A Superimposed Component Based Fault Detector Technique for Power Transmission Line Protection

D. Umamaheswari, N. Srinivasu

Abstract: Fault occurrence on a transmission line is more predominant as compared to other power system equipment because transmission line is exposed to open atmosphere. To protect transmission line from faults first we have to detect the fault. This paper presents a superimposed component based fault detector for the transmission line protection. When there is a fault in the power system network, this fault detector uses a superimposed current value. The proposed algorithm provides proper discrimination between normal state and abnormal state even in the presence of disturbance and harmonics in the current signal. This method is very simple to implement and accurate. It is tested for various cases like different fault locations, different fault resistances, different kinds of faults, differenttimes of fault inceptionand comparative assessment with conventional techniques is carried out, which clearly shows the effectiveness and accuracy of proposed technique.

***Index Terms*: Fault detection, Fault inception time, Fault resistance, superimposed component, Protection of Transmission line.**

I. INTRODUCTION

In an electrical power system, the presence of fault in a power transmission line may experience element failure or imbalance of the power system network. Recent scheme uses digital relays for protection to determine the power system state. Different quantities such as current, voltage and angle between phasesare examined and checked by this relay for selection. These quantities are monitored if they move across a prespecified threshold parameter. Earlier a more number of suitable schemes have been proposed to raise the adaptability of the present-day system protection. Different tools based on Neuro-Fuzzy, Fuzzy Logic,Artificial Neural Network and Wavelet based Techniques have been outlined to calculate fault distance from the relay position in the power system network [1], [2]. For the system protection, some methods based on Phasor estimation techniques and other methods uses current and voltage signals as input by considering the sample values.

Mainly, three steps of computation are utilized in relays for resolving the fault condition 1.Detection, 2.Classification and 3.Location. In these three stages, the first stage is more crucial because it discriminates the condition of fault from usual system condition. The time for determining the fault in the system using the fault detection technique is in milliseconds, being which the relay performs series of actions to achieve the next relay algorithms to classify and locate the fault. The accuracy and speed of the relay is rely upon the components of the fault detector.In recent years different schemeshave been outlined for detection of fault. When a fault exists on a power transmission line, corresponding current and voltage signals will differ from steady state and this discrepancy is pre-owned by the protective relay. Two traditional methods are used to determine the fault, comparison of sample to sample and comparison of cycle to cycle [3], [4]. These methods are influenced due to disturbance in the signal, harmonics, deviation in frequency limits, and other uncertainties. Complicated algorithms are also in operation based on Least Mean Square, Phasor estimation and Kalman Filtering techniques [5], [6]. But the major drawback of these techniques is, it requires more time for calculating the Phasor values. These techniques are also altered by deviation in frequency, harmonics and disturbance signal [7]-[9].

Thispaper proposes a fault detection algorithmbased on superimposed components which are available only in fault situation. The algorithm calculates superimposed components by observing sum of absolute values of present sample with the previous sample. Under normal condition, superimposed components are zero. But when fault occurs on a transmission line, high levels of superimposed components are present in current or voltage signal. The precision and validness of proposed method is tested by large variety of different signals.

This paper is standardized into four sections. Section II explains the traditional methods to detect the fault. Section III describes the proposed technique. Under different fault conditions the performance of the proposed method is explained in Section IV. In section V conclusion is given.

II. TRADITIONAL FAULT DETECTION METHODS

At the beginning of fault in a power transmission line, the current and voltage signal waveforms alter. Fault detector technique should perceive these variations in signal within a short period of time. To detect the abnormal condition in a power transmission line, two simple methods are used: 1. Comparison of Sample to Sample, 2. Comparison of Cycle to Cycle. For successive number

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of samples, if absolute value of the signal exceeds the prearranged threshold parameter then a fault is registered. A fault detector technique takes time of fraction of seconds to transmit the instructions to the relay algorithm.

In this proposed method, to detect the fault in power transmission line current signals are taken as input signal.

A. Comparison of Sample to Samplemethod

Comparison of Sample to Sample is an easy method to identify the fault in a power transmission line. In this method difference is computed between current sample value and preceding sample value. The fault is recorded if this dissimilarity is tested with a prearranged threshold parameter. Under steady state the sample difference is very small and at the condition of fault, the difference of sample values is extremely high.

