over excitation. The differential function offers a high sensitivity for low-level internal faults. The unique and innovative sensitive differential protection feature of the RET670 provides the best possible coverage for winding internal turn-to-turn faults, based on the theory of symmetrical components.

Fig.1: Internal Conventions of the directionality in the IED.

Tripping from pressure relief/Buchholz and temperature devices can be done through the transformer IED where pulsing, lock-out contact output and so on, is performed. The binary inputs are heavily stabilized against disturbance to prevent incorrect operations at for example dc system capacitive discharges or DC earth faults. The transformer IED can also be provided with a full control and interlocking functionality including Synchrocheck function to allow integration of the main and/or a local back-up control. Out of Step function is available to separate power system sections close to electrical centre at occurring out of step.

RET670 can be used in applications with the IEC 61850-9-2LE process bus with up to two Merging Units (MU) as in fig1.1. Each MU has eight analogue channels, normally four current and four voltages. Conventional and Merging Unit channels can be mixed freely in your application.
1.1 RET 670 hardware

Fig.1.1 Rear side view of RET670

1.1.1 Available functions of RET670

Differential protection, Distance protection, Current protection, Voltage protection, Frequency protection, Multipurpose protection, Control, Logic, Metering, Monitoring, Station communication etc are the functions carried out by RET670.

II. Block diagram

The block diagram in fig.2 shows the implementation of RET670 in transformer protection.

PCM600 is a connectivity package which provides the means for system products and tools to connect and interact with the IED in an efficient way as well as data to allow efficient engineering of system products. RET670 supports IEC 61850 standard. Configuration of RET670 is done by using signal matrix tool of PCM600, generating a .pcmi file. After establishing communication with RET670 the .pcmi file is uploaded to RET670 and then the parameter setting is done as per the required transformer protection scheme.

The CT's and VT's will provide the necessary actuating signals to RET670 under the fault condition. Operation of RET670 gives the trip signal to the physical trip coils. When once the IED is configured for different protection schemes the fault voltage is applied by simulating the fault condition through Mobile test kit.

2.1. Protection and Control Manager (PCM 600) with Connectivity Package for Relay.

PCM600 is used to do complete engineering and configuration activities needed for the IEDs. Product type and version specific engineering data needed by PCM600 for protection, control and communication engineering of a particular IED is given in an IED connectivity package. A PC with PCM600 can be connected to any 670 series IED within a station using the Ethernet connection. The connection allows to reading and writing all configuration data needed for proper operation from or to the IED. The IEDs have communication interfaces for protocols and media used for station communication. IED IEC-61850 station communication files can export from PCM600 to station engineering tools for engineering of station communication between bay IEDs and station IEDs.

2.1.1 Tasks of PCM600 in IED engineering process

IED engineering management, Communication engineering, Disturbance record management, Service management are the tasks of PCM600 in IED engineering process.

2.1.2 Available Protection

The following are the few among the various protections which is provided to the above mentioned transformer by an IED, RET670.

i. Two winding differential protection.
ii. High impedance differential protection (REF).
iii. Over current and Earth fault protection.
iv. Over excitation protection.
v. Transformer troubles.

III. TWO WINDING DIFFERENTIAL PROTECTION

The task of the power transformer differential protection is to determine whether a fault is within the protected zone, or outside the protected zone. The protected zone is delimited by the position of current transformers, and in principle can include more objects than just transformer. If the fault is found to be internal, the faulty power transformer must be quickly disconnected. Thus the IED will always internally measure the currents on all sides of the power transformer with the same reference direction towards the power transformer windings.

3.1 Configuration

The functions Transformer differential protection, two-winding (T2WPDIFF) is provided with internal CT ratio matching and vector group compensation and when required zero sequence current elimination is also made internally in the software. T2WPDIFF is the functional block of two winding differential protection.
Fig 3.1 : Two winding differential protection functional block

The configuration of the particular functional block is as shown in fig.3.1.

1 - T2WPDIFF Analog inputs from SMAI.
2 - T2WPDIFF output signals to SMBO.
3 - Outputs which gives the magnitude of fundamental frequency differential currents.
4 - OR logic functional blocks which gives the indication for the presence of 2nd and/or 5th harmonics.
5 - Output indicating the presence of harmonics.

Analog inputs from SMAI
AI_HV_1MS = Current reading from the HV side CT obtained from SMAI.
AI_LV_1MS = Current reading from the LV side CT obtained from SMAI.

Output signals to SMBO
DIFF_TRIP = General differential trip signal.
DIFF_RESTRAIN_TRIP = Trip signal under restrained condition.
DIFF_UNRESTRAIN_TRIP = Trip signal under unrestrained condition.
These trip signals are given to the trip logic and in-turn goes to SMBO block.

3.2 Parameter setting
This is done in PCM600 by using Parameter Setting Tool (PST) as in table 3.2. The specified settings for the parameters of the physical IED for communication channels, CT and VT conversion values of the transformer modules, presentation parameters for local HMI, settings for protection and control functions, number of setting groups etc., are provided by using PST.

