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ACCURATE FAULT LOCATION IDENTIFICATION ON SERIES COMPENSATED TRANSMISSION LINE

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Abstract:- Series capacitors (SCs) are installed on long Transmission lines to reduce the inductive reactance of the lines. SCs and their associated over-voltage protection devices like metal oxide visitors, and/or air gaps creates several problems for distance relays and fault locators due to harmonic present in actuating quantities, errors in measurement leads to mal-operation of distance relay. This can be eliminated by using LPF or certain combinations of LPFs. In this paper, using sampling of voltage and current waveforms and concepts of sequence network models of different faults, a simple and accurate fault location algorithm is presented for series compensated transmission lines ,later tried to enhance the accuracy with different combinations of RC filters. The power system is simulated using PSCAD/SIMULINK to provide fault data. It is found that with the increase of the stages of RC filter the accuracy can be increased provided the time delay required for operation is kept adjusted.

Index Terms:- Fault location, filter refinement, RC filter, Stage of filter.

I. INTRODUCTION

Series capacitors (SCs) are used to improve the problem of stability, increase power transmission capability and improve voltage control problem of EHV transmission systems. On the other hand, application of these series compensation devices could result in various problems for transmission line protective systems, e.g. distance relays and fault locators [15]. In a typical series compensation arrangement, the Metal Oxide Varistor (MOV) which protects the capacitor from over-voltages, acts nonlinearly during faults and increases the complexity of the fault location and protection problems.

Difficulties caused by the sudden removal and insertion of capacitors into the circuit are voltage and/or current inversion and loss of directionality in the case of using directional line protective relays. Recently some research efforts have been focused on protection and fault location for series compensated transmission lines [15]. This paper describes an approach to locate fault distance for a series compensated transmission line from the sampling of voltage and current waveforms and later tried to enhance the accuracy of the proposed work with different combinations of Low pass filters. The technique is tested on different systems for different types of faults with different combination and stages used in RC filters.

II. SERIES CAPACITOR EFFECTS ON DISTANCE MEASUREMENT

Distance relays are designed to perform correctly on a resistive/inductive system. When SCs are introduced, the normal voltage/current relationships are affected, especially when the fault levels are not sufficient to flash-over the gaps or to produce significant conduction in the MOV's [15].

III. STUDIED SYSTEM

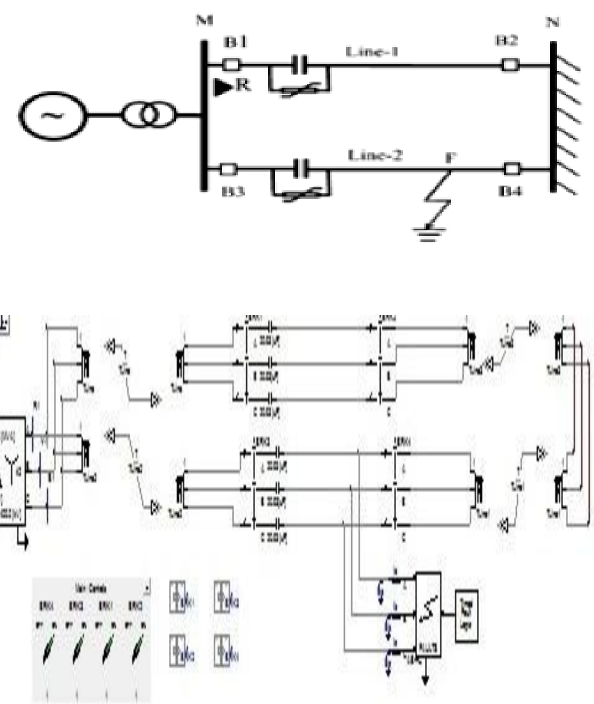


Fig. 1. A 400 KV SMIB System with its PSCAD Implementation

Power 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 different locations and tallied with our methodology.

IV. LOCATION OF THE DETECTED FAULT

Fault location is computed using faulted voltage and current samples that described as below:

Fault impedance $Z_f = (V_f/I_f)$ Ohm (1)
Fault Location= (Z_f / Z_1) (2)

More the length increases the algorithm for fault location identification gives more accurate value. In case of fault impedance, during healthy state positive sequence impedance ($Z_{1\ Ohm/Km}$) present in the system and the value is given in the paper. V_f and If are obtained from the sampling of the waveforms after creation of different faults at different lengths.

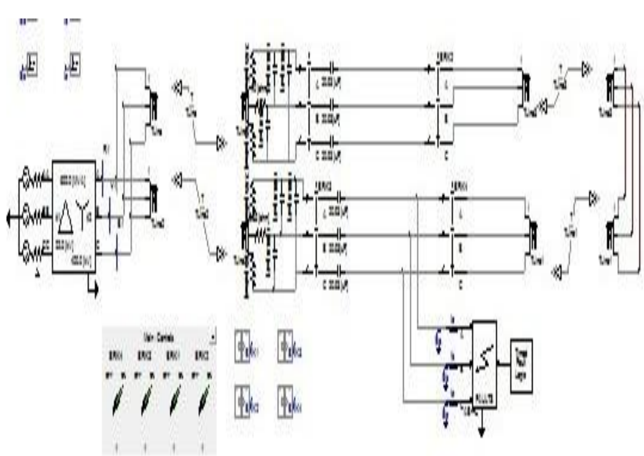
Case-I

The obtained fault location results before signal refinement is shown in table-1.

Type of fault	Actual Fault Distance(KM)	Obtained Fault distance before refinement(KM)	%error	Reach
LLG	**110**	**108.04**	**1.78**	**Under**
	150	**146.375**	**2.42**	**Under**
	240	**241.07**	**0.45**	**Over**
	300	**299.699**	**0.1**	**Under**
	200	**201.578**	**0.789**	**Over**
LL	**110**	**110.9751**	**0.886**	**Over**
	150	**150.514**	**0.343**	**Over**
	200	**205.8257**	**2.91**	**Over**

Table. 1. Fault location results

Refinement in Samples Measurement



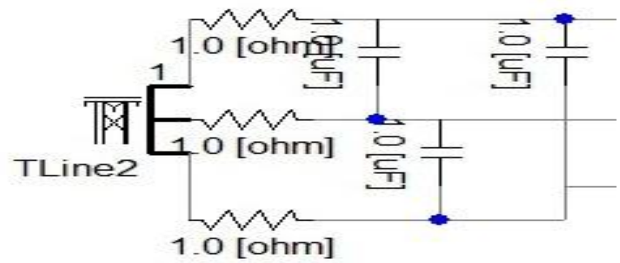


Fig. 2. (a&b): By Using 1-Stage RC Filter

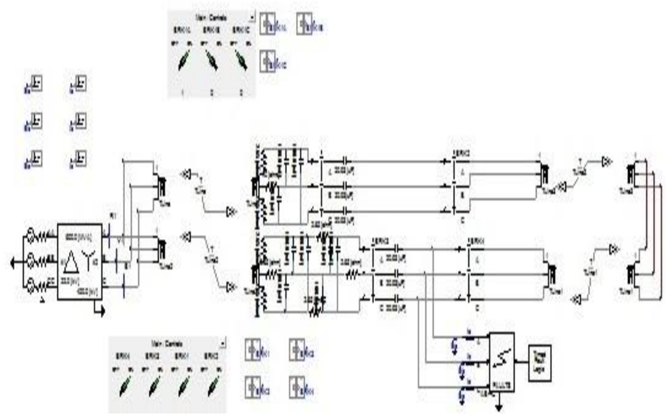


Fig. 3. (a): By Cascading of RC Filters

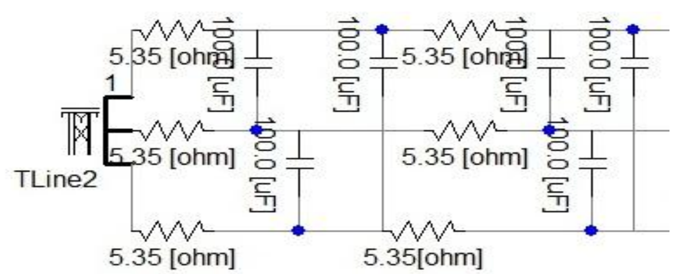


Fig. 3. (b): Cascade Connection of RC Filters

The obtained accuracy of fault location can be enhanced by using certain RC filter or combinations of RC filters in the circuit which can eliminate harmonics above some certain cut off frequency.

Cut off frequency $f_c = (1/2*pi*RC)$ (3)

If low pass filter is used in the circuit, then accuracy level of the work can be increased and the accuracy of the work can be further increased by cascading n number of such filters keeping the time delay caused due to the operation under control.

Study of obtained fault distance after refinement:

Case-2

Cut off frequency fixed= 600 HZ Results obtained by 1-stage RC Filter is shown in Table-2:

Table-2

Type of fault	Actual Fault Distance(KM)	Obtained Fault distance after refinement(KM)	%error	Reach
LLG	**110**	**111.0**	**0.909**	**Over**
	150	**149.0**	**0.666**	**Under**
	240	**239.0**	**0.416**	**Under**
	300	**299.899**	**0.034**	**Under**
	200	**201.578**	**0.789**	**Over**
LL	**110**	**110.9751**	**0.886**	**Over**
	150	**150.2514**	**0.168**	**Over**
	200	**205.257**	**2.629**	**Over**

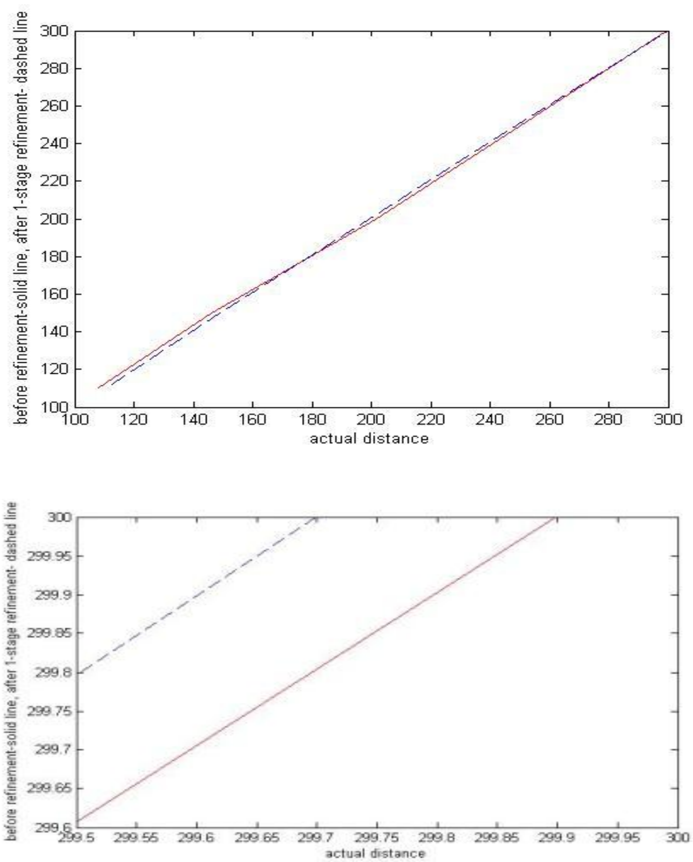


Fig. 4. Comparison between before and after 1-stage filtering for a LLG Fault

Results obtained by 2-stage Filter

Table-3

Type of fault	Actual Fault Distance(KM)	Obtained Fault distance after refinement(KM)	%error	Reach
LLG	**110**	**110.50**	**0.455**	**Over**
	150	**149.50**	**0.333**	**Under**
	240	**239.50**	**0.208**	**Under**
	300	**299.991**	**0.003**	**Under**
	200	**201.47**	**0.735**	**Over**
LL	**110**	**110.9751**	**0.886**	**Over**
	150	**150.2**	**0.1333**	**Over**
	200	**202.8257**	**1.4129**	**Over**

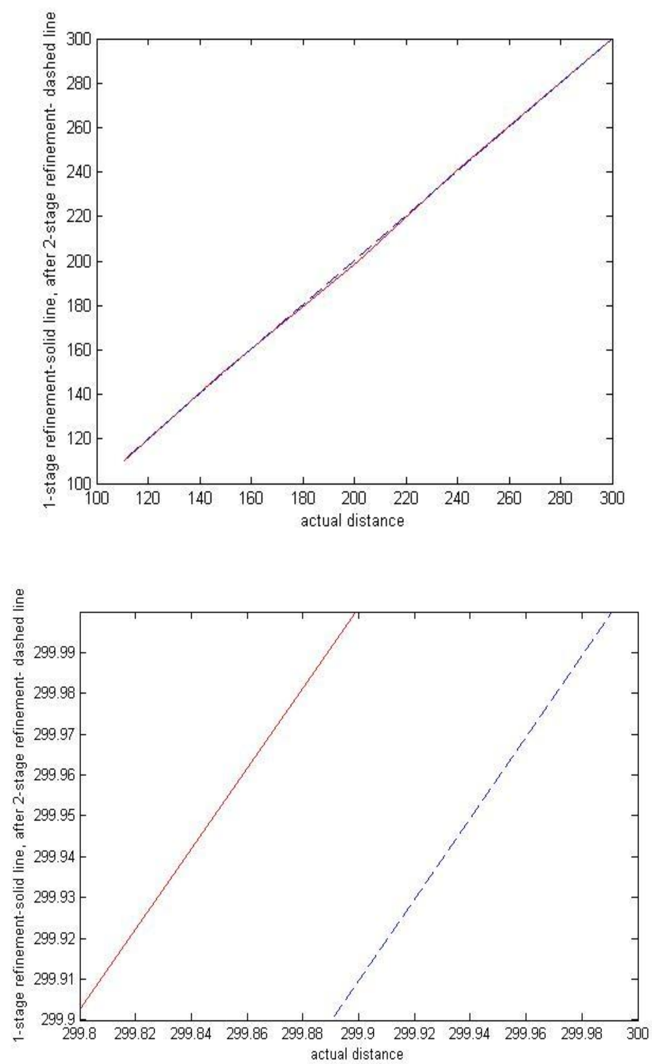


Fig. 5. Comparison between 1-stage and 2-stage refinement

V. APPLICATION TO THE MULTIMACHINE 9-BUS SYSTEM

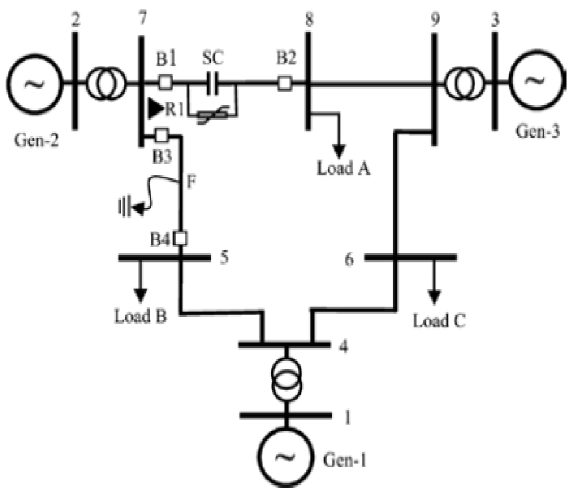


Fig. 6. A WSCC-3Machine-9bus System

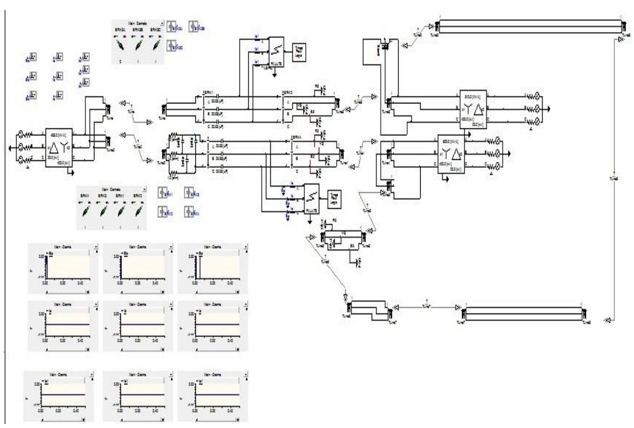


Fig. 7. Single Stage Refining Arrangement

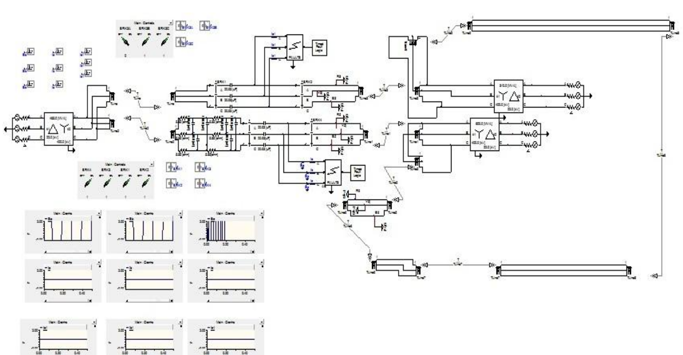


Fig. 8. 2-Stage Refinement Arrangement

TABLE-4

Type of fault	Actual Fault Distance(KM)	Obtained Fault distance before refinement(KM)	%error	Reach
LL	**110**	**112.293**	**2.085**	**Over**
	150	**153.0039**	**2.0026**	**Over**
	240	**241.6774**	**0.699**	**Over**
	300	**301.6471**	**0.549**	**Over**
	200	**204.1952**	**2.0976**	**Over**
LLG	**110**	**111.5898**	**1.445**	**Over**
	150	**147.2094**	**1.8604**	**Under**
	200	**196.784**	**1.608**	**Under**

TABLE-5

Type of fault	Actual Fault Distance (KM)	Obtained Fault distance after 1-stage refinement(KM)	Obtained Fault distance after 2-stage refinement(KM)	%error after 1-stage	%error after 2-stage	Reach
LL	**110**	**108.3088**	**109.3639**	**1.537**	**0.578**	**Under**
	150	**146.375**	**148.7527**	**2.42**	**0.83**	**Under**
	200	**201.578**	**200.8723**	**0.789**	**0.436**	**Over**
LL-G	**110**	**110.9751**	**110.5721**	**0.886**	**0.52**	**Over**
	150	**150.2514**	**150.2**	**0.1676**	**0.133**	**Over**
	200	**205.8257**	**202.5214**	**2.91**	**1.26**	**Over**

VI. CONCLUSION

From the above results it is cleared that %error for all types of faults after signal refinement is very less and % error minimizes with the increase of number of steps of RC filter. Here the basis of choosing R&C value is, the product of R&C should be constant according to chosen cut off frequency and order of magnitude of R&C should be kept O.K., i.e. C is in microfarad range and R is in Ohm range. And the stages of the RC should be chosen such that time delay should be adjusted properly due to the course of operation. Hence we developed a technique for the refinement of fault distance by using the fine tuning method.

APPENDIX A

System data for SMIB
Generator:
600MVA, 22KV, 50HZ, H=4.4MW/MVA
Xd=1.81p.u,Xd'=0.3p.u,Xd''=0.23p.u,Td0'=8s,Td0''=0.03s,X0=1.76 p.u,Xq''=0.25p.u,Tq0''=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:
Generators
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 parameters used are same as APPENDIX A

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