Mathematically, it is written as

$$p_k = |\, i_k - i_{k-1} \,| \qquad (1)$$

A fault is identified, if

$$p_k > a$$

Where ‘a’ is the prearranged threshold value

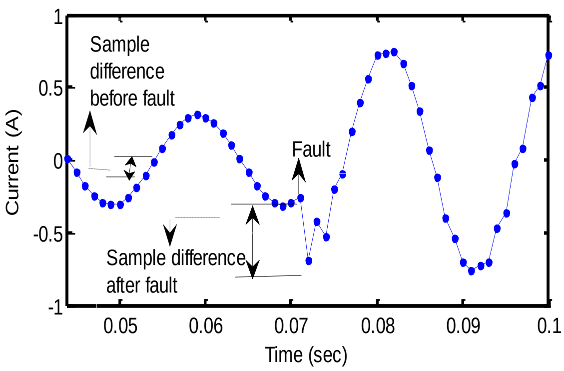

Fig. 1 Comparison of Sample to Sample

It can be noticed from the Fig.1 sample difference varies considerably at the time of fault only in the given current signal. Due to disturbance in the signal and other incertitude’s, this approach is influenced.

B. Comparison of Cycle to Cycle method

This method is based on deviation between latest sample and its corresponding sample in earlier cycle. During steady state situation, the deviations of samples are zero and at the condition of fault the deviation increases to a higher value. If the difference exceeds the prearranged threshold value then a fault is identified.

Mathematically, it is written as

$$q_k = |i_k - i_{k-N+1}| \qquad (2)$$

A fault is identified, if

$$q_k > c$$

Where ‘c’ is the prearranged threshold parameter

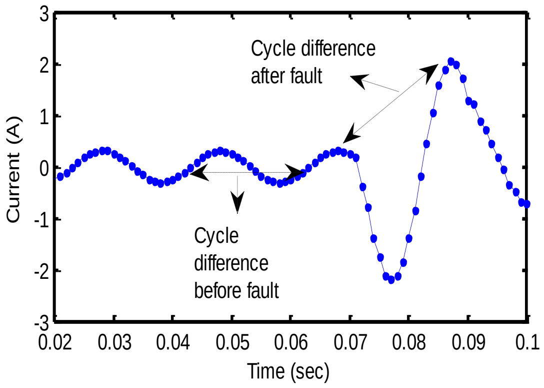

Fig.2 Comparison of Cycle to Cycle

It can be seen from the Fig.2 the cycle difference changes during fault, this difference is used for fault detection. However, these existing techniques are influenced by noise and frequency change.

III. PROPOSED FAULT DETECTION TECHNIQUE

The methods explained in the above section uses differential principle and these are suffers from sensitive to the noise level and other uncertainties in the signal. This problem can be overwhelmed by integral approach where, unlike moving sum approach [10] a superimposed component based technique is used. At the initiation of fault in a power transmission line,an unstable transition occurs. A sudden change in voltage or current waveforms occurs during a fault. The protection system will monitor these abrupt changesin current or voltage signals in the network. As shown in Fig.3 the faulted current signal will be dissimilar from original current signal as faulted current signal consists of superimposed components. Superimposed components are obtained by subtracting the steady state signal from the transient signal, when no changes occur superimposed components are zero [11]-[15].

Considering the given signal as y, at the sampling frequency fs, the superimposed component could be separated as follows,

$$\Delta y(k)=y(k)-y(k-iN)-[y(k-iN)-y(k-jN)] \qquad (3)$$

$N \leq j$

Where y (k) is the present signal sample, iand j are the two collected value of integersand N is the number of samples per cycle.Thus, y (k-iN) is the sample equivalent to y(k) conquered at previous n cycles. The controls of the vigorous variations in load and deviations in frequency on the derived components of fault are removed using the additional terms displayed in equation (3), i.e., the difference of samples in the given signal occupied before i and j cycles. Here i and j values corresponds to one and two cycles.