<table>
<thead>
<tr>
<th>Description</th>
<th>Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trans Rating</td>
<td>75 MVA</td>
</tr>
<tr>
<td>Trans. Vector Group</td>
<td>YY0</td>
</tr>
<tr>
<td>HV side full load current (pri)</td>
<td>197 A</td>
</tr>
<tr>
<td>HV side full load current (sec)</td>
<td>0.985 A</td>
</tr>
<tr>
<td>LV side full load current (pri)</td>
<td>1972 A</td>
</tr>
<tr>
<td>LV side full load current (sec)</td>
<td>0.986 A</td>
</tr>
<tr>
<td>Diff. Pickup Id&gt;(restraint)</td>
<td>30% of full load current</td>
</tr>
<tr>
<td>Diff. Pickup Id&gt;(restraint)</td>
<td>30% of full load current</td>
</tr>
<tr>
<td>Diff. Pickup Id&gt;(Unrestraint)</td>
<td>10 Times of full load current</td>
</tr>
<tr>
<td>Slope Section 2</td>
<td>40%</td>
</tr>
<tr>
<td>Slope Section 3</td>
<td>80%</td>
</tr>
<tr>
<td>2nd Harmonic Blocking</td>
<td>15%</td>
</tr>
</tbody>
</table>
3.4 Testing procedure

When once the complete configuration of an IED is done it is tested for its operation and reliability by using mobile test kit (Doble, Omicron).

Differential protection test is classified based on the parameters which are to be checked. They are,

i. Pick up test
ii. Stability test
iii. Slope test

3.4.1. PICK UP TEST

Pick up test is done to verify the pick-up value of the relay on both HV and LV side of the transformer in fig 3.4.1 & 3.4.1.1.

For a 75MVA, 220kV/22kV power transformer, HV tripping value = 0.985A

We have \(I_{dmin} = 0.3\)

Therefore, HV pick up = \(0.985 \times 0.3 = 0.295A\)

Similarly,

LV tripping value = 0.984A

We have \(I_{dmin} = 0.3\)

Therefore, LV pick up = \(0.984 \times 0.3 = 0.295A\)

This value of current is injected to the relay for each one of the phases and also for all the three phase by using Doble or omicron test kit and is checked for its reliability. Pick up value of current is been injected to the R phase of HV and LV as in table 3.4.1.2 & for LV side as in table 3.4.1.3. As soon as the injected current exceeds 295mA the relay gets tripped.

### Table 3.4.1.2 Pickup Test Tabulation on HV Side

<table>
<thead>
<tr>
<th>Phase</th>
<th>Injected Current (HV Side)</th>
<th>Operating Time (MS)</th>
<th>Differential Current BIAS CURRENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>R-PH</td>
<td>0.295</td>
<td>26.3</td>
<td>59</td>
</tr>
<tr>
<td>Y-PH</td>
<td>0.296</td>
<td>29.3</td>
<td>59</td>
</tr>
<tr>
<td>B-PH</td>
<td>0.295</td>
<td>27.2</td>
<td>59</td>
</tr>
</tbody>
</table>

### Table 3.4.1.3 Pickup Test Tabulation on LV Side

<table>
<thead>
<tr>
<th>Phase</th>
<th>Injected Current (LV Side)</th>
<th>Operating Time (MS)</th>
<th>Differential Current BIAS CURRENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>R-PH</td>
<td>0.294</td>
<td>26.1</td>
<td>59</td>
</tr>
<tr>
<td>Y-PH</td>
<td>0.293</td>
<td>29.8</td>
<td>59</td>
</tr>
<tr>
<td>B-PH</td>
<td>0.295</td>
<td>27.1</td>
<td>59</td>
</tr>
</tbody>
</table>

3.4.2. STABILITY TEST

This test is done to check the stability of the relay. The transformer under consideration is a Y-Y connected transformer with 0 degree phase shift. An equal current of magnitude 1A is been injected to both HV and LV (when both HV and LV has CTs of same ratio) or current of magnitude equal to the pick-up value of HV and LV respectively is been injected. The phase angle of any one of the phases of either HV or LV is changed. When once the current goes out of phase the relay is tripped. This is indicated by indication LED as in the Figure 3.4.2. 75MVA, 220kV/22kV power transformer has different CT ratios of HV and LV is different. Hence, the actuating value of 0.295A is been injected for R phase of HV and LV. Since the phase angles are balanced the relay is under stable state. When once the phase angle of either HV or LV is changed the currents become out of phase issuing a trip.
3.4.2.1 STABILITY TEST RESULTS

<table>
<thead>
<tr>
<th>Phase</th>
<th>Injected Current (HV Side)</th>
<th>Injected Current (LV Side)</th>
<th>Stability</th>
</tr>
</thead>
<tbody>
<tr>
<td>R-PH</td>
<td>1A 0°</td>
<td>1A 180°</td>
<td>OK</td>
</tr>
<tr>
<td>Y-PH</td>
<td>1A 240°</td>
<td>1A 60°</td>
<td>OK</td>
</tr>
<tr>
<td>B-PH</td>
<td>1A 120°</td>
<td>1A 300°</td>
<td>OK</td>
</tr>
</tbody>
</table>

Table 3.2.2.1 Stability Test Tabulation

3.4.3. SLOPE TEST

The operate restrain characteristic has three regions. One is non-operating region in which the relay won’t operate. Operating region in which the relay operates but conditionally. The unrestrained region in which the relay is operated unconditionally. This operation of the relay is verified by conducting slope test as in fig 3.4.3.

