# A Novel Approach for Faulty Phase Detection of Series Compensated Transmission Line

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**ABSTRACT**- Like fault location and identification and Classification, faulty phase identification is also an important aspect, if any fault has been taken place in the transmission line. This will help to take preventive measures and quick fault restoration. In this paper a method is discussed to identify the phase of the fault by using the sampling of voltage and current waveforms in the system with different conditions and cases and with different fault data's by using SMIB and WSCC-9bus system. Like in case of an LG fault, fault could be a Ph-A to G or Ph-B to G or Ph-C to G type. It is seen that phase of the fault can be predicted from the study of the properties of voltage and current waveform samples by using certain mathematical operator on it. Fault data is obtained through simulation of the studied system implemented by PSCAD/SIMULINK/EMTDC software.

**Index Terms:** Faulty Phase Identification, Greatest change, Voltage, Current, fault resistance, Distance, Sampling.

## I. Introduction

In Power system majority of the faults are happened to be single line to ground fault [9]. Other than this, other important type of faults are LLG, LLL, LL, LLLG faults. In case any of these types of faults happens in the system, it is necessary to detect the presence, type, location as well as which phase involves fault to diagnose and restoration of the fault. Earlier the line or phase of the fault is tried to identify with the help of the electromagnetic coupling approach between faulty phases and non-faulty phases in a wide range of free oscillation frequency enables us to extract multiple frequency signals from non-faulty phases that includes the information of the free oscillating components of transient current in the faulty phase[8].In order to identify the faulty phase/line, many principles and methods have been proposed earlies line opening line approach, the injection signal technique and methods based on steady state components of fault currents. All the methods having many drawbacks like long outage time, inaccuracy and improper operation.

This paper presents a new method for identification of the faulty phases in case of occurance of fault in a transmission line. The Technique here is used by tracking the greatest change of current and greatest current sample or the least change of voltage and the least voltage sample. The faulty phase can be identified fast, accurately and reliably. The faulty data is provided by simulation of the studied system implemented by PSCAD/SIMULINK/EMTDC software. Other than this software mat lab codings are used to do complex and indispensible long calculations.

## II.Studied System

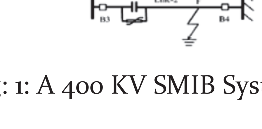


Fig: 1: A 400 KV SMIB System

The system is simulated using PSCAD to develop fault voltage and current signals including harmonics and decay DC components in addition to the fundamental frequency. Both Line1 and Line2 are 40% compensated here. Different types of faults are created at different conditions and combinations and with the proposed methodology the phase of the fault is detected.

## III. Proposed Methodology for Detection of Faulty Phase/phases

Faulty phase identification can be categorized into two cases.

1) When only one Phase is involved in fault.
2) When more than one phase is involved in fault.

The necessary parameters required for the calculation are as follows:

a) Greatest Voltage
b) Greatest Change in Voltage
c) Greatest Current
d) Greatest Change in current.

The necessary steps for computation are as follows:

1) Sampling the simulated voltage and current waveforms.
2) From the samples calculate either greatest current and greatest change in current or greatest voltage and greatest change in voltage containing sample.
3) The phase which contains the greatest change in current sample or least change in voltage sample must contain fault. This will eliminate the problems of Zero Crossing Detector (ZCD) Case.

Now check for whether two or more phases contain fault or not. The computational steps are as follows:

1) Find out greatest current or least voltage contain sample.
2) Check the magnitude of the all the phases of current or voltage of that particular sample. If the values are found within ±5% tolerance limit of the greatest current or least voltage then those Phase or Phases will also contain the fault. Due to discrete time samples taken during the experiment the values of all the phases may not be exactly equal, so, a tolerance limit in the magnitude is set up. If the sampling frequency is increased then the accuracy of the algorithm will also be increased. Here sampling frequency is used 4KHZ for the work of this particular paper.

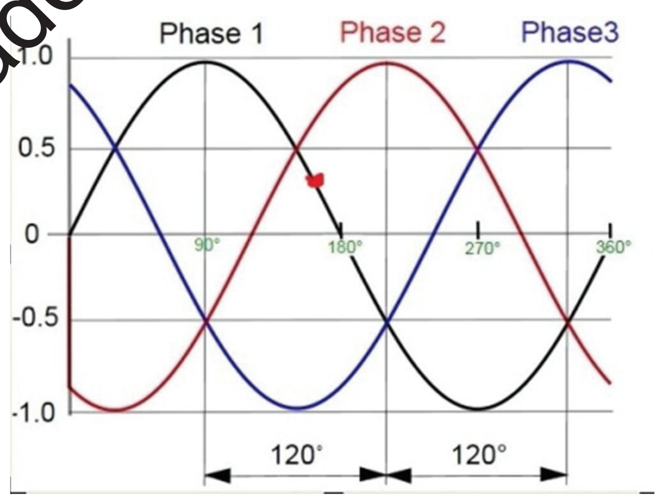


Fig2: A 3-Ph Waveform (Red mark Indicates the Occurrence of the fault-ZCD case)

## IV. Case-I

## Smib Test System & Results

Different types of faults are created by varying different parameters of the system like fault resistance and length and cross checked the obtained phase with this methodology and results are tabulated as below :

Least Voltage /Voltage Change Check Approach:

Table-1 with varrying Fault Resistance

| Type of The Fault | Fault Resistance(Ohm) | Least voltage change(v) | Actual Phase Involved fault | Obtained Phase involved Fault |
|---|---|---|---|---|
| LG | 0.1 | 3.33715E-07 | Ph-A | Ph-A |
| LG | 1 | 3.33714E-06 | Ph-A | Ph-A |
| LG | 10 | 0.002171937 | Ph-A | Ph-A |
| LG | 100 | 0.000333597 | Ph-A | Ph-A |

| Type | Fault Resistance(Ohm) | $V_a$ (v) | $V_b$ (v) | $V_c$ (v) | Actual Phase | Ph-obtained |
|---|---|---|---|---|---|---|
| LLL | 0.1 | -2.9156 | -3.04483 | -3.00602 | Ph-A,B,C | Ph-A,B,C |
| LLG | 0.1 | -0.0003 | 0.000298 | -9.092 | Ph-A,B | Ph-A,B |
| LL | 0.1 | 5.407825 | 5.407529 | -10.3163 | Ph-A,B | Ph-A,B |
| LLG | 10 | -0.0292 | 0.030091 | -30.6149 | Ph-A,B | Ph-A,B |

Table-2 with varrying Fault Distance

| Type of The Fault | Fault Distance(KM) | Least voltage change(v) | Actual Phase Involved fault | Obtained Phase involved Fault |
|---|---|---|---|---|
| LG | 50 | 0.00017851 | Ph-A | Ph-A |
| LG | 70 | 0.000626696 | Ph-A | Ph-A |
| LG | 80 | -0.00022962 | Ph-A | Ph-A |

| Type | Fault Distance(KM) | $V_a$ (v) | $V_b$ (v) | $V_c$ (v) | Actual Phase | Ph-obtained |
|---|---|---|---|---|---|---|
| LLG | 150 | -0.29763 | 0.295076 | 7.875798 | Ph-A,B | Ph-A,B |
| LLG | 100 | -0.29363 | 0.298981 | -18.4249 | Ph-A,B | Ph-A,B |

Greatest Current /Current Change Check Approach:

Table-3 with varrying Fault Resistance:

| Type of The Fault | Fault Resistance(Ohm | Greatest Current change(Amp) | Actual Phase Involved fault | Obtained Phase involved Fault |
|---|---|---|---|---|
| LG | 0.1 | 0.000323 | Ph-A | Ph-A |
| LLL | 0.1 | 0.000322924 | Ph-A,B,C | Ph-A,B,C |
| LLG | 100 | 0.000289536 | Ph-A,B | Ph-A,B |
| LLG | 1 | 0.000322816 | Ph-A,B | Ph-A,B |

Table-4 with varrying Fault Distance

| Type of The Fault | Fault Distance(KM) | Greatest Current change(Amp) | Actual Phase Involved fault | Obtained Phase involved Fault |
|---|---|---|---|---|
| LG | 100 | 0.000322658 | Ph-A | Ph-A |
| LG | 120 | 0.000322536 | Ph-A | Ph-A |

| Type | Fault Distance(KM) | $I_a$ (amp) | $I_b$ (ampo | $I_c$ (amp) | Actual Phase | Ph-obtained |
|---|---|---|---|---|---|---|
| LG | 240 | 0.003456 | -0.00092 | -0.00081 | Ph-A | Ph-A |
| LLG | 80 | -0.00296 | 0.002973 | 9.62E-06 | Ph-A,B | Ph-A,B |
| LLG | 80 | -0.00134 | [illegible] | 0.002041 | Ph-B,C | Ph-B,C |
| LL | 100 | [illegible] | 0.002995 | -6.12E-05 | Ph-A,B | Ph-A,B |
| LL | 100 | -0.00297 | 0.001457 | 0.001518 | Ph-B,C | Ph-B,C |

## V.Case-II

### Application to the Multimachine 9-Bus System:

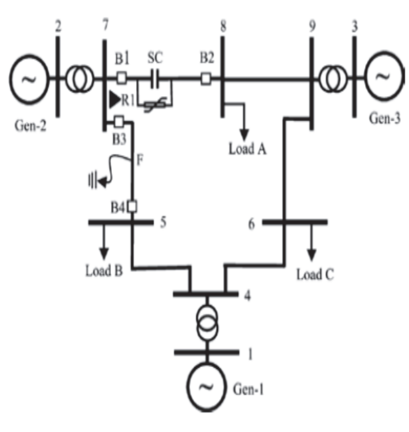


Fig3: A WSCC-3Machine-9bus System

The experimental result on Multi-machine-9 bus system is as follows:

Table-5 Least Voltage Change Approach With Varrying Fault Resistance

| Type of The Fault | Fault Resistance(Ohm) | Least voltage change(v) | Actual Phase Involved fault | Obtained Phase involved Fault |
|---|---|---|---|---|
| LLL | 1 | 1.74149255 | Ph-A,B,C | Ph-A,B,C |
| LLL | 10 | 1.74006701 | Ph-A,B,C | Ph-A,B,C |
| LG | 1 | 0.011717168 | Ph-A | Ph-A |
| LL | 10 | 0.451666 | Ph-A,B | Ph-A,B |

With varying fault distance:

| Type | Fault Distance(KM) | $V_a$ (v) | $V_b$ (v) | $V_c$ (v) | Actual Phase | Ph-obtained |
|---|---|---|---|---|---|---|
| LLL | 50 | -1438.79 | -1438.67 | -1438.97 | Ph-A,B,C | Ph-A,B,C |
| LLG | 20 | -841.86 | 0.286246 | -869.074 | Ph-A,C | Ph-A,C |

Greatest Current/current change Check Approach

Table-6 with Varrying fault Distance

| Type of The Fault | Fault Distance(km | Greatest Current change(Amp) | Actual Phase Involved fault | Obtained Phase involved Fault |
|---|---|---|---|---|
| LG | 20 | 2.20481 | Ph-A | Ph-A |
| LG | 50 | 2.2603 | Ph-A | Ph-A |

| Type | Fault Distance(KM) | $I_a$ | $I_b$ | $I_c$ | Actual Phase | Ph-obtained |
|---|---|---|---|---|---|---|
| LLG | 20 | 1.320816 | 0.003487 | -0.0032 | Ph-B,C | Ph-B,C |
| LL | 20 | -0.00572 | 0.005683 | -0.00242 | Ph-A,B | Ph-A,B |

By varrying fault resistance :

| Type of The Fault | Fault Resistance(Ohm | Greatest Current change(Amp) | Actual Phase Involved fault | Obtained Phase involved Fault |
|---|---|---|---|---|
| LG | 10 | 0.002133 | Ph-A | Ph-A |

| Type | Fault Resistance(Ohm) | $I_a$ | $I_b$ | $I_c$ | Actual Phase | Ph-obtained |
|---|---|---|---|---|---|---|
| LLG | 0.1 | -7.46157 | -0.00292 | 0.002479 | Ph-B,C | Ph-B,C |

| | | | | | | |
|---|---|---|---|---|---|---|
| LLG | 1 | 2.109717 | 0.003337 | -0.00346 | Ph-B,C | Ph-B,C |

## VI. Conclusion

From the above results it is cleared that Phase detection for all types of faults are possible by analysis of the properties of voltage and current waveforms irrespective of varying fault resistance, fault distance or any other parameters.

Hence, we developed a technique for the actual detection of faulty phase of a series compensated transmission line with the sampling analysis of voltage and current waveforms.

## Appendix A

System data for SMIB
Geneator:
600MVA,22KV,50HZ,H=4.4MW/MVA
Xd=1.81p.u,Xd'=0.3p.u,Xd''=0.23p.u,Tdo'=8s,Tdo''=0.03s,Xo=1.76 p.u,Xq''=0.25p.u,Tqo''=0.03s,Ra=0.003p.u,Xp(Potier reactance)=0.15p.u.
Transformer:
600MVA,22/400KV,50HZ,D/Y,X=0.163p.u,
Xcore=0.33p.u,Rcore=0.0p.u,Pcopper=0.00177p.u
Transmission lines:
Length=320Km
Positive-sequence impedance=0.12+j0.88 Ohm/Km
Zero-Sequence Impedance=0.309+j1.297 Ohm/Km
Positive-sequence capacitive reactance=487.723x1000 Ohm-Km
Zero-sequence capacitive reactance=419.34x1000 Ohm-Km.

## Appendix B

System data for 3-machine 9-bus configuration:
Gererators
Gen-1: 600 MVA,22KV,50HZ
Gen-2: 465 MVA,22KV,50HZ
Gen-3: 310 MVA,22KV,50HZ
Transformers
T1: 600 MVA,22/400KV,50HZ,D/Y;
T2: 465 MVA,22/400KV,50HZ,D/Y;
T3: 310 MVA,22/400KV,50HZ,D/Y;
Transmission line:
Length of line 7-8=320Km.,line 8-9=400Km,line 7-5=310Km.,line 5-4=350Km,line 6-4=350Km,line 6-9=300Km.
Loads
Load A=300MW+j100MVAr.
Load B=200MW+j75MVAr.
Load C=150MW+j75MVAr.
Other parameter used are same as APPENDIX A



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