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Sequence Current Based Fault Detection in Compensated Lines

Anila.R.Pillai[1], Rachel Rose[2], Dr.Manju Mathew[3]

PG Student, Dept. of EEE, Saintgits College of Engineering, Kottayam, Kerala, India[1]

Assistant Professor, Dept. of EEE, Saintgits College of Engineering, Kottayam, Kerala, India[2]

Associate Professor, Dept. of EEE, Saintgits College of Engineering, Kottayam, Kerala, India[3]

ABSTRACT: The rapid growth of the electric power system has in recent decades resulted in an increase of the number of transmission lines. The challenges of fast growing electrical grids has also resulted in huge increase of overhead lines and their total length. These lines are experiencing faults due to various reasons that cause major disruptions. A distance relaying scheme is sometimes influenced by noise conditions. To avoid unnecessary trip operation during such conditions, a negative sequence based algorithm is utilized in distance relays. However, if a fault occurs during noise conditions, the relay must detect the fault and trip as soon as possible. The detection of fault in compensated lines during the signal noise condition is further complicated. This paper proposes a technique for detecting all types of faults during the noise conditions in uncompensated and compensated transmission lines. The technique is tested for faults occurring during no-noise and noise upto 50dB conditions. The method proved to be useful for both balanced and unbalanced fault conditions. The method is tested for different fault conditions in MATLAB/SIMULINK.

KEYWORDS: Negative sequence algorithm,Shuntcompensation, Series compensation,Noise,MATLAB/SIMULINK.

I.INTRODUCTION

Electric energy is generated, transmitted and distributed to the load centers. Transmission lines are used to transmit electric power to distant large load centers. The increased growth of electric power systems over the last few decades has resulted in a large increase of the number of transmission lines in operation and their total length. These lines are exposed to faults as a result of lightning, short circuits, human errors, overload, and aging. Increased electricity demand, and restrictions on buildingnew transmission lines result in enhanced transmission line loading and necessitate optimized operation of transmission networks. To fulfill such requirements, the inclusion of compensators in long transmission lines is increasing day by day[1]. However, compensators in a line introduce protection problems.

Noise can be defined as undesirable and unwanted electricalsignal, which interfere with an original power signal. Noisecould be temporary or constant. Temporary noise is causedmainly by lightning. Constant noise can be due to thepredictable 50 or 60 Hz ac signals from power circuits orharmonic multiples of power frequency close to the datacommunication cable. In normal fault condition measuredimpedance value lie within set impedance value of relay butduring signal noise, measured impedance value lie within setimpedance value without having any fault. So to solve thisproblem an algorithm is proposed that can distinguish signalnoiseand fault. The detection of fault in compensated line duringnoise is more challenging due to the generation of differentfrequency components in the fault signals which depend onthe fault location, fault type, the level of compensation, andfunctioning of MOV (in series compensated lines).

Recently, a discrete wavelettransform (DWT) and independent component analysis (ICA)based approach is proposed for fault detection in series compensated transmission lines[2].The negative sequencecurrent signal is passed through DWT and ICA for detectingthe faults under both no-noise and 20 dB noise scenarios.ANN and wavelet techniques are used to detect faults in transmission lines[3].Techniques based on S-transform and wavelets were also proposed to detect faults but all these techniques failed in the presence of high dB noises. These techniques are able to distinguish faults only for noises upto a small amount. There are several techniques which are able to distinguish faults during other disturbances, but they have some limitations during signal-noise condition[4]-[12].Shunt reactors [13]with their

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compensating effect on the capacitive generation of the line offer an economical and technically sound means of controlling the undesirable over-voltage The distance relay misoperates forthe transmission line with shunt compensator. The under-reaching and over-reaching ismore severe with shunt compensator at mid-point of thetransmission line.Series capacitors (SCs) are used in transmission systems to increase load capacity, enhancesystem stability, improve load division on parallel paths,and reduce losses. Series capacitors[1] and their over voltageprotection devices (typically Metal Oxide Varistors, MOVs),in spite of their beneficial effects on the power systemperformance, introduce additional problems and make theoperating conditions unfavorable for the protective relays thatuse conventional techniques. The most important singularitylays in the fact that the positive sequence impedance measuredby traditional distance relays is no longer an indicator of thedistance to a fault.

This paper introduces a negative sequence current based technique for detecting all types of faults in uncompensated and compensated line during the noise condition. During unbalanced faults, the negative sequence components become significant and due to transients in current signals in the initial period, a negative sequence component is noticed even for three-phase faults. To discriminate the faults duringnoise conditions in a compensated and uncompensated lines, change in negative sequence current method is utilized.The performance of the technique is tested using MATLAB/SIMULINK. The method proved to be accurate and fast.

II.PROPOSED FAULT DETECTION TECHNIQUE

Recent regulatory developments, increased electricity demand, and restrictions on building new transmission lines result in enhanced transmission-line loading and necessitate optimized operation of transmission networks. To fulfill such requirements, the inclusion of compensators in long transmission lines is increasing day by day.

The series compensator is functionally a controlled voltage source which is connected in series with the transmission line to control its current. In transmission system, due to the transmission line reactance, there are limitations on power transmit ability of line so that it leads towards building of new transmission line which is very costly. Series capacitive compensation is used to increase power transmission capability by canceling the line reactance.Series capacitors require spark gaps or metal oxide varistor (MOVs) to reduce or eliminate overvoltage across the capacitors. Spark gaps flash over to remove the capacitor when the voltage exceeds a given value, but they may not fire for low-current faults. Transmission line series compensation increases power transfer capability and improves power system stability.With capacitive reactive compensation, the contribution of a capacitor bank to current pulse is similar to fault. Series compensation increases the fault current level and may also cause generator subsynchronousresonance.

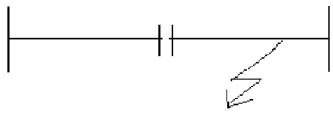

Fig. 1. Fault on series compensated transmission line

Shunt reactors with their compensating effect on the capacitive generation of the line offer a good method of controlling the undesirable over voltage.Regardless of where the point of maximum voltage is located, the reactor mounted at themiddle of the line requires minimum reactor rating to bring the maximum voltage on the line within limit.The main reason why the shunt compensation is provided at the midpoint is that the voltage sag will be maximum at the midpont.

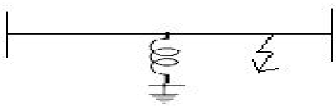

Fig. 2. Fault on shunt compensated transmission line

There are a number of techniques available to detect fault during the signal noise condition for transmissionlines. Those techniques were able to detect signal noises upto 20dB. In some techniques the fault during the signal noise in

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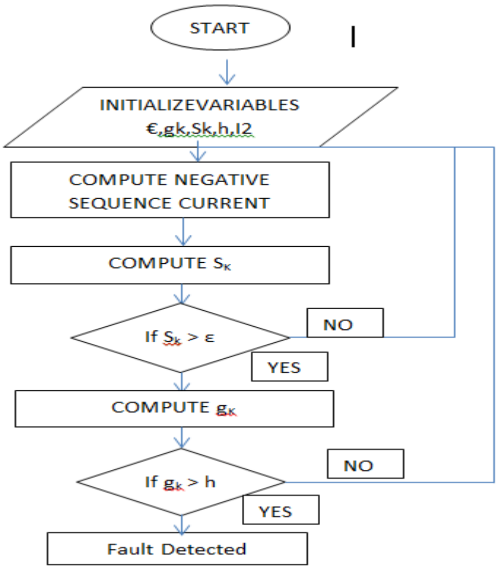
uncompensated lines find limitations in the presence of compensation due to the nonlinear functioning of the series capacitor combination. A small amount of negative sequence current is present during both balanced and unbalanced faults. In case of a three-phase fault during the system disturbances a small amount of negative-sequence current is observed at the initial period of the fault due to transients in the current signals and in the subsequent period due to the presence of modulated frequency components due to the disturbances. To differentiate the faults and signal noises in a series and shunt compensated transmission line, change in the magnitude of the negative sequence current based approach is used. A high index value during fault was observed. The input signal used here is negative sequence current. The flow chart of the method is shown below.



Firstly the negative sequence current is obtained using the sequence analyzer. The value of negative sequence current will be zero during normal conditions and it will have some value during fault.The value of Skis set in such a way that it should be zero during all the conditions except the faulty situation. € is taken as 0.05 and it is known as drift parameter.gk is known as the test statistics.The value of gk will be high during fault and will remain zero in normal conditions.In ideal conditions the value of h will be equal to zero. Practically there will be a small value for h.In this paper h is taken as 0.5

III.RESULTS AND DISCUSSIONS

The technique is tested in MATLAB/Simulink R2013a.The technique is tested for all types of faults(both balanced and unbalanced faults). The method used in this paper is such that the output of the algorithm should be one during fault and must be zero during the signal noise condition. The index value should begin to rise at the instant of fault, until then it should be zero.The method is tested in both shunt and series compensated transmission lines and is found satisfactory.

1)Series compensated line

The series compensated transmission system is designed in MATLAB/Simulink R2013a. A capacitor is connected in series with the line. Inorder to protect the capacitor from over voltage MOV is provided across it. The output of the model is observed in a scope. The faults are created at an instant of 0.6s and asignal noise of 30dB is created in between 0.1s and 0.9s. From the graphs it is clear that the technique prove to be accurate.

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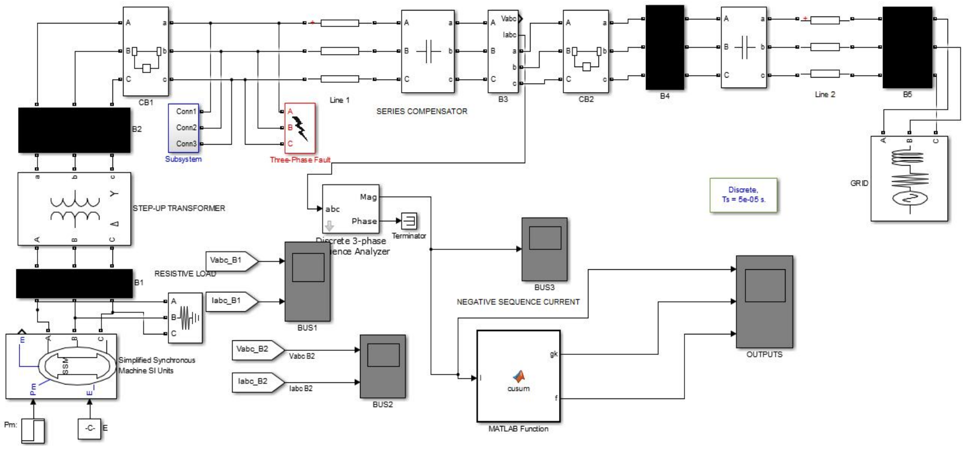

Fig. 3. Simulink model of series compensated transmission line with fault and signal noise

a)Single Line to Ground Fault

Single line to ground fault is created by applying a fault in between any phase and ground. Here the fault is created in between phase "a" and ground. The length of the transmission line at which the fault occured is taken as 250km. The fault is created at an instant of 0.6s. The index value will be zero till the instant of fault and will begin to increase at the time of fault initiation. The output is one after the fault initiation.

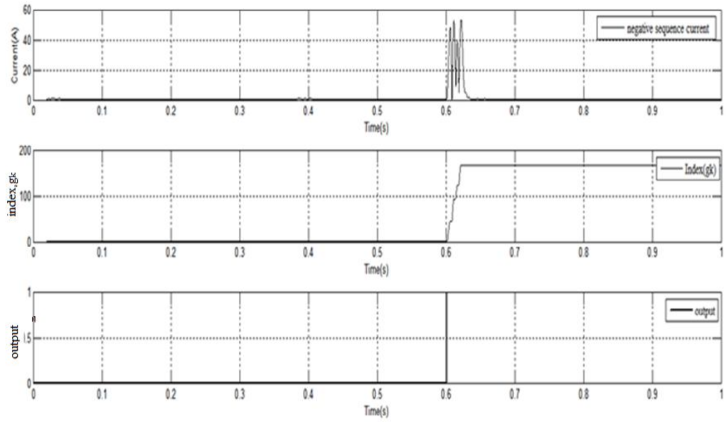

Fig. 4. Single line to ground fault

a)Single Line to Ground Fault with High Fault Resistance

As the value of fault resistance increases the value of negative sequence current decreases but even during that time the algorithm works satisfactorily and the output becomes one only during that instant.It is clearly observed that the presence of high fault path resistance reduces negative sequence current compared to single line to ground fault during the fault, but the pattern of current is unaltered. Here also the fault is created at an instant of 0.6s. The index value will be zero till the instant of fault and will begin to increase at the time of fault initiation. The output is one after the fault initiation.

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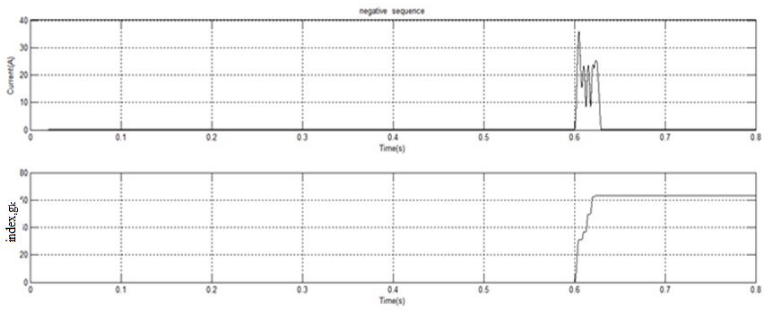

Fig. 5. Single line to ground fault during high fault resistance

b)Double Line to Ground fault

Double line to ground fault is created in between any of the two lines and the ground at an instant of 0.6s.Signal noise is created for a duration of 0.1s to 0.9s. The index value was zero until the initiation of fault and it will starts to increase at the instant of fault. The output will be zero during the signal noise and will be one after the initiation of fault.

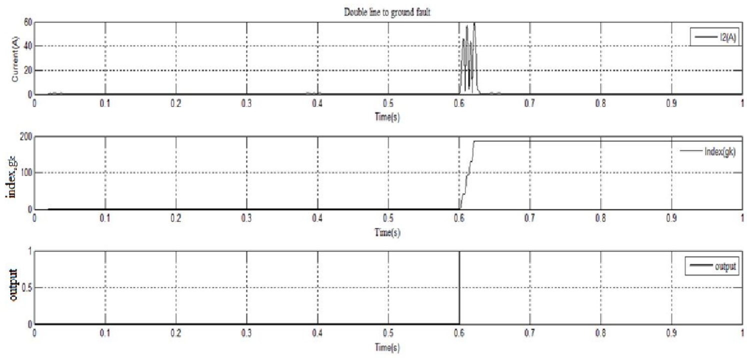

Fig. 6.Double line to ground fault

c)Three phase to ground fault

Three phase to ground fault is created in between all of the three phases and ground at an instant of 0.6s.Three phase faults are symmetrical faults. Signal noise is created for a duration of 0.1s to 0.9s.It is difficult to distinguish three-phase faults during the signal noise. But the method worked satisfactorily in thiscase also. The index value starts to increase at the instant of fault and the output will be one.

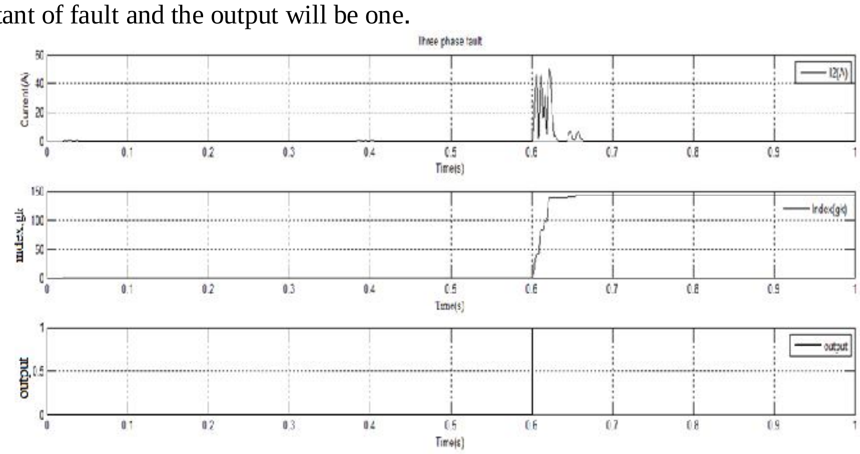

Fig. 7. Three phase to ground fault

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2)Shunt Compensated Line

The shunt compensated transmission system is designed in MATLAB/Simulink R2013a. A reactor is connected in parallel with the line. The output of the model is observed in a scope. The faults are created at an instant of 0.6s and the duration of signal noise is in between 0.1s and 0.9s. From the graphs it is clear that the technique is accurate. The technique is applicable not only to series compensated linesbut also for the shunt compensated lines.

All the faults are tested in shunt compensated lines also.The output is one only during the instant of fault and the index value starts rising from zero at the instant of fault.

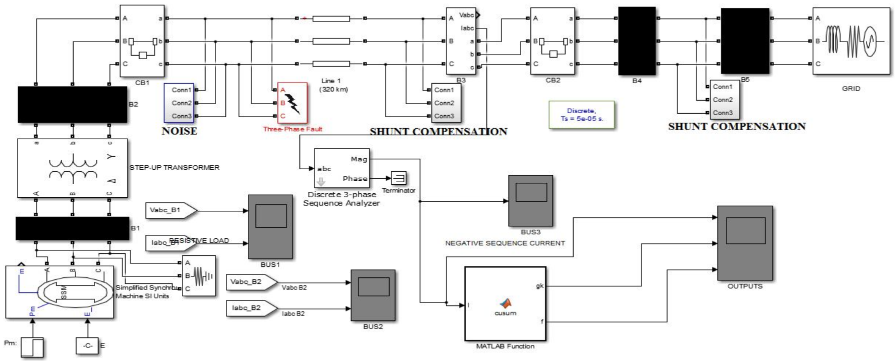

Fig. 8. Simulink model of shunt compensated transmission line with fault and signal noise

The method can be said to be accurate only if it is zeroin theabsence of fault and in the presence of signalnoise. That condition was also checked and is found to be good from the graph given below.The method is satisfactory for long distance transmission lines also.

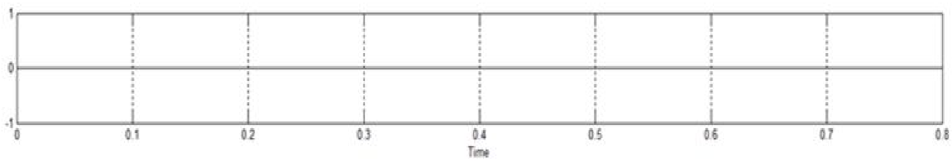

Fig. 9. Output without fault and with 30dB noise

IV. CONCLUSION

Fault detection in series and shunt compensated transmission lines is studied using negative sequencetechniques in absence as well as presence of fault. 20dB to 50dB noises were injected to the signals along with different types of faults. The technique is good not only compensated but also for the uncompensated lines. The simulated results show that the algorithm proved to be a better method of fault detection under noisy condition.The algorithm was effective in differentiating noise and faults.

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BIOGRAPHY

Anila.R.Pillai, received B.Tech degree in Electrical and Electronics Engineering underCochin University in 2013. She is currently pursuing her M.Tech in Power SystemsatSaintgits College of Engineering, Kerala, India.

Rachel Rose receivedB.Tech degree in Electrical and Electronics Engineering under Kerala University in 2002, M.Tech in Power Systems under Mahatma Gandhi University in 2013. She is currently working as Assistant Professor atSaintgits College of Engineering, Kerala, India.

Dr.ManjuMathew receivedB.Tech degree in Electrical and Electronics Engineering under Mahatma Gandhi University in 2002, integrated phD in wireless communication from nanyang technological university in 2012. She is currently working as Associate Professor at Saintgits College of Engineering, Kerala, India.