Application Example
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Applying High Impedance Differential Protection with IED 670

This document described the high impedance differential protection and such applications with 670 series products.

1 High Impedance Differential Protection Basic Principles

High impedance protection system is a simple technique which requires that all CTs, used in the protection scheme, have relatively high knee point voltage, similar magnetizing characteristic and the same ratio. These CT shall be installed in all ends of the protected object. In order to make a scheme all CTs belonging to one phase shall be connected in parallel. From the CT junction points a measuring branch is connected. The measuring branch is a series connection of one variable setting resistor (R_S) with high ohmic value and overcurrent relay. Thus, the high impedance differential protection responds to a current flowing through the measuring brunch. However, this current is result of a differential voltage caused by this parallel CT connection across the measuring branch. This current and voltage are interrelated by Ohms Low. Typical high impedance differential scheme is shown in Figure 1. Note that only one phase is shown in this figure.

Due to the parallel CT connections the high impedance differential relay can only measure the operating quantity. That means that there is no any stabilizing quantity in such schemes. Therefore in order to guaranty the stability of the relay during external faults the operating quantity must not exceed the set pickup value. Thus, for external faults, even with severe saturation of some of the current transformers, the voltage across the CT paralleling point shall not rise above the relay pickup value. To achieve that a suitable value for setting resistor R_S shall be selected in such a way that the saturated CT provides a much lower impedance path as compared with the measuring branch. In case of an external fault causing current transformer saturation, the non-saturated current transformers will drive most of the spill differential current through the secondary winding of the saturated current transformer and not through the measuring brunch. The voltage drop across the saturated current transformer secondary winding will appear also across the measuring brunch, however it will typically be relatively small. Therefore, the pick-up value of the relay has to be set above this false operating voltage.

In case of an internal fault, the fault current tries to flow through the measuring brunch. Due to high ohmic value of RS this will result in a steep voltage increase across the whole scheme and fast saturation of all current transformers. The differential relay is designed to operate under such conditions.

To ensure reliable operation with internal faults, the knee-point voltage of the current transformers used in the scheme must be about two times the set pickup voltage. Often the non-linear resistors are required in order to limit the overvoltages during internal fault to less than 2kV peak value, which is standard insulation level for used for secondary equipment and wiring. The differential protection sensitivity corresponds to the sum of magnetizing currents of all parallel connected current transformers, current drawn by non-linear resistor and the relay operating current for set pick-up voltage.

It shall be kept in mind that the whole scheme, its built-in components and wiring must be adequately maintained in order to be able to withstand this high voltage pulses which appears during internal fault throughout the lifetime of the equipment. Otherwise during fault within the zone of protection any flashover in CT secondary circuits or any other part of the scheme may prevent correct operation of the high impedance differential relay.

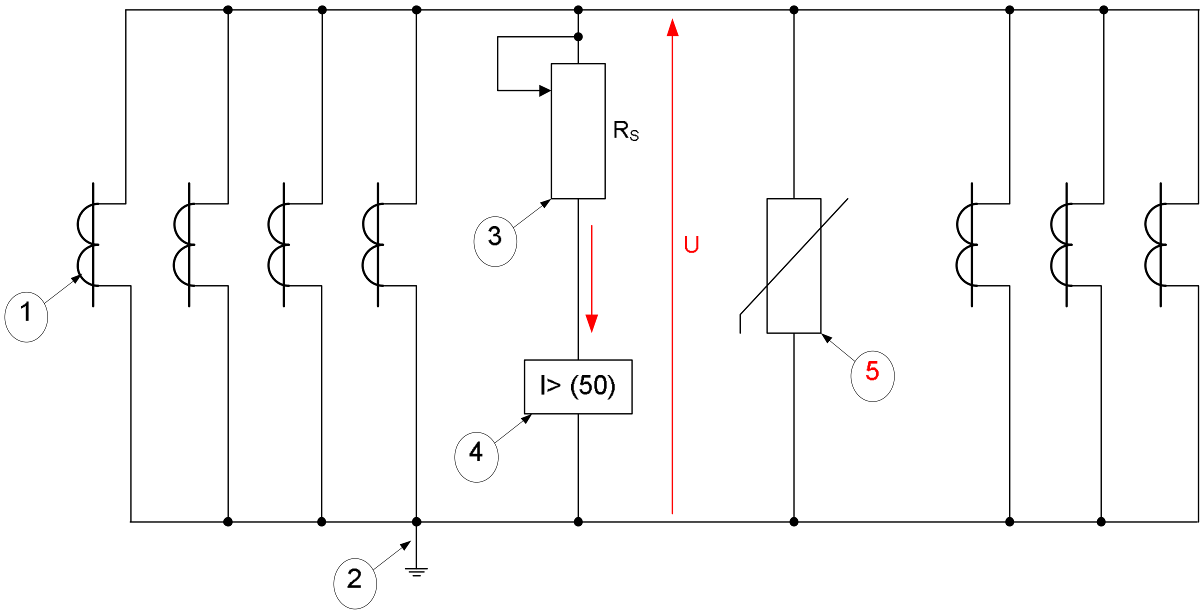

Figure 1: Typical High Impedance Differential Protection Scheme (one phase shown only)

Where:

- Number 1 shows one main CT connected in parallel with all other CTs, from the same phase, connected to this scheme
- Number 2 shows the scheme earthing point. Note that it is of outmost importance to insure that only one earthing point exist in such scheme.

- Number 3 shows the (variable) stabilising resistor R_S
- Number 4 shows the overcurrent relay. Note that the series connection of stabilising resistor and overcurrent element is designated as measuring branch.
- Number 5 shows the non-linear resistor (i.e. metrosil)
- U is the voltage across the CT paralleling point (e.g. across the measuring branch)
- I is the current flowing through the measuring branch
- Note that U and I are interrelated in accordance with the following formula $U=R_S \cdot I$

High impedance differential protection is available in all 670 series products. It is designed as single phase function. Thus, for a phase segregated (i.e. three-phase) application three such functions are required within 670 series software library (i.e. one per phase). Note that this function has strict requirements on main current transformers as stated in IED 670 Application Manual.

This function can be used in many applications. Some typically applications are listed below:

- Generator differential protection;
- Reactor differential protection;
- Busbar differential protection;
- Autotransformer differential protection (for common and serial windings only);
- T-feeder differential protection;
- Capacitor differential protection; and
- Restricted earth fault protection for transformer, generator and shunt reactor windings.

2 Additional Hardware Requirements for 670 Series

Note that additional hardware components, as listed below, are required in such installations:

- setting resistor with high ohmic value; and

- non-linear resistor (i.e. metrosil)

For three-phase high impedance differential protection applications with 670 series three setting resistors (Rs) and three metrosils are assembled on one 4U high, 19” wide plate. The following two versions of such plate are available as optional accessories for 670 series:

- Part No RK 795 101-MB for setting range of 20-100V; Rs=0 - 1,8kOhms
- Part No RK 795 101-DC for setting range of 100-400V; Rs=1,5 - 6,8kOhms

For one-phase applications one setting resistor (Rs) and one metrosils are assembled on a 4U high, 19” wide plate. The following two versions of such plate are available as optional accessories for IED 670:

- Part No RK 795 101-MA for setting range of 20-100V; Rs=0 - 1,8kOhms
- Part No RK 795 101-CB for setting range of 100-400V; Rs=1,5 - 6,8kOhms

Note that metrosils used on all four plates are exactly the same. The voltage-current characteristic for used metrosil is given in Figure 2.

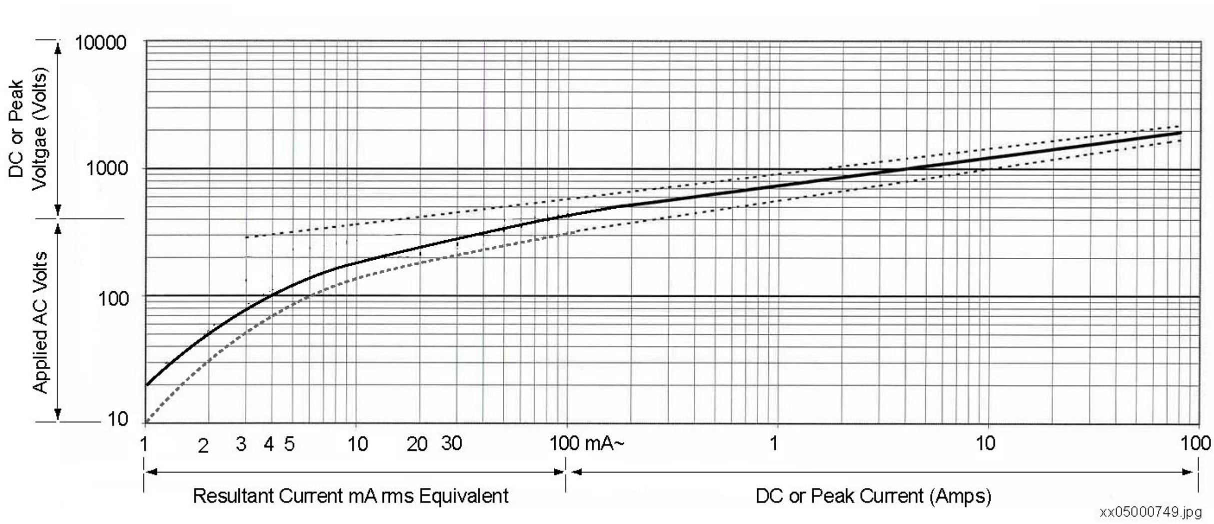

Figure 2: U-I characteristics for the non-linear resistor (metrosil)

Note that exactly the same plates are used for COMBIFLEX® RADHA and RADHD high impedance differential relays.

3 Connections for three-phase high impedance differential protection

Generator, reactor or busbar differential protection is a typical application for three-phase high impedance differential protection. Typical CT connections for three-phase high impedance differential protection scheme with 670 series are shown in Figure 3.

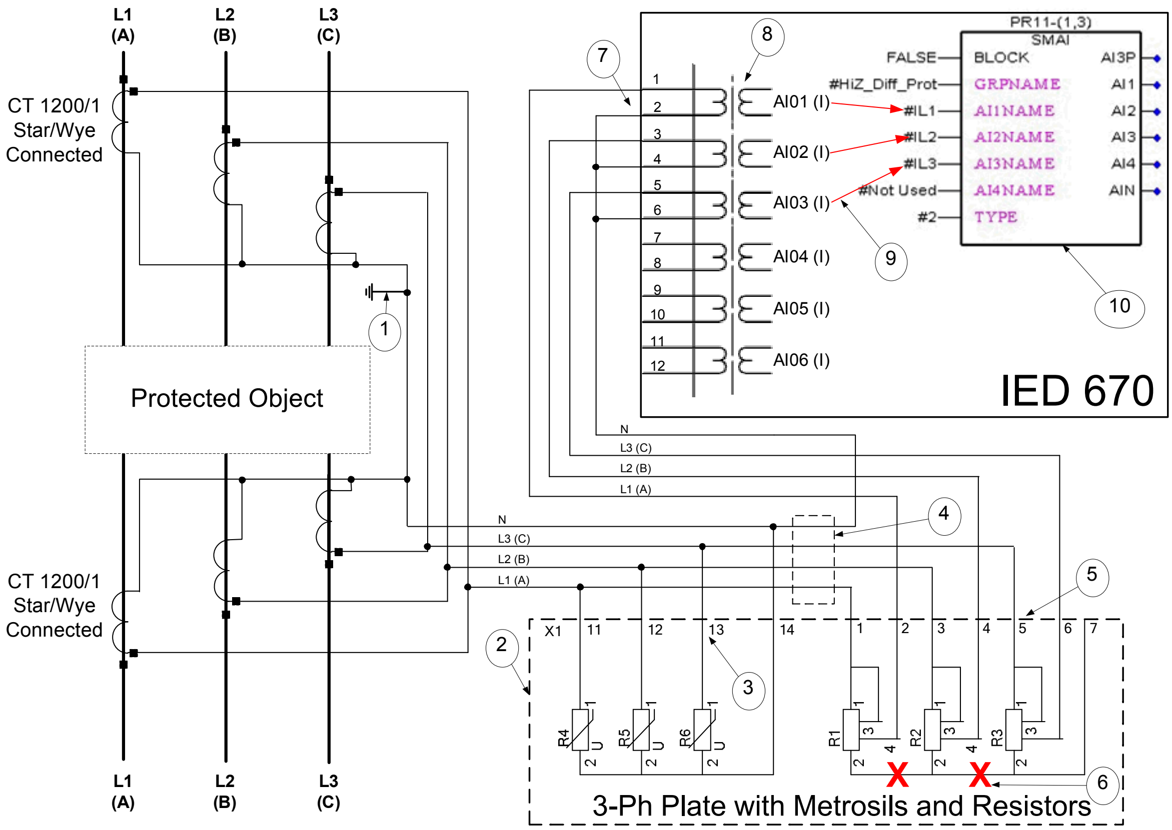

Figure 3: CT connections for High Impedance Differential Protection

Where:

- Number 1 shows the scheme earthing point. Note that it is of outmost importance to insure that only one earthing point exist in such scheme.
- Number 2 shows the three-phase plate with setting resistors and metrosils.
- Number 3 shows the necessary connection for three-phase metrosil set. Shown connections are applicable for both types of three-phase plate.

