Technical Paper

الدار الدولية للهندسة
DAR ENGINEERING

THE EFFECT OF THE FAULT IMPEDANCE ON THE PERFORMANCE OF THE DIRECTIONAL OVER CURRENT AND DIRECTIONAL EARTH FAULT RELAYS IN COMPENSATED AND UNCOMPENSATED TRANSMISSION LINE NETWORKS-A CASE STUDY.

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Study committee D1

Protection & control

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The Effect of the Fault Impedance on the Performance of the Directional Over Current and Directional Earth Fault Relays in Compensated and Uncompensated Transmission Line Networks-A case study.

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Motivation

- In case of compensated transmission lines, protection engineers face a lot of problems in settings of protection relays such as voltage inversion phenomenon in directional and distance relays and zone discrimination for distance relays.
- A New relay algorithm was proposed and proved its strength against all types of short circuit faults considering fault resistance in analysis where in all cases mal-operation is avoided and the relay correctly detects the fault either in forward or in reverse direction. The algorithm uses Phasor Measurement Units (PMU's) to provide synchronized real-time measurement of voltage signals at remote end substation .These PMU's are widely used in the last few decades in power system protection system for Wide Area Monitoring, Protection, and Control (WAMPC).

Method/Approach

- The Technical approach is based on a new relay algorithm that depends on the remote end phase voltage as a polarizing quantity and considering its direction as a separation between operating and restraining zones.

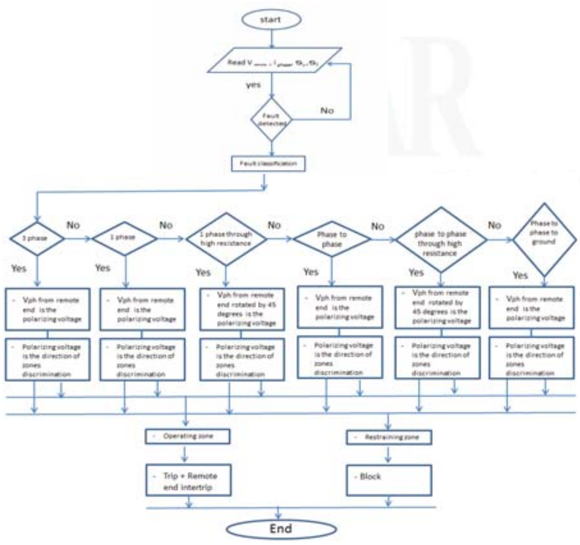

Fig 1 : Proposed algorism

Objects of investigation

- SEC (Saudi Electricity Company) decided to boost the power transmission capability between the central and western transmission operating areas because of fast-growing electrical power demand in both networks.
- For this purpose they have established a project for installation of Fixed Series Capacitors (FSC) on the midpoint of the 380 kV overhead transmission line between MADINAH-EAST and QASSIM-2 substations.

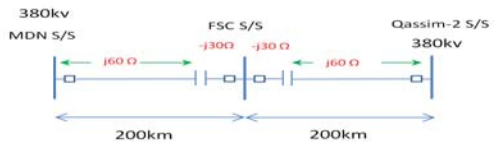

Fig 2: System under study

Parameter	Value
System Rated Voltage	380 kV
System Frequency	60 Hz
System X/R Ratio	50
Maximum Short Circuit Level	63 kA
Positive-Sequence Source Impedance	0.07 + j 3.482 Ω/ph
Line Length (MDN–FSC or FSC–QASS)	200 km approximately
Positive-Sequence Line Impedance	0.017059+j0.3227 Ω/km/ph
Series Capacitor Rated Power	474.4 MVAR
Series Capacitor Rated Current	2255 A
Series Capacitor Reactance	30Ω/ph approximately
Series Capacitor Capacitance	85.29 µF/ph
Series Compensation Degree	50 % approximately

table: System parameters

Experimental setup & test results

- In order to overcome the voltage inversion phenomenon that results from the presence of series compensation, an algorithm is proposed which mainly depends on taking the polarizing voltage for the DOC relays at FSC substation from remote end substation (Qassim-2) S/S.
- 1st **a 1LG fault without fault resistance** was performed on phase (a) on line (FSC- Qassim-2); the fault distance was varied with respect to FSC SS (20, 40 … 180 KM),

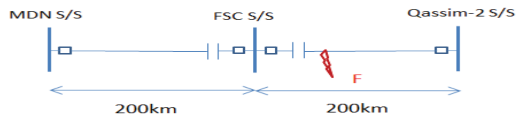

Fig 3: Forward Fault (1L-G) at distance < 100 km of the T.L between FSC S/S & Qassim-2 S/S

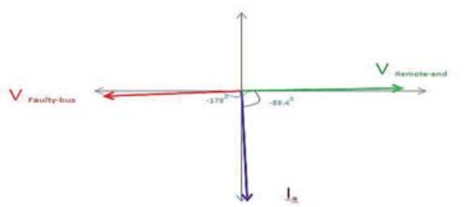

Fig 4:Direction of phase voltage & current at the faulty bus at distance < 100 km of the T.L along with the voltage at the remote end.

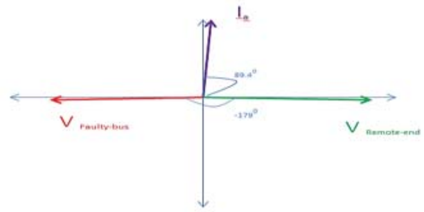

Fig 5: Reverse Fault (1L-G) at distance < 100 km of the T.L between FSC S/S & Qassim-2 S/S

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Experimental setup & test results (cont.)

- 2nd **a 1LG fault with fault resistance** was performed on phase (a) on line (FSC- Qassim-2).

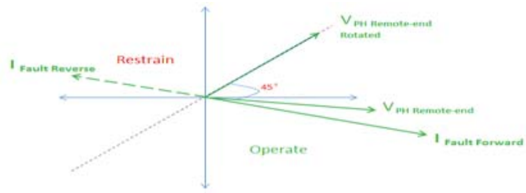

Fig 6:Forward Fault (1Lg) With R at the T.L between FSC S/S & Qassim-2 S/s

- 3rd ***a L-L fault without fault resistance:***

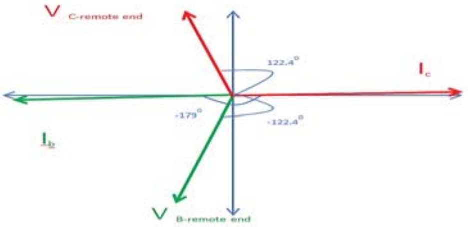

Fig.7:Forward Fault (L-L) Without R at the T.L between FSC S/S & Qassim-2 S/s

- 4th **a *L-L fault with fault resistance***

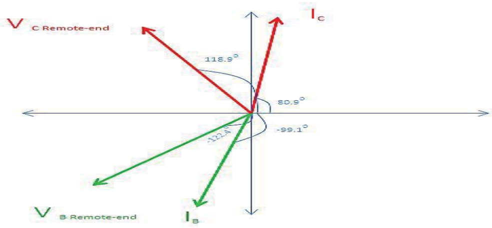

Fig.8: Forward Fault (L-L) With R=200Ω at the T.L between FSC S/S & Qassim-2 S/S without RCA

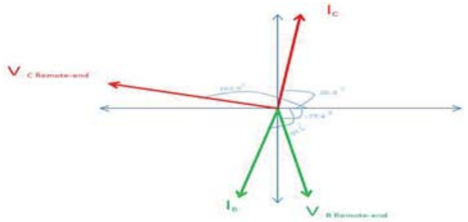

Fig.9: Forward Fault (L-L) With R=200 Ω at the T.L between FSC S/S & Qassim-2 S/S with RCA=45 deg.

- ***5TH Line to line to ground fault:***

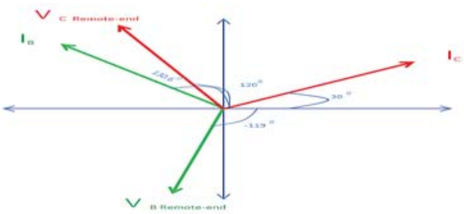

Fig.10Forward Fault (L-L) to ground Without Resistance at the T.L between FSC S/S & Qassim-2 S/S

Discussion

- In *1LG fault without fault resistance* It is clear that if we take the phase voltage Va at FSC SS as a polarizing quantity, voltage inversion will occur , However if we take the phase voltage Va of Qassim-2 SS as a polarizing quantity to the DOC relay at FSC SS will correctly see the fault as a forward one. Also in reverse faults with respect to FSC, the relay will discriminate the fault in reverse direction as well.
- *In 1LG fault with fault resistance* the operating current direction will theoretically lay in operating zone &it will be so close from the restraining zone and hence it is suggested to rotate the polarizing voltage by an RCA angle 45 deg. for safe operation. For reverse faults operating current will be as far as possible from operating zone.
- In *L-L without fault resistance* the operation will be safe and the DOC relay will detect the fault correctly as a forward fault or reverse fault.
- In *LL fault with fault resistance B*y increasing the fault resistance to 200 Ω and for a forward fault, one of the faulted phases will miss-detect the fault while the other phase still sees the fault in the forward direction ,so that a relay characteristic angle (RCA) shall be added to the polarizing remote end voltage by 45 deg.
- In *Line to line to ground fault* Analysis shows that whatever was the value of fault resistance the relay can safely detect the forward and reverse faults

Conclusion

- The effect of the arc resistance, tower footing resistance and resistivity of nearby soil seen by the directional relay during a fault has a great influence on its behavior when used for protection of overhead transmission lines.
- New relay algorithm was proposed that depends on the remote end phase voltage as a polarizing quantity and considering its direction as a separation between operating and restraining zones. The algorithm has proved its strength against all types of short circuit faults considering fault resistance in analysis where in all cases mal-operation is avoided and the relay correctly detects the fault either in forward or in reverse direction.


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