Research Article Impact Factor: 4.226 ISSN: 2319-507X
Gulsan Ahmad, IJPRET, 2018; Volume 6 (8): 460-469 IJPRET

INTERNATIONAL JOURNAL OF PURE AND APPLIED RESEARCH IN ENGINEERING AND TECHNOLOGY

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SPECIAL ISSUE FOR
NATIONAL LEVEL CONFERENCE
"Technology Enabling Modernization of Rural India (TMRI- 2018)"

DETECTION OF TRANSMISSION LINE FAULTS IN THE PRESENCE OF THYRISTOR CONTROLLED REACTOR USING STOCKWELL TRANSFORM

GULHASAN AHMAD[1], OM PRAKASH MAHELA[2], SHEESH RAM OLA[1]

1. Apex Institute of Engineering & Technology, Jaipur, India
2. Indian Institute of Technology, Jodhpur, India

Accepted Date: 19/03/2018; Published Date: 01/04/2018

Abstract: In transmission and distribution parts of the power system network, the power system faults are frequently observed. Behaviour of the power system faults changes with FACTS devices. Accurate detection of these power system faults is essentially required for providing effective protection and relaying system of power system network. This paper presents a technique for the detection of power system faults in the presence of Thyristor controlled reactor (TCR). Investigated faults include line to ground (LG), double line (LL), double line to ground (LLG) and three phase fault involving ground (LLLG). The median based fault index is calculated for the investigated faults from the S-matrix of the voltage and current. The study of test system has been carried out and results have been validated in MATLAB/Simulink environment.

Keywords: Fault index; Stockwell transform, thyristor controlled reactor.

Corresponding Author: RAM THAPA

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How to Cite This Article:

Gulsan Ahmad, IJPRET, 2018; Volume 6 (8): 460-469

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INTRODUCTION

The FACTS devices are widely used in power system operations. To alter power system parameters for controlling the power flow, FACTS devices is used. FACTS technology, like static var compensators (SVCs), static synchronous series compensators (SSSCs), static synchronous compensators (STATCOMs), and unified power flow controllers (UPFCs) are commonly used. With FACTS technology, bus voltages, phase angle and line impedances in the power system network can be flexibly and rapidly regulated. FACTS devices are also capable to increase transmission capabilities, improve the security, decrease the generation cost and stability of power system. During faulty condition, the presence of compensating devices affects both steady-state and transient components of current and voltage signals and it creates problems with relay functionality [1]. Hence the power system faults detection with the compensating devices is a very important and most challenging task.

The Fourier transform (FT), wavelet transform (WT),

short-time Fourier transform (STFT), Kalman filter, and Stockwell transform (ST) are the mathematical and signal processing technique and these technique have been utilized for the detection of power system faults. On high voltage transmission lines, detection, classification and location of faults using the comparative study of the performance of DWT (Discrete wavelet transform) and DFT (Discrete Fourier transform) and techniques has been reported in [2]. Authors introduced a two phase method for identification of fault zone a series compensated transmission line in the reference [3]. During the first phase, detailed coefficients of the three phase currents are extracted by using DWT (Discrete Wavelet Transform) and then these coefficients are provided during second phase at the input to a SVM (Support Vector Machine) and it finds the faulty zone. In [4], authors proposed a system for transmission lines by combining data acquisition system power line carrier (PLC) system for fault detection and fault identification system. By using this system we can capture many types of events such as insulator short circuit, cable rupture, circuit breaker opening and closing, broken insulator, In [5], authors introduced a new idea of protection technique by using phasor measuring technique for power transmission grids in a wide area system. It is successfully proved the identification of the faulted line and distinguish between internal and external faults by protection scheme all over the interconnected system. Authors in [6] introduced a new technique for detection and location of fault by replacing current transformers with magnetic field sensing coils. for proper fault detection and location this proposed technique uses the magnetic field sensors as alternative measurement devices

This paper presents a technique for the detection 978-1-4673-8962-4/16/$31.00 ©2016 IEEE and discrimination of different types of power system fault using the Stockwell transform based fault index in the presence of TCR.

This paper has five Sections in which contents are arranged. The introduction is described in the Section I. The Section II describes the proposed test system used for the study. Algorithm which is based on proposed Stockwell transform is presented in section

The simulation results and their discussions are presented in the Section IV.The Section V describes the conclusions of this paper.