3.4.3.1 SLOPE TEST (HV&LV) RESULTS FOR SLOPE-1

Current injected as below:

<table>
<thead>
<tr>
<th>Phase</th>
<th>Injected Current (HV Side)</th>
<th>Injected Current (LV Side)</th>
<th>Differential Current</th>
<th>Bias Current</th>
<th>Tripping</th>
</tr>
</thead>
<tbody>
<tr>
<td>R-PH</td>
<td>1.71A 0°</td>
<td>1A 180°</td>
<td>97.503A</td>
<td>347.88</td>
<td>Operated</td>
</tr>
<tr>
<td>Y-PH</td>
<td>1.71A 240°</td>
<td>1A 60°</td>
<td>97.503A</td>
<td>347.88</td>
<td>Operated</td>
</tr>
<tr>
<td>B-PH</td>
<td>1.71A 120°</td>
<td>1A 300°</td>
<td>97.503A</td>
<td>347.88</td>
<td>Operated</td>
</tr>
</tbody>
</table>

Current injected at HV side and LV side 2 times of full load current and LV side current is reduced.

Table 3.4.3.1 Slope-1 Test Results

3.4.3.2 CALCULATION:

\[
\text{slope} = \frac{\text{IDL}1 - \text{IDL}2}{\text{IB}1 - \text{IB}2} \times 100
\]

\[
\text{slope} = \frac{137.5 - 97.503}{438.12 - 347.88} \times 100
\]

\[
\text{slope} = 43.09\%
\]

3.4.3.3 SLOPE TEST (HV&LV) RESULTS FOR SLOPE-2

Current injected as below:

<table>
<thead>
<tr>
<th>Phase</th>
<th>Injected Current (HV Side)</th>
<th>Injected Current (LV Side)</th>
<th>Differential Current</th>
<th>Bias Current</th>
<th>Tripping</th>
</tr>
</thead>
<tbody>
<tr>
<td>R-PH</td>
<td>7.71A 0°</td>
<td>4.7A 180°</td>
<td>1425A</td>
<td>2127A</td>
<td>Operated</td>
</tr>
<tr>
<td>Y-PH</td>
<td>7.70A 240°</td>
<td>4.7A 60°</td>
<td>1425A</td>
<td>2127A</td>
<td>Operated</td>
</tr>
<tr>
<td>B-PH</td>
<td>7.71A 120°</td>
<td>4.7A 300°</td>
<td>1425A</td>
<td>2127A</td>
<td>Operated</td>
</tr>
</tbody>
</table>

Current injected at HV side and LV side 2 times of full load current and LV side current is reduced.

Table 3.4.3.3 Slope-2 Test Results

3.4.3.4 CALCULATION:

\[
\text{slope} = \frac{\text{IDL}1 - \text{IDL}2}{\text{IB}1 - \text{IB}2} \times 100
\]

\[
\text{slope} = \frac{1425 - 1230}{2127 - 1882} \times 100
\]

\[
\text{slope} = 79.59\%
\]

IV. APPLICATIONS

The protection and control IEDs have many functions included. They included self supervision with internal event list function block provides good supervision of the IED. The fault signals make it easier to analyze and locate a fault.

Both hardware and software supervision is included and it is also possible to indicate possible faults through a hardware contact on the power supply module and/or through the software...
communication. Internal events are generated by the built-in supervisory functions. The supervisory functions supervise the status of the various modules in the IED and, in case of failure, a corresponding event is generated. Similarly, when the failure is corrected, a corresponding event is generated.

V. CONCLUSION

The Protection Scheme with a particular rating of the transformer has been designed. For that rating of the transformer the CT ratio on primary and secondary sides are calculated and by using that ratio HV and LV tripping values are calculated. Now by using PCM600 Connectivity Package the configuration is done.

In PCM600 there are different functional blocks by using those functional blocks the configuration for different faults is done according to the scheme. The harmonic effect and stable operation regions are also taken into consideration. Once the configuration is done it is tested using doble or omicron and parameter setting are done. The test involves pickup test, slope test, stability test etc. the protection for different faults have been done. Hence by doing this, the protection system has become more reliable and efficient. The transformer is protected against different faults by Intelligent electronic device.

References


Journal Papers:


Books: