Supervised Zone-3 Distance Relay Protection: Prototype Evaluation

Version 1.0

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Revisions History

Version	Date
1.0	May 21, 2016

Typographical Conventions

Information	Formatting Convention
Key Names	Keys on the keyboard appear in title case (first letter in upper case). For example, Page Up, Caps Lock. A combination of keys is connected by a +. For example, Shift + Tab means you should press the Shift key and Tab key together.
Filenames	Names of files are italic. Example, *CaseStudy.dat*
Command and **Screen** element names	Buttons, check boxes and commands that chosen from the menus dialog boxes appear in bold font. Example: Click **Components** from the **Action** menu.
File/directory path, urls	All navigation paths are typographed in sans-serif font. Example: http://www.iitb.ac.in

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1 Introduction

The purpose of "Supervised Zone-3 Distance Relay Protection" analytic is to provide a supervisory scheme to avoid incorrect zone3 relay operation. Incorrect Zone3 relay operation may be a consequnce of either

1. quasi-stationary events like load encroachment, overload and undervoltage, or,
2. electromechanical oscillations like power swings.

Such mal-operation can act as a catalyst for or even trigger a system collapse situation.

A distance relay is immune to communication system failure since it relies solely on local measurements. However, relying only on local measuremets is also the reason behind its incorrect tripping. On the other hand, differential current provides excellent discrimination between faulted and unfaulted transmission line. However, it requires measurements to be communicated from each end to the other. The associated delay with communication means that except for short enough lines, this scheme is not feasible as primary protection i.e., Zone-1 and Zone-2. In contrast, Zone-3 operates in around a second, providing ample time to communicate the information. Using this idea and with PMUs installed at both end of the transmission lines, a supervision scheme for Zone-3 protection can be achieved.

2 Philosophy

With PMUs placed at both ends of the transmission lines, differential currents can be computed. Once differential currents for all backed up lines are available, it is trivial to ascertain whether the Zone-3 of the back up relay should be blocked or not. Once, the Zone-3 is blocked, the relay won't operate even if it sees low impedance. The critical aspect is that the whole procedure, i.e. obtaining syncrhophasors from PMUs, differential currents computation and thereater communicating appropriate decision to relay, should happen well within one second.

This scheme can even be used to signal *accelerated* trip in case a fault is actually observed. Consequently, we have ASSERT_BLOCK and ASSERT_TRIP signals to be communicated to the relay. The later can be used for accelerated trip. Further, if enough information is not available to ascertain whether there is actually a fault in any of the backed up lines or not, then the scheme cannot issue either of the command with certainty. This can happen due to communication failure or unreliable data. Hence, a third signal is required to indicated undecided, which we call as ENABLE_TRIP.

Under normal conditions, when apparent impedance is far from, Zone-3 of relays are not required to be blocked. The requirement arises only if it enters Zone-3. Hence, rather than sending a decision for each PMU sample (every

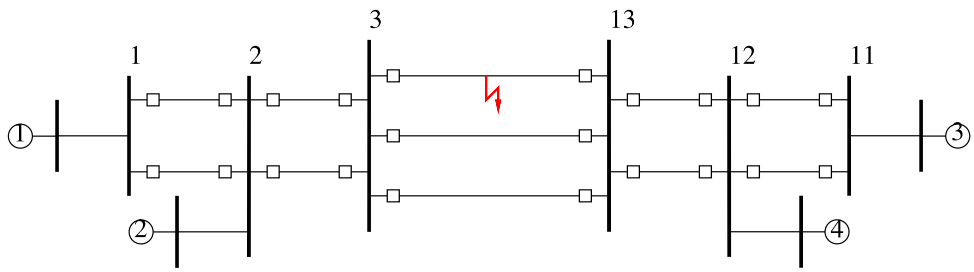


Figure 1: Four machine ten bus test system

20-40 msecs) we can start communicating as soon as apparent impedance is close enough to Zone-3. Also, as soon as the impedance is far enough, communication can be stopped. Toe define closeness, we construct an *envelope* zone, which is magnified version of Zone-3 by certain factor. We have used the factor of 1.3. If for a certain period (slightly longer than sampling period), no *decision* is received from the server, the state at the relay end will be set back to ENABLE_TRIP. We have used this timeout duration to be 50 msecs.

With this strategy, it will be necessary to enter relay characteristics at the analytic server end. The entered relay characteristics, if not accurate, should at least closely resemble the actual.

3 Case Studies

The prototype has been demonstrated over a four machine ten bus test system as shown in fig. 1. Samples have been generated through transient stability analysis. A fault is created on one of the line between Bus-3 and Bus-13. Different scenarios are constructed based on type of fault and how the protection system behaves. Relay at Bus-2 on one of the line between Bus-2 and Bus-3 is monitored.

Scenario 1. Single Phase to Ground Fault

Case 1a Cleared by SPS at both ends in Zone-1 and reclosed. As seen in fig. 2 ASSERT_TRIP is sent for a short while. However, once the fault is cleared in Zone-1, the apparent impedance moves out of the envelope. This causes the analytic to stop sending futher messages. As a result, the receiver times out and the state is reset to ENABLE_TRIP.

Case 1b Cleared by SPS at both ends in Zone-1 and failed reclose resulting in line tripping. Again, as seen in fig. 3, the fault causes the apparent impedance to enter the envelope, but as soon as the fault is cleared, it is out of the envelope. Fault persists while attempting reclosing causing the tripping again. Which repeats the earlier cycle. Hence, we observe two ASSERT_TRIP pulses of short duration.

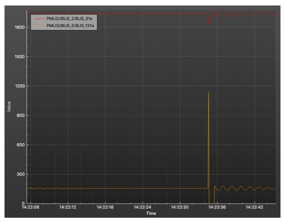
Case 1c Cleared by SPS at Bus-13 end in Zone-1 and failed protection at Bus-3 end. Since the fault remains feeding at Bus-3 end, Zone-3 will keep sensing the fault. With ASSERT_TRIP signal, tripping can be accelerated. As observed in fig. 4, ASSERT_TRIP message is received for a quite a long duration.

Scenario 2. Single Phase to Ground Fault

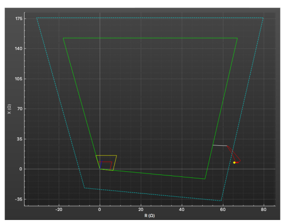
Case 2a Cleared in Zone-1 at both ends. As the fault is cleared in Zone-1, impedance trajectory enters the envelope and Zone-3 for a very short duration. During this period, ASSERT_TRIP signal is received. As the apparent impedance exits the envelope as soon as the fault is cleared, no further message is transmitted. Consequently, ENABLE_TRIP state is attained and remains there. Since, relay will observe the impedance outside the Zone-3, tripping won't happen. This observation can be seen in fig. 5.

Case 2b Cleared in Zone-1 at Bus-13 ends and Zone-2 at Bus-3. As the fault is cleared in Zone-2 at Bus-3, the relay at Bus-2 and on the line between Bus-2 and Bus-3 will find the impedance to be on lower side for a bit longer duration. This will have imparted enough oscillation into the system causing the relay to still repeatedly observe lower impedance even after the fault is cleared. This is the period when Zone-3 of the relay need to be blocked. Fig. 6. Initially, till the fault is not cleared in Zone-2, ASSERT_TRIP is transmitted for this short duration. Thereafter, bursts of ASSERT_BLOCK, with reducing width, is received.

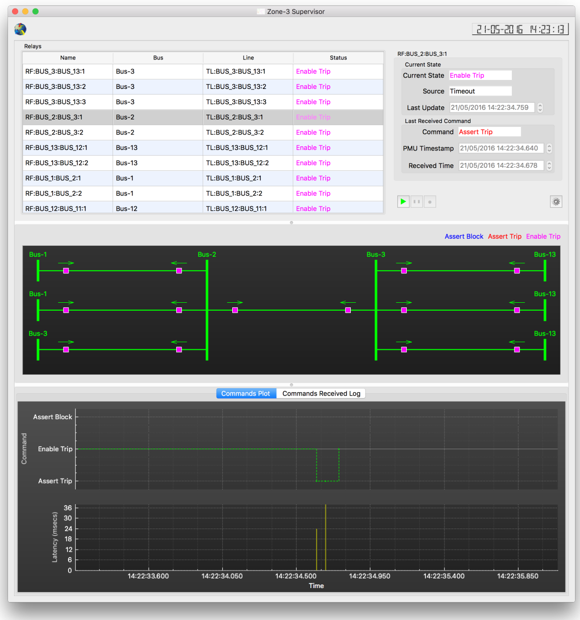
Case 2c Cleared in Zone-1 at Bus-13 ends and one pole stuck at Bus-3. The observation, as seen in the fig. 7, is similar to that in the Case 1c.



(a) Current magnitude plots

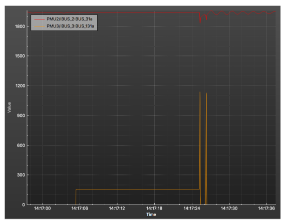


(b) Apparent impedance trajectory as seen by the relay

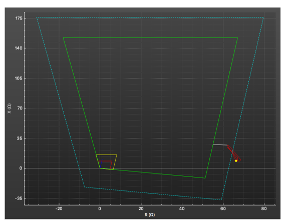


(c) Generated signals

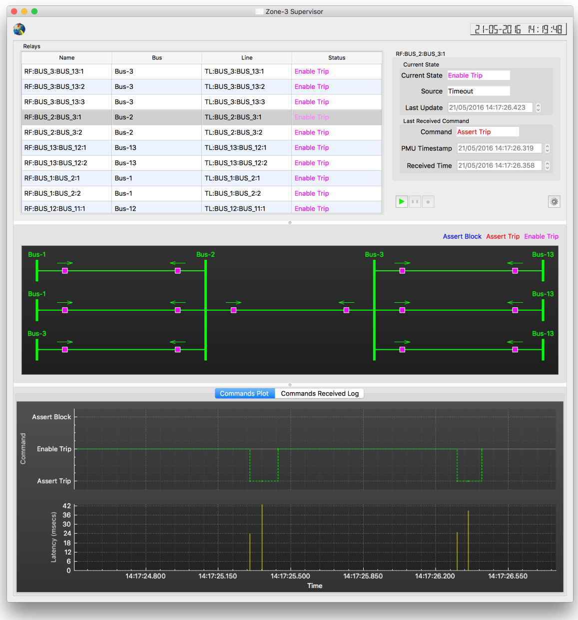
Figure 2: Output from the software for case 1(a)



(a) Current magnitude plots

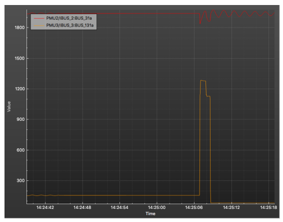


(b) Apparent impedance trajectory as seen by the relay

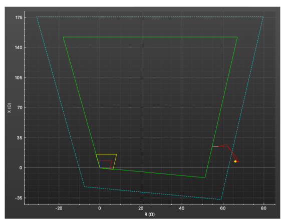


(c) Generated signals

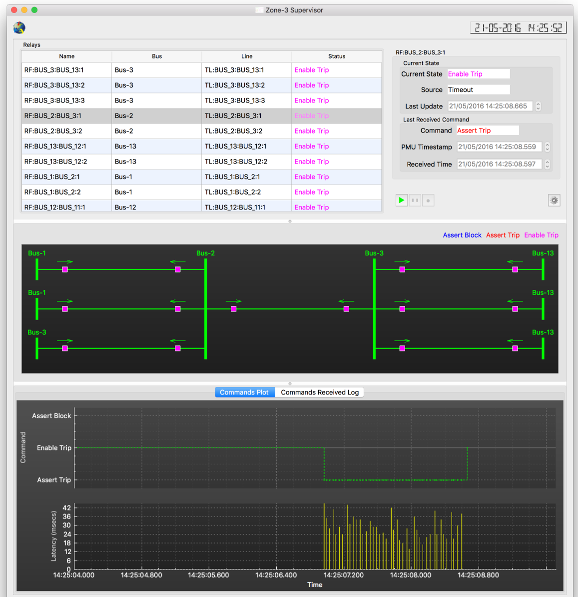
Figure 3: Output from the software for case 1(b)



(a) Current magnitude plots

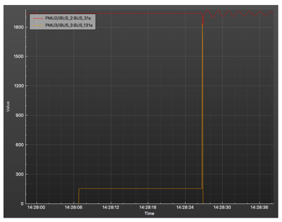


(b) Apparent impedance trajectory as seen by the relay

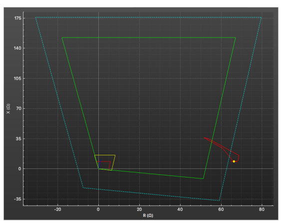


(c) Generated signals

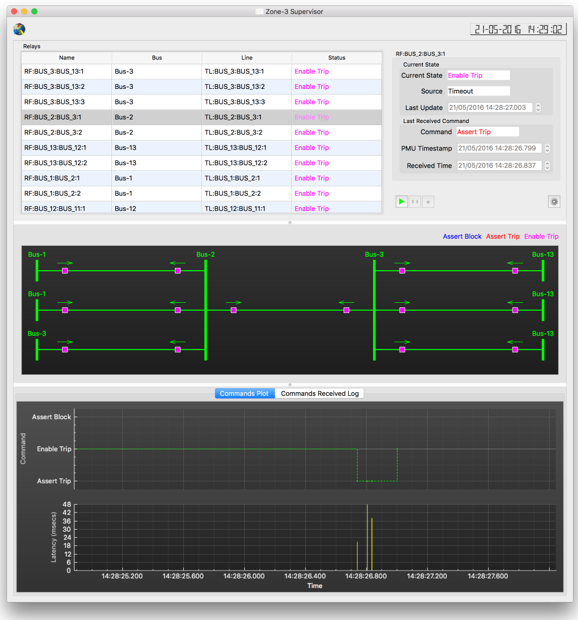
Figure 4: Output from the software for case 1(c)



(a) Current magnitude plots

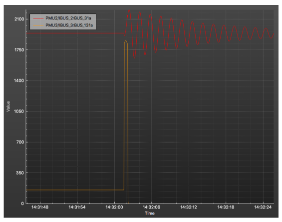


(b) Apparent impedance trajectory as seen by the relay

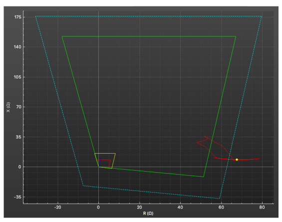


(c) Generated signals

Figure 5: Output from the software for case 2(a)



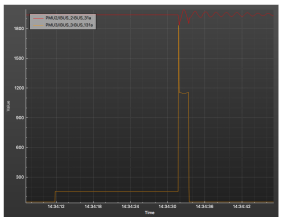
(a) Current magnitude plots



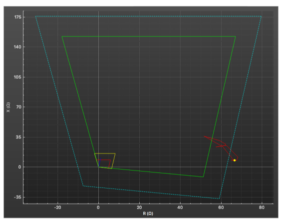
(b) Apparent impedance trajectory as seen by the relay

(c) Generated signals

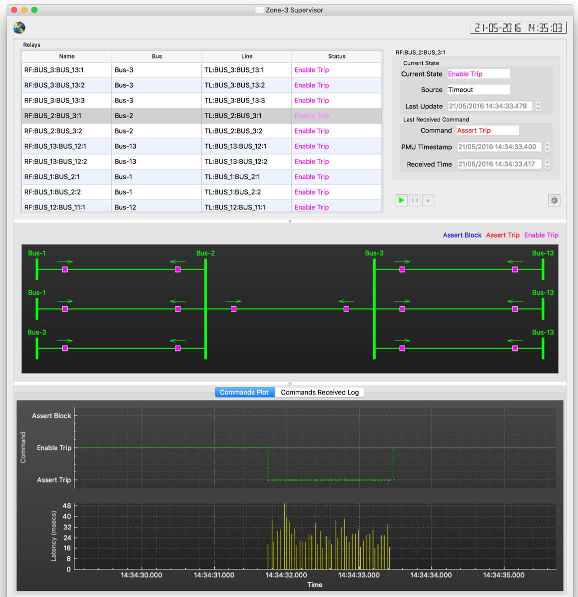
Figure 6: Output from the software for case 2(b)



(a) Current magnitude plots



(b) Apparent impedance trajectory as seen by the relay



(c) Generated signals

Figure 7: Output from the software for case 2(c)

3.1 Interfacing with Relay

Relay interfacing was demonstrated using :emote I/O unit by Masibus over modbus protocol establishing the feasibility of closed loop operation.

4 Concluding Remarks

Certification

Certified that results of Supervised Zone-3 Distance Relay Protection analytic were analyzed on simulated data. Performance has been found to be satisfactory.

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