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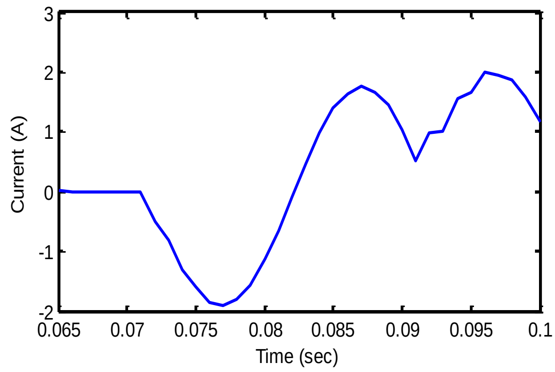

Fig. 3 Superimposed component of fault current

IV. PERFORMANCE OF PROPOSED METHOD WITH DIFFERENT SWITCHING INSTANTS, FAULT LOCATIONS, FAULT RESISTANCES AND FAULT TYPES

A power system model of 400kv, 50Hz, three phases overhead transmission line of length 300km as shown in Fig.4 is simulated for obtaining accomplishment of the proposed technique. The proposed system one line diagram is as shown in Fig.4.

At the occurrence of fault in a power transmission line, the proposed method index value increments to a intensely larger value in comparison with traditional techniques. To clearly observe the detection speed and effect of otherparameters, mostly normalized index value has been plotted in this paper.

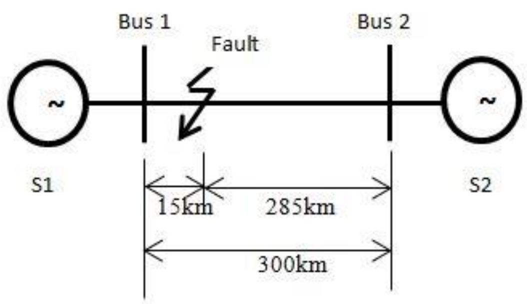

Fig.4 One line diagram

a. Different switching instants

Fault at different instants will affect the current signal accordingly. The results at different switching instants are shown in figure. To notice the detection, speed a single line to ground (A-G) fault at 10% of line with a low fault resistance of 10 ohms has been introduced. The fault instants are varied from 0.07 sec to 0.08 sec with a time span of 0.0025 sec. Figures from 5 to 8 gives plots for faults at different switching instants for different fault detection methods. It can be noticed from the graphs that all the methods detect the fault immediately. In the method of sample comparison index oscillates appreciably which will lead to an unpredictable detection. In cycle comparison method index value falls to zero with in a cycle and proposed technique index increases consequently after the fault which shows consistent detection of fault. At the same time as, conventional techniques gives non zero index values, nonetheless the proposed method retain a zero index value in prefault conditions. Lower threshold gives accurate detection, the proposed method uses lower threshold value as comparison to conventional techniques which points to accurate detection. So proposed method performance is admirable as compared to other traditional methods.

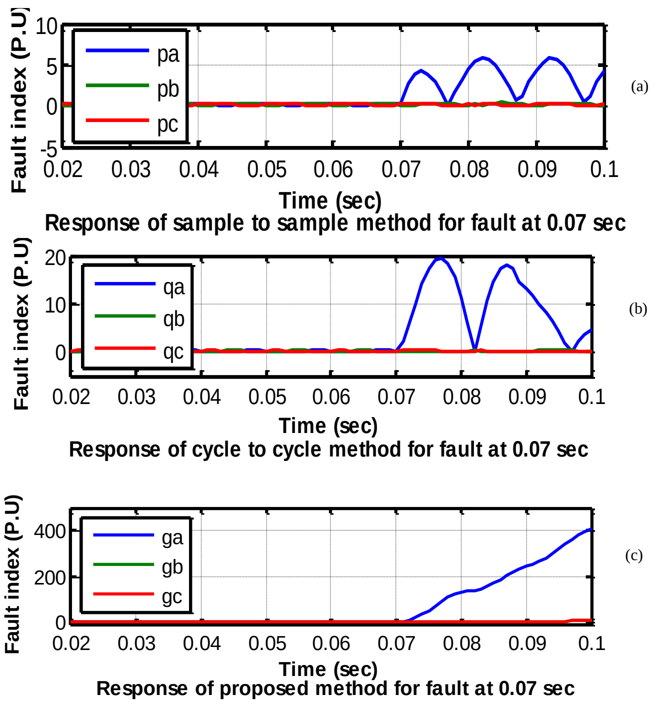

Fig.5 (a) Sample comparison, (b) Cycle comparison, (c) Proposed method

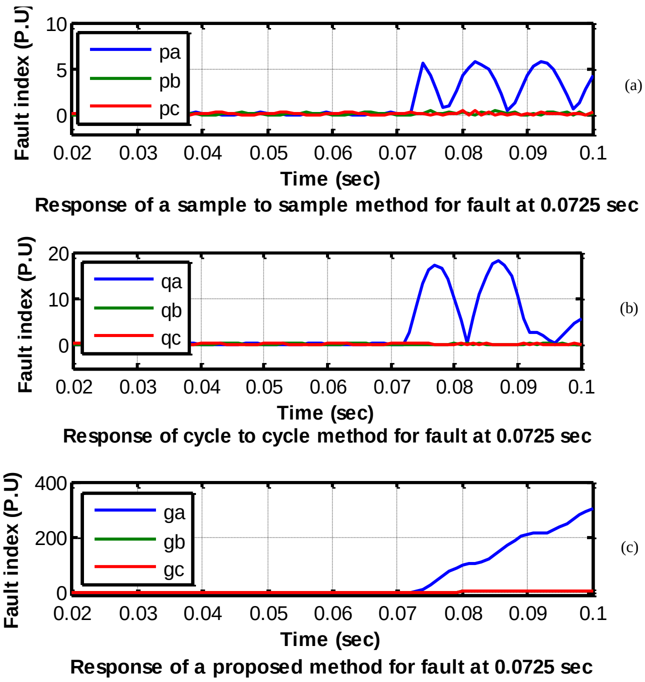

Fig.6 (a) Sample comparison, (b) Cycle comparison,(c) Proposed method

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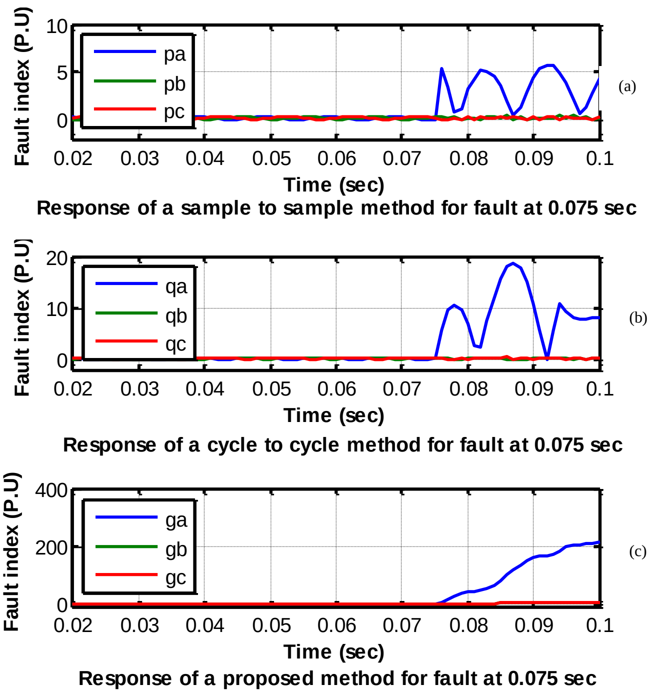

Fig.7 (a) Sample comparison, (b) Cycle comparison, (c) Proposed method

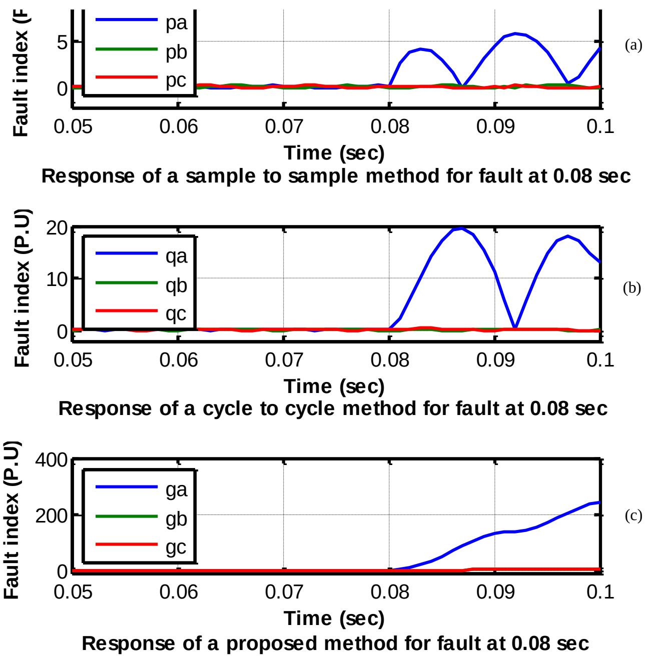

Fig.8 (a) Sample comparison, (b) Cycle comparison,(c) Proposed method

b. Different fault resistances

Fault resistance value affects the relay performance. Fault resistance may vary depends on type of fault, a powerful fault detector technique should identify fault of each resistance formed in that extensive area. To study the accomplishment of various fault detectors accompanying different high value of resistances, a line to ground fault at 0.07sec is generated with a resistance of 100 ohms and 200 ohms. All fault detection techniques works perfectly for all low resistances, however the detectors attainment changes excessively for high value of resistance fault as shown in Figs. 9 and 10. At the time of fault, comparison of sample to sample method index value recorded a small value and comparison of cycle to cycle method index droops and then rises to a larger value. However the proposed technique index value alters instantaneously and starts from zero. This represents that, it is appropriately crucial to set an outstanding threshold value for traditional methods, as they influenced with high fault resistances and the proposed technique is unaffected by high fault resistances.

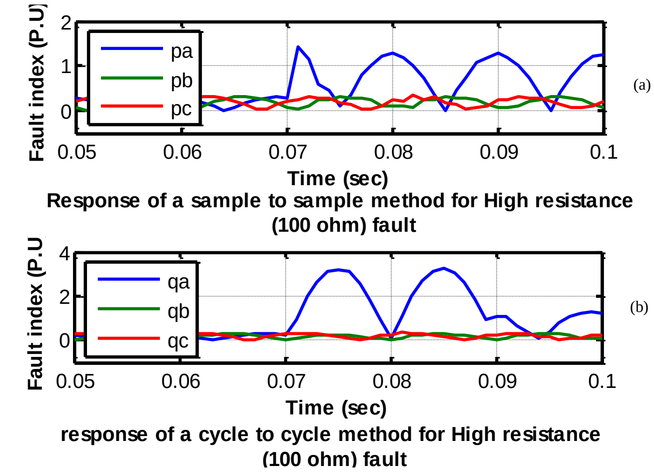

Fig.9 (a) Sample comparison, (b) Cycle comparison,(c) Proposed method

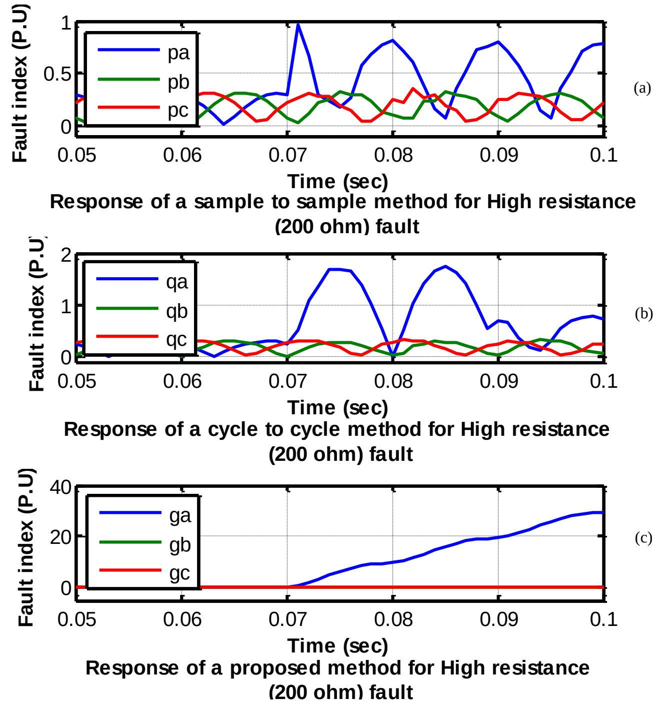

Fig.10 (a) Sample comparison, (b) Cycle comparison, (c) Proposed method

c. Different fault locations

As transmission line is exposed to open atmosphere fault will exists at indiscriminate location on power transmission line. To recognize the

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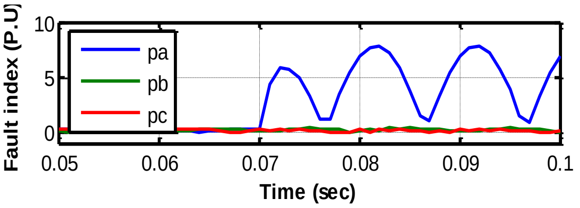
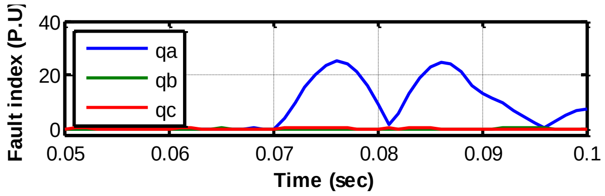
consequence of location of fault, two test cases are considered. Fault at starting of the line (5km) and at the end of the line (295km). At the far end of the line, impedance of the line will affect the fault current. The output obtained from Simulink model is prepared through distinct algorithms and equivalent indices are plotted in figures. It can be observe from the Figs.11 and 12 that three fault detection techniques are not affected by fault location of 5km but available two techniques are affected by fault location at far end. But proposed method shows more consistency in all fault locations as from above cases also.



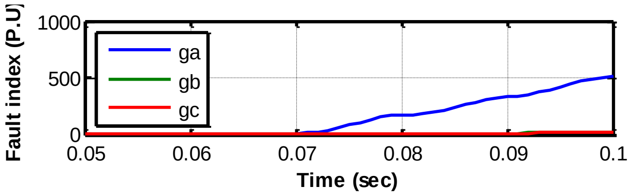
(a)

Response of a sample to sample method for fault at 5km



(b)

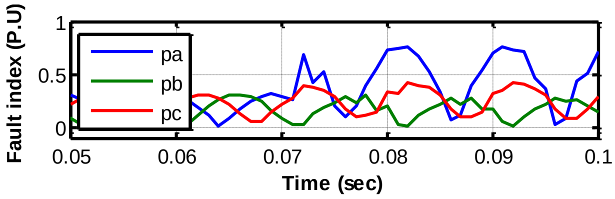
Response of a cycle to cycle method for fault at 5km



(c)

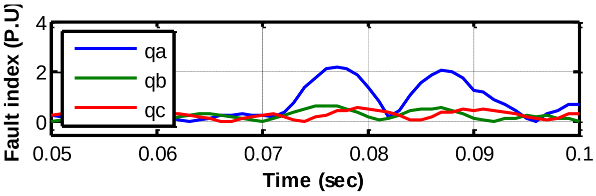
Response of a proposed method for fault at 5km

Fig.11 (a) Sample comparison, (b) Cycle comparison,(c) Proposed method



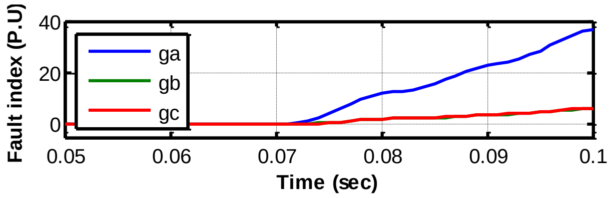
(a)

Response of a sample to sample method for fault at 295 km



(b)

Response of a cycle to cycle method for fault at 295km



(c)

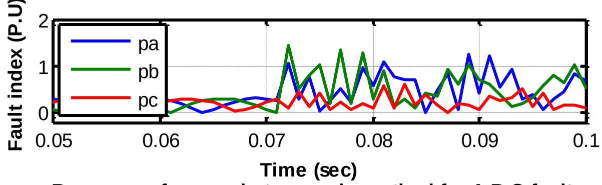
Response of a proposed method for fault at 295 km

Fig.12. (a) Sample comparison, (b) Cycle comparison,

(c) Proposed method

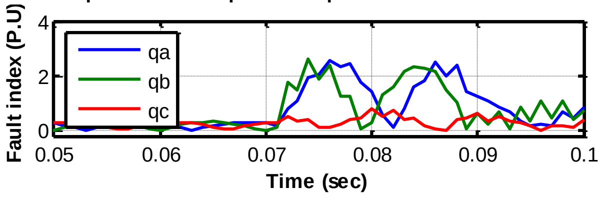
d. Different types of faults

As said earlier to notice each and every type of fault in 3-phase system any one signal is enough. Implementation with ground faults are examined in above sections and alter with various types of fault, a double line to ground fault, three phases to ground fault are created at 0.0725 sec. The proportionate circuitous signal is handled through distinct fault detection methods and corresponding graphs are plotted in Figs.13 and 14. It can be observed from the graphs that index of two methods grows increasing but un faulted phase shows some value but proposed method shows consistent result whose index value grows and highest value of the proposed method is 20 times and 10 times of sample comparison and cycle comparison respectively. However theproposed method is moderate but index value increases extremely over fault of any type. The three methods are checked for various types of fault values and similar graphs are observed.



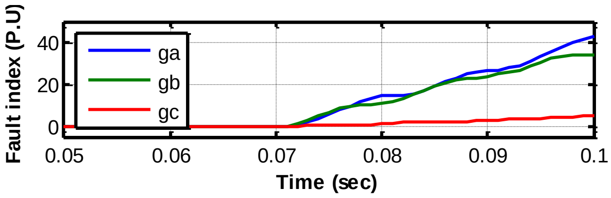
(a)

Response of a sample to sample method for A-B-G fault



(b)

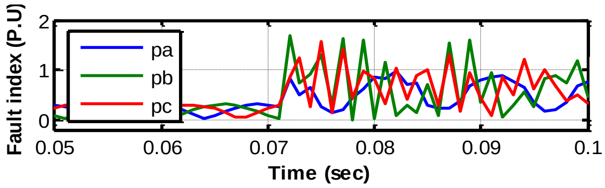
Response of a cycle to cycle method for A-B-G fault



(c)

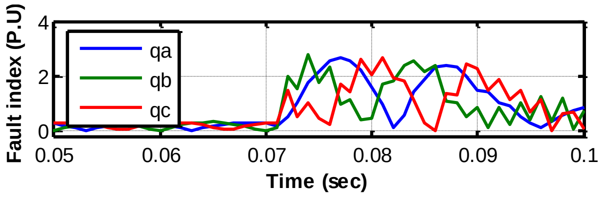
Response of a proposed method for A-B-G fault

Fig.13 (a) Sample comparison, (b) Cycle comparison,(c) Proposed method



(a)

Response of a sample to sample method for A-B-C-G fault



(b)

Response of a cycle to cycle method for A-B-C-G fault

(c)

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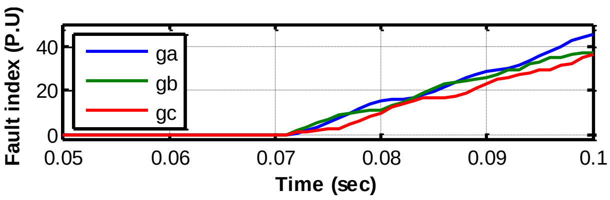

Response of a proposed method for A-B-C-G fault

V. CONCLUSION

An easy technique for detection of fault in electrical power system is recommended in this paper. This technique uses superimposed components which are present in faulted condition to identify the fault on power transmission line. A relative performance of the proposed technique is considered with the signals at distinctpositions of the electrical power system they are different switching instants, different high resistance faults, different types of faults and different fault locations. The time taken to identify the fault is almost same forthese three techniques. This method is found to be used with power system relaying to detect the fault. Computational complexity of the proposed method is very less. When tested at different power system situations proposed technique shows good results and better performance associatedwith other traditional methods.

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