



B5 - Protection & Automation Committee

PS2 - Applications of emerging technology for protection, automation and control

Paper ID - 968

Automated Hardware in the Loop test bed for protection relays using a decision three algorithm

Mauricio SÁNCHEZ; Jose MONTOYA; Jhonatan ANAYA

XM : Intercolombia

The problem

- Most TSO in Colombia must validate the expected behavior of protection relays due to new relay models or firmware upgrades.
- Extensive Protection & control tests for new projects, commissioning and relay malfunction are also carried out very often

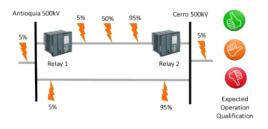


Photo credit: elect-pc.com

 With a fleet of around 2300 relays for Colombia alone, this processes has been time demanding and needs the involvement of very skilled protection engineers.

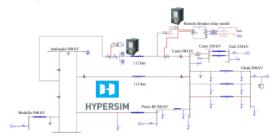
Approach and Value Proposal

- Automate the execution of multiple distance relay tests and operation scenarios
- New possibility to test the real relays of both ends of the line interacting
- Relays measuring Sampled Values and GOOSE signals for tripping and interacting
- Automate Comtrade file analysis and reporting



Network digital twin

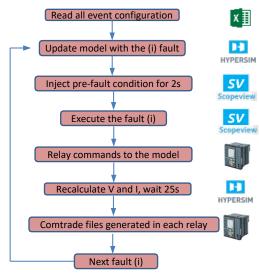
Development and validation against ATP of a digital twin of a portion of the network (7 nodes + equivalents)



Test bed HIL arquitecture



The Automatic Test Sequence







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10 Protection functions in the route map

Line distance protection relay

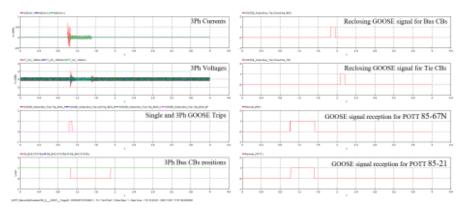
Protection function (ANSI code)	Description
21	Distance (impedance)
67N	Directional overcurrent
85-21	Permissive Over-Reaching Transfer Trip (POTT)
85-67N	Directional Overcurrent comparison scheme (67NCD)
LOP	Loss of potential
SOTF V	Switch onto fault
27/59	Low/over voltage
25	Synchro check
79	Reclosing scheme
PD	Pole discrepancy

13 Binary variables used for the evaluation logic

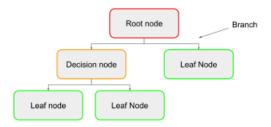
Variable	Description
TripPa	Trip phase A
TripPb	Trip phase B
TripPc	Trip phase C
Pickup FW	Forward direction detection
Pickup BW	Backwards direction detection
Trip Rev	Trip reverse zone
Trip Z2	Trip Zone 2
Trip Z1	Trip Zone 1
Trip 67N	Directional overcurrent trip 67N
85-67N Op	Directional overcurrent comparison trip
85-67N Send	Directional overcurrent comparison signal send
85-21 Op	Permissive Over-Reaching Transfer trip
85-21 Send	Permissive Over-Reaching Transfer - signal send

HIL test example

Typical HIL test for a phase A to ground fault in the middle of the line is presented. The overcurrent and undervoltage produced by the short – circuit are seen by the relay which short after, sends trip signal to phase A CBs, followed by a successful reclosing to normalize the line operation.



Decision Tree generic scheme



The data set needed to train the Decision Tree algorithm was built with the experience of an expert in power system protections, putting his knowledge in a data set containing around 3000 combinations for 30 event cases. These combinations are variations of relay responses that can be possible to occur due to its parameter's configurations, firmware version, and some other situations.





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Output report for a case of intentional POTT failure

Case	Calification	Distance	85 - 21 Op	85 - 21 send	85 - 67N Op	86 - 6771 servid	Phase Selection	Three Phase Operation for Single Phase Fault		
Case 1	Correct with Anomaly	Without Operation 21 Correct	Without Operation Incorrect	Omisión Sendjincorrect	Operation Correct	Seed Correct	Incorrect Selection of Faulty Phase	Three Phase Operation		
Case 2	Correct with Anomaly	Operation 21 Correct	Without Operation Incorrect	Send Omission Incorrect	Without Operation Incorrect	Send Correct	Incorrect Selection of Faulty Phase	Three Phase Operation		
Case 3	Correct with Anomaly	Operation 21 Correct	Without Operation Incorrect	Send Omission Incorrect	Without Operation Incorrect	Send Correct	Incorrect Selection of Faulty Phase	Three Phase Operation		
Case 4	Correct with Anomaly	Operation 22 Correct	Without Operation Correct	Send Omission Incorrect	Without Operation Correct	Send Correct	Correct Selection of Faulty Phase	-		
Case 5	Correct	Opera 24(Correct	Without Operation Correct	Send Omission Incorrect	Without Operation Correct	Send Omission[Correct	Correct Selection of Faulty Phase			
Case 6	Correct with Anomaly	Operation Z1 Correct	Without Operation Incorrect	Send Omission Incorrect	Without Operation Correct	Send Omission Correct	Correct Selection of Faulty Phase	-		
Case 7		Operation 21 Correct	Without Operation Incorrect	Send Omission Incorrect	Without Operation Incorrect	Send Omission Incorrect	Correct Selection of Faulty Phase	-		
Case 8	Correct with Anomaly	Without Operation 21 Correct	Without Operation Incorrect	Send Omission Incorrect	Operation Correct	Send Correct	Incorrect Selection of Faulty Phase	Three Phase Operation		
Case 9	Correct with Anomaly	Operation 21 Correct	Without Operation Incorrect	Send Omission Incorrect	Without Operation Incorrect	Send Correct	Incorrect Selection of Faulty Phase	Three Phase Operation		

Case	Californion	Distant	81-21Op	H-Dond	III - 1174 Ch	M - C'Ni ared	Phase Infestion	These Phase Operation to Disgle Phase Field	Gintaner Operation Debutter	POTT and Decree	EPMESE Erest Osesseles	POTT Outcodes	EDMDC Destroite	Open Pade Automino	POST Secured Secure	STACK Incomesi Canada	Talp open pilles for Other Francisco	Phase Selection or Execu-	Arthretten Outcolen	21 Deserved	21 Condemnents	Con Phase Complies for Two Phase Fault	Trip Eponation For Entered	Bredding
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Conclusions

- A successful implementation of an automatic test bed for distance relays was achieved along with automated analysis and classification of events
- Great value in effort and time saving is foreseen
- Due to the fast diagnosis and time saving, more test scenarios could be implemented. This would lead to better relay settings and protection logics to increasing security and reliability

Future work

- Expand the knowledge data base with more binary signals and include response time for the DT algorithm to cover more possible relay behaviors
- Create the ability to test multiple relay brands
- Develop the test bed for transformer, generator and differential protections
- Turn this prototype into a IEC61850 test bed to help TSOs address the substation digitalization

16 min. for 30 events
6 s for analytics & reporting