PROPOSED TEST SYSTEM

The proposed study using the test system has been carried as shown in Fig. 1. This system include a conventional generator (G) which is rated at 735 kV, the three buses B1 to B3 and the loads L1 and L2 which are connected as shown in Fig. 1. The loading status of node B1 and B2 is provided in Table 1. Table 2 presents the data of transformer XFM. Thyristor controlled reactor (TCR) is connected to the bus B2. TCR consists of a fixed reactor of inductance L in series with a bidirectional thyristor switch. Voltage up to 4000 to 9000 volts can be blocked by currently available large thyristor and conduction of current take place up to 3000 to 6000 amperes. Thus, many thyristors (typically 10 to 20) at a given power rating are connected in series in a practical valve to meet the required blocking voltage levels. A thyristor valve can be conducted by simultaneous application of a gate pulse to all the thyristors of same polarity. Immediately the valve will automatically block when ac current crosses zero, unless the gate signal is applied again. The inductance of TCR is 18.7e-3 and has a quality factor of 50. The values of thyristor snubber resistance and capacitance are 500 ohm and 250e-9 F respectively.

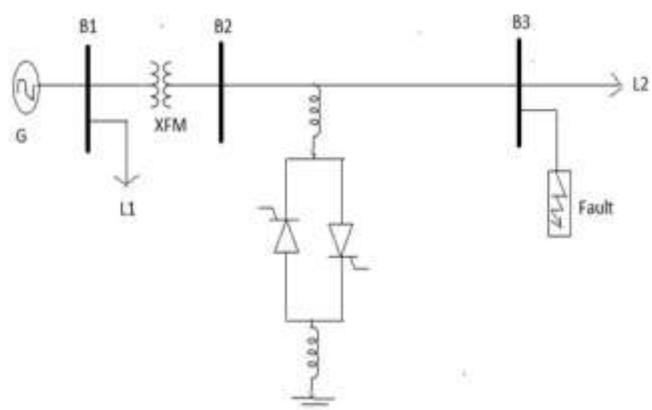

Fig. 1. Single line diagram of the proposed test system.

TABLE 1. LOAD DATA

Node	Active power (W)	Reactive power
B1	200e6	0
B2	10000	100

TABLE 2. TRANSFORMER DATA PROPOSED ALGORITHM

Transformer	MVA	kV-high		kV-low		R (pu)	L (pu)
XFM	333	735		16		0.0025	0.105

The following steps are used in the proposed algorithm:-

- The voltage and current signals are captured on the bus B2 of the test system.

- Decomposition of the voltage and current signals can be done to obtain the S-matrix using the Stockwell transform at a frequency of 1920Hz.

- A fault index for the detection of the power system faults is proposed. This fault index is equal to the median which is calculated from the S-matrix.

- The voltage signal, current signal and the fault index based on the voltage and current signals are plotted. These plots detect and discriminate the different types of power system faults.

SIMULATION RESULTS AND DISCUSSION

This section presents the simulation results which are related to the detection of power system faults in the presence of Thyristor controlled reactor (TCR) using Stockwell transform based median. The study has been carried out with the help of test system in MATLAB/Simulink environment. The investigated power system faults include ground (LG), double line (LL), double line to ground (LLG) and three phase fault involving ground (LLLG). All the investigated transmission line faults have been created at the end of 10th cycle from the start of the simulation and for the 60 cycles data is recorded. Decomposition based on Stockwell transform is carried out for the current supplied by the conventional generator to the load and load bus voltage . The various case studies are explained in the various subsections of this section.

Line to Ground Fault

Line to ground fault is created at 10th cycle from the start of the simulation on phase-A. Voltage signal is captured on the test system bus B2 and decomposed using Stockwell transform. Fault index is calculated from the S-matrix which is obtained using the Stockwell transform with the help of median function. The voltage signal and fault index are illustrated as shown in the Fig. 2. From the Fig. 2 (b) the value of fault index is observed high at the time of fault occurrence and for all other instants of time it has zero value. Hence, the detection of LG fault is effectively done with the help of proposed fault index. double line fault is created by short circuiting the phases A and B. Measuring of voltage signal is done on the bus B2 of given test system. Voltage signal is decomposed using Stockwell transform. In fig. 4, the voltage signal and proposed fault index are shown. From fig. 4, the value of fault index has been observed high at the time of fault occurrence and for all other instants of time it has zero value. Hence, the detection of LL fault is effectively done with the help of proposed fault index based on the median.

