A Wavelet Based Protection Scheme For Distribution Networks With Distributed Generation

***Abstract*— Integration of Distributed Generation (DG) in distribution power system would affect the fault current level and therefore the relay settings. This paper presents a protection scheme based on the Wavelet Transforms for the detection of the faults with and without DGs. Faults are simulated at each bus and the fault currents are analyzed with Haar wavelet to obtain detail coefficients of single level decomposition. Fault indices are calculated based on d-coefficients and compared with threshold for detecting the fault. The performance of the proposed protection scheme is tested by considering the variations in location and capacity of DG successfully.**

***Index Terms*- Distributed Generation(DG), protection,relay, Fault index (F_i), wavelets.**

I. INTRODUCTION

Protection systems are designed to isolate the faults quickly and to protect major components of the power system from possible damages by abnormal voltage or current. Most distribution network protection schemes are initially designed without DGs. According to [1], the penetration of DGs changes the traditional power system short circuit power, fault current level and the characteristics of the fault current.

Capacity and location of DG in the network have much influence on the protection system. The Effect of DG capacity on protection is studied in [2] and the maximum and minimum capacities of DG that can be placed at a particular bus are obtained without changing the relay settings. Integration of distributed generation (DG) in radial distribution network disturbs the setting of the existing over-current protective devices in the network. [3]. Thus many protection schemes are proposed in order to identify and isolate the faults and also to maintain the protection coordination.

Wavelet Transform (WT) technique is used effectively to analyze current and voltage signals of transient nature. The entropy of wavelet coefficients of the measured bus currents by relay agents is used to detect faults. Non normalized Shannon Entropy is used in [1]. In transmission lines, fault indices are calculated based on the sum of local and remote end detail coefficients, and compared with threshold values to detect and classify the faults by using Bior 2.2 wavelet [5].

A feed forward neural network is used to identify the fault location and to isolate the faulted sections [6]. An algorithm is proposed for determining current directionality changes and, thus, the fault location enabling a trip signal to the corresponding remote node by comparing the phase jump measured at each node of the network [7].

In this paper a Wavelet based Multi Resolution analysis is used to analyze the fault current transients at various buses using Haar mother wavelet. The d-coefficients are utilized to calculate a Fault Index which is compared with a threshold to detect the fault and to arrive at a trip decision. The scheme has been tested for various fault locations of the distribution system. A DG is introduced in distribution system to test performance of the proposed protection scheme. The variations in DG location and its size of are varied and detection of faults has been established using the proposed scheme successfully.

II. WAVELET ANALYSIS OF SIGNALS

In wavelet analysis there are two components of the signal they are approximations and details. The approximations are the high-scale, low-frequency components of the signal. The details are the low-scale, high-frequency components.
The filtering process is shown in Fig 1.

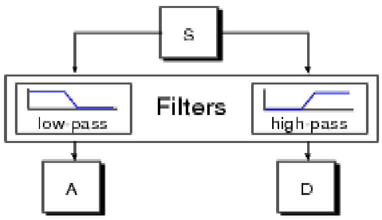

Fig 1. Decomposition of the signal by filters

The original signal, S, passes through two complementary filters and emerges as two signals.

Wavelet Transform (WT) is an effective method for the analysis of transient currents and voltages in both frequency and time domains. This can be achieved by analyzing the signal in frequency bands with uniform and non uniform division of frequency domain unlike Discrete Fourier Transform (DFT). WT helps in analyzing the signals by using short and long windows at higher and lower frequencies respectively. Wavelets are used in decomposition of the signal in various frequency bands. These are a set of functions which are obtained from a mother wavelet by translation and dilation. Thus the amplitude and incidence of each frequency can be found with precision.

A sequence of a function {h(n)}(low pass filter) and {g(n)}(high pass filter) defines the Wavelet Transform(WT). The scaling function $\varphi(t)$ is determined by the low pass filter and produces approximations and wavelet function $\psi(t)$ is determined by the high-pass filter and generates details. The relationship between the functions and filters is defined by the following equations

$$\varphi(t) = \sqrt{2}\sum h(n)\, \varphi(2t-n)$$
$$\psi(t) = \sqrt{2}\sum g(n)\, \psi(2t-n)$$

Where $g(n) = (-1)^n h(1-n)$

Various types of wavelets such as Haar, Daubachies, Coiflets and Symlet etc. can be used and the selection of mother wavelet is based on the type of application [5]. The transient currents associated with the fault are analyzed using a novel WT method for fault detection, using Haar wavelets in the following section.

III. PROPOSED SCHEME

A. Test System

Fig.2 represents the configuration of the distribution system at Tanta city as a part of the Egyptian West Delta distribution system [4]. The studied distribution system consists of 15 nodes. The flat voltage for the systems is (11kV) at node 1. Node 1 is 66/11 transformer, other buses refers to possible loading point. The voltage at the first node on the feeder is (10.27 kV).Table 1 presents the bus data and the line data of this system.

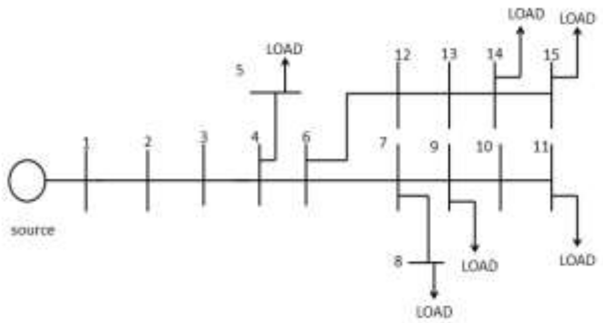

Fig 2: Single line diagram of the real distribution system

B. Test system data

TABLE I
BASIC DATA FOR THE DISTRIBUTION SYSTEM

Node Number	line from	line to	Length (Km)	Line parameters R (Ω/km)	X (Ω/km)	Y/2
2	1	2	0.078	0.163	0.089	0.00007
3	2	3	0.85	0.266	0.095	0.00005
4	3	4	0.22	0.569	0.106	0.00004
5	4	5	0.05	0.569	0.106	0.00004
6	4	6	0.33	0.569	0.106	0.00004
7	6	7	0.2	0.569	0.106	0.00004
8	7	8	0.04	0.569	0.106	0.00004
9	7	9	0.65	0.266	0.095	0.00005
10	9	10	0.15	0.569	0.106	0.00004
11	10	11	0.1	1.113	0.117	0.00003
12	6	12	0.44	0.569	0.106	0.00004
13	12	13	0.15	0.266	0.095	0.00005
14	13	14	0.45	0.266	0.095	0.00005
15	14	15	0.2	0.266	0.095	0.00005

C. Proposed Algortihm and Flowchart:

The Fault currents at each bus are sampled at a frequency of 1600 Hz. The Fault currents are then analyzed at first level of decomposition using the Haar wavelet. The absolute values of the resultant d1 coefficients are calculated. The sum of the absolute detail coefficients over a moving window with half cycle length is calculated to obtain the fault Index. This Fault Index is compared with the threshold value. Fig.3 represents the 3-phase currents for a 3-phase fault at bus 9. The absolute values of the d1-coefficients of phase-a fault current are presented in Fig.4.

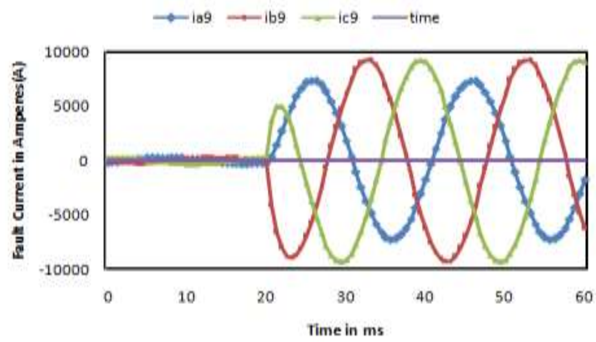

Fig 3. Three phase fault currents at bus 9

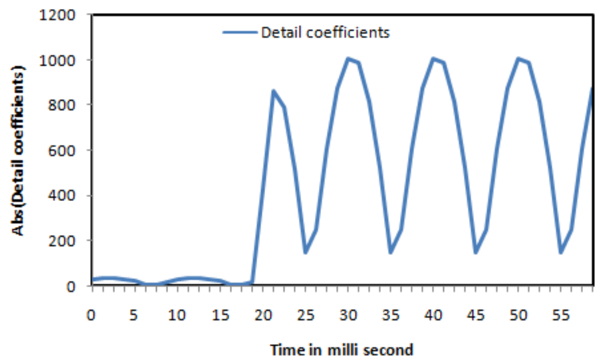

Fig 4. Absolute detail coefficients of phase –A of bus 9

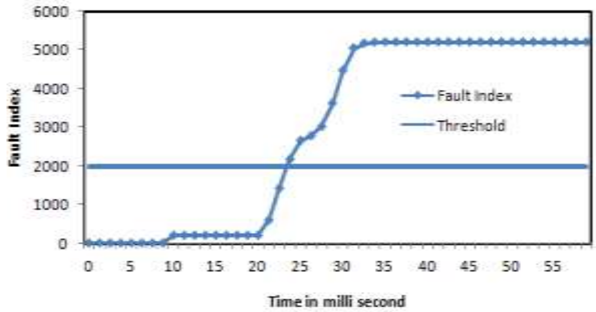

Fig 5. Fault index for 3 phase fault at bus 9

Fig. 5 depicts the variation of Fault Index for 3-phase fault at bus 9. This process is repeated for faults at all the buses to detect the affected buses. The Fig. 6 shows the flowchart of the proposed algorithm.