- Number 4 shows the position of optional test switch for secondary injection into the high impedance differential relay.

- Number 5 shows the necessary connection for setting resistors. Shown connections are applicable for both types of three-phase plate.

- Number 6 shows that the factory made star point on a three-phase setting resistor set **shall be removed** for installations with 670 series. This star point is required for RADHA schemes only!

- Number 7shows how to connect three individual phase currents for high impedance scheme to three CT inputs in IED 670.

- Number 8shows a TRM module where these current inputs are located. Note that the CT ratio for high impedance differential protection application must be set as one! Thus for main CTs with 1A secondary rating the following setting values shall be entered: *CTprim*=1A and *CTsec*=1A; while for main CTs with 5A secondary rating the following setting values shall be entered: *CTprim*=5A and *CTsec*=5A. The parameter *CTStarPoint* shall be always left to the default value ToObject.

- Number 9 shows three connections made in Signal Matrix Tool (i.e. SMT) which connect these three current inputs to first three input channels of the preprocessing function block (10). For high impedance differential protection preprocessing function block in 3ms task shall be used.

- Number 10 shows the preprocessing block which has a task to digitally filter the connected analogue inputs. Preprocessing block outputs AI1, AI2 and AI3 shall be connected to three instances of high impedance differential protection function blocks (e.g. HZD1, HZD2 and HZD3 function blocks in the configuration tool).

4 Connections for one-phase high impedance differential protection

Restricted earth fault (REF) protection is a typical application for one-phase high impedance differential protection. Typical CT connections for high impedance based REF protection scheme with 670 series are shown in Figure 4.

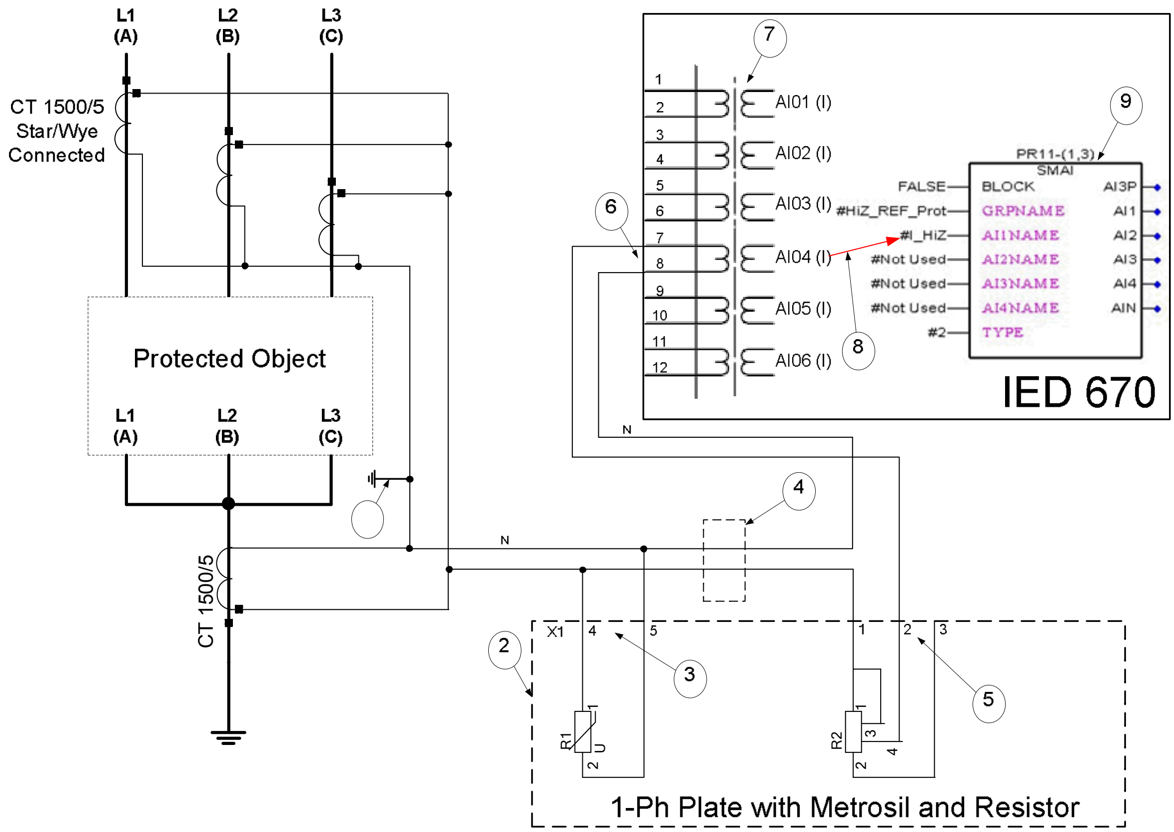

Figure 4: CT connections for Restricted Earth Fault Protection

Where:

- Number 1 shows the scheme earthing point. Note that it is of outmost importance to insure that only one earthing point exist in such scheme.
- Number 2 shows the one-phase plate with setting resistor and metrosil.
- Number 3 shows the necessary connection for the metrosil. Shown connections are applicable for both types of one-phase plate.

- Number 4 shows the position of optional test switch for secondary injection into the high impedance differential relay.

- Number 5 shows the necessary connection for setting resistor. Shown connections are applicable for both types of one-phase plate.

- Number 6 shows how to connect the REF high impedance scheme to one CT input in IED 670.

- Number 7 shows a TRM module where this current input is located. Note that the CT ratio for high impedance differential protection application must be set as one! Thus for main CTs with 1A secondary rating the following setting values shall be entered: *CTprim*=1A and *CTsec*=1A; while for main CTs with 5A secondary rating the following setting values shall be entered: *CTprim*=5A and *CTsec*=5A. The parameter *CTStarPoint* shall be always left to the default value ToObject.

- Number 8 shows a connection made in Signal Matrix Tool (i.e. SMT) which connects this current input to first input channel of the preprocessing function block (10). For high impedance differential protection preprocessing function block in 3ms task shall be used.

- Number 9 shows the preprocessing block which has a task to digitally filter the connected analogue inputs. Preprocessing block output AI1 shall be connected to one instances of high impedance differential protection function block (e.g. HZD1 function block in the configuration tool).

5 Available Features with 670 series

The high impedance differential protection function in 670 series is based on long experience obtained from COMBIFLEX® RADHA and RADHD high impedance differential relays. Their measuring principle has been replicated into the "digital world". This insures fast and correct operation of this function as well as excellent rejection of a DC component commonly present in the power system fault current.

By using advances of the numerical technology the RMS value of the measured voltage U (from Figure 1) is available as a service value from the function. Thus it can be monitored during secondary testing and normal operation of the relay. At the same time it can be connected to the disturbance recorder in order to evaluate operation of the high impedance differential relay during external/internal faults. Separately settable Alarm Stage is as well available. It can be typically used for busbar protection applications where many CTs are connected to the same differential relay.

Pickup value for the high impedance differential scheme is set in secondary volts. At the same time the actual value of the setting resistor R_S shall be entered as well. From these two parameters relay re-calculates the required secondary current pickup value and operates accordingly. More information regarding setting calculation, selection of R_S value and configuration of the relay can be found in [1].

It is also quite easy to add additional tripping criteria for high impedance differential protection. Due to configuration facility of 670 series undervoltage release or overcurrent release from the incoming feeders can be easily engineered in the differential protection scheme.

Finally it is possible to use the communication facility of 670 series, including IEC 61850, to interface the high impedance differential scheme to the substation control system. Thus all alarms, operation indications, events and service values can be made available to the substation control or SCADA system.

6 Summary and conclusions

670 series gives possibility to apply high impedance differential protection as main or backup protections for different power system elements. This function is available in all 670 series products giving interesting application possibilities such for example is T-feeder differential protection in Distance Protection REL 670 for one-and-a-half breaker station arrangment. Due to fully numerical implementation all benefits of the numerical technology of the 670 series platform are readily available.

7 References

[1] ABB Document No: 1MRK 504 089-UEN; Application manual “Transformer protection IED RET 670”; Product version: 1.1; Issued: March 2007