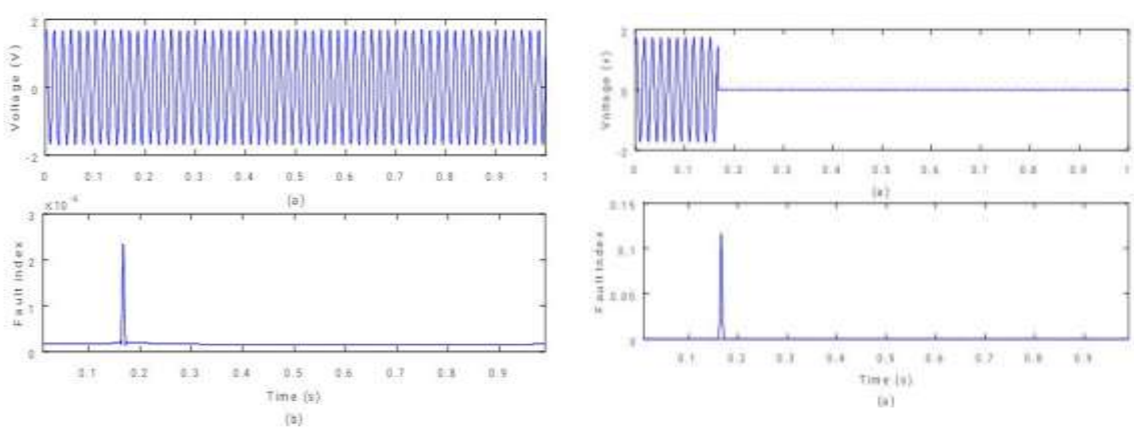

Fig. 2. (a) Voltage signal (phase-A) (b) proposed median based fault index during LG fault.

The current is calculated on the bus B2 of the test system. It is decomposed using the Stockwell transform. In Fig. 3, Current waveform and median based fault index are shown. Fault index is observed high at the time of fault ocurrence which detects the LG fault in the power system network. During the faulty condition, magnitude of current is relatively high as compared to the healthy condition which shows the detection the LG fault.

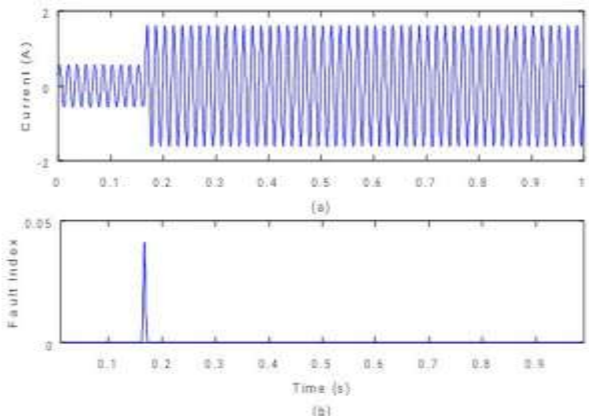

Fig. 3. (a) Current signal (phase-A) (b) proposed median based fault index during LG fault.

Double Line Fault

At 10th cycle from the start of the simulation

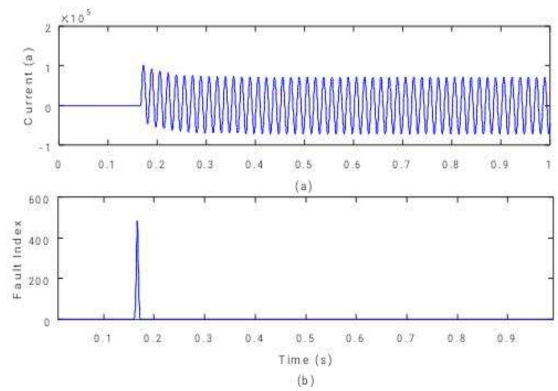

Fig. 4. (a) Voltage signal (phase-A) (b) proposed median based fault index during LL fault.

On bus B2 of the test system the current is measured during LL fault. Current signal is decomposed using the Stockwell transform. In fig 5(a) current waveform and in fig 5(b) median based fault index are shown. From fig 5 the value of fault index has been observed high at the time of fault occurrence and for other instant of time it has zero value. Hence it detects the occurrence of LL fault effectively with the help of proposed fault index based on median.

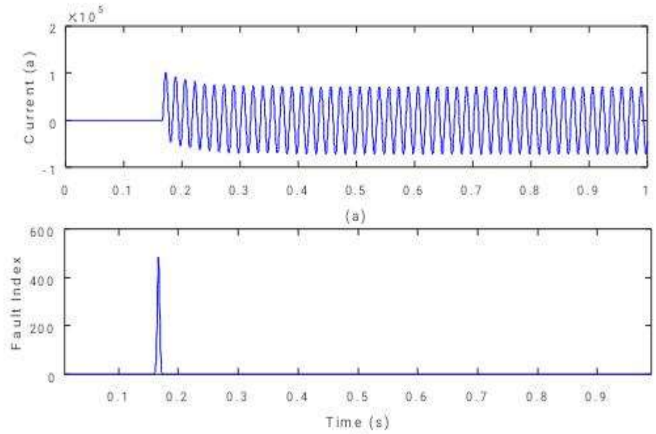

Fig. 5. (a) Current signal (phase-A) (b) proposed median based fault index during LL fault.

Double Line to Ground Fault

At 10th cycle from the start of the simulation, double line to ground fault is created by grounding the both phases A and B simultaneously. Measuring of Voltage signal is done on the bus B2 of the given test system. Voltage signal is decomposed using Stockwell transform. Fig.(6) presents the voltage signal and proposed fault index respectively. From fig. 6 the value of fault index has been observed high at the time of fault occurrence and for all othe instants of time it has zero value. Hence, the detection of LLG fault is done effectively with the help of proposed fault index which is based on the median.

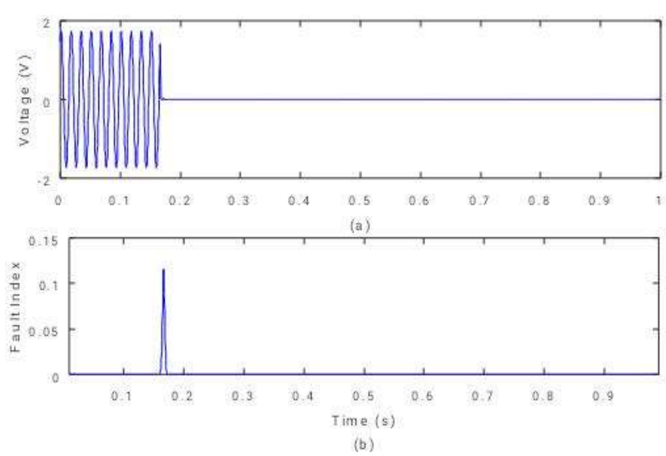

Fig. 6. (a) Voltage signal (phase-A) (b) proposed median based fault index during LLG fault.

On the bus B2 of the given test system the current is measured during LLG fault. Current signal is decomposed using the Stockwell transform. In fig 7(a) current waveform and in fig 7(b) median based fault index are shown. From fig 7 the value of fault index has been observed high at the time of fault occurrence and for other instant of time it has zero value. Hence it detects the occurrence of the LLG fault effectively during faulty condition in power system network.

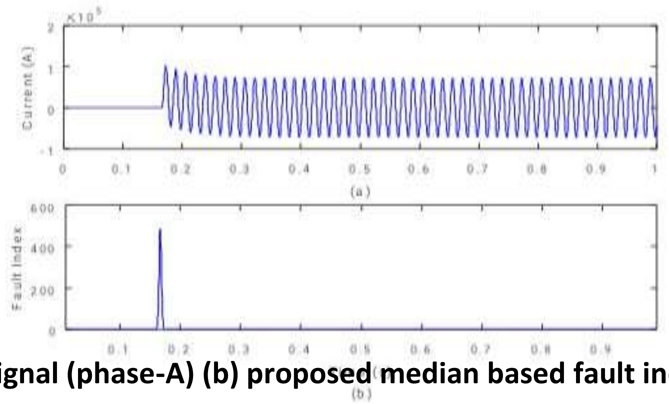

Fig. 7. (a) Current signal (phase-A) (b) proposed median based fault index during LLG fault.

Three-Phase Fault Involving Ground

At 10th cycle from the start of the simulation, three-phase fault involving ground fault is created by grounding all the phases simultaneously. On the bus B2 of the given test system voltage signal is measured. Voltege signal is decomposed by using Stockwell transform. In fig 8 the voltage signal and fault index are shown respectively. From fig 8 the value of fault index is observed high during faulty condition and for healthy condition it has zero value. Hence, Detection of LLLG fault is done effectively with the help of proposed fault index based on the median.

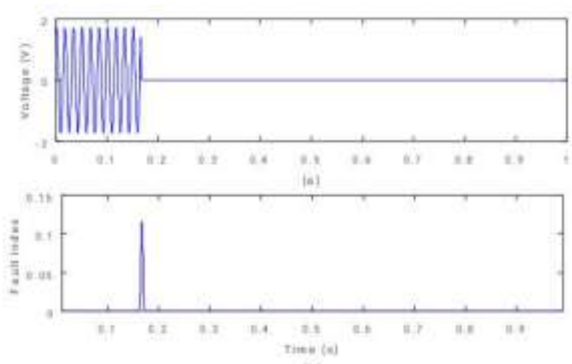

Fig. 8. (a) Voltage signal (phase-A) (b) proposed median based fault index during LLLG fault.

On the bus B2 of the given test system, current is measured.Current signal is decomposed by using the Stockwell transform. In fig 9 (a) Current signal and in fig 9(b) median based fault index are shown. From fig 9 the values of fault has been observed high during faulty condition and it has zero value during healthy condition. Hence detection of LLG fault is done effectively during faulty condition in power system network

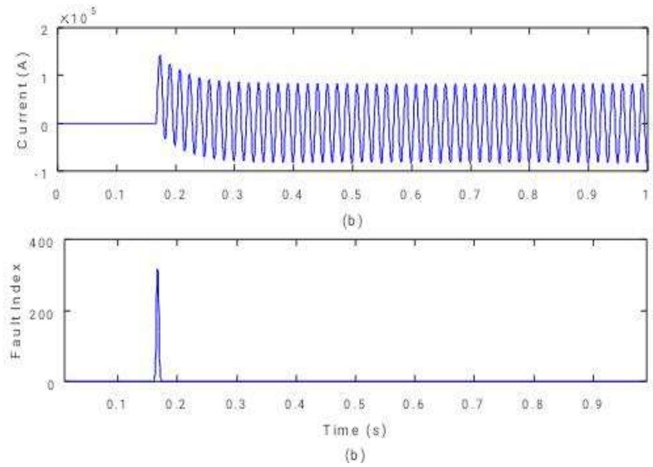

Fig. 9. (a) Current signal (phase-A) (b) proposed median based fault index during LLLG fault.

TABLE 3. MAXIMUM VALUES FAULT INDEX

Type of	Maximum value of fault index	
Fault	Voltage based	Current based
LG	2.5	0.045
LL	0.125	475
LLG	0.125	525
LLLG	0.125	350

From the Table 3, it is observed for the voltage based fault index that LG fault has maximum value and for the current based fault index LLG fault has the maximum value, followed by LL, LLLG and minimum for the LG fault. Hence, from table 3 it is clear that voltage based index is more effective for the detection of the power system faults in the presence of TCR.

CONCLUSION

This paper introduces a technique for the detection of power system faults which is based on Stockwell transform in the presence of Thyristor controlled reactor. From the decomposition of voltage and current signal which is based on stockwell transform, a fault index based on the median of the S-matrix is obtained. Thus this proposed technique is used for the detection of faults in the presence of TCR. Power system faults such as LG, LL, LLG and LLLG have been successfully detected and discriminated using the voltage based fault index. Detection of faults in the presence of TCR is done more effectively with the voltage based fault index compared to the current based fault index. The proposed study has been carried out in the MATLAB/Simulink environment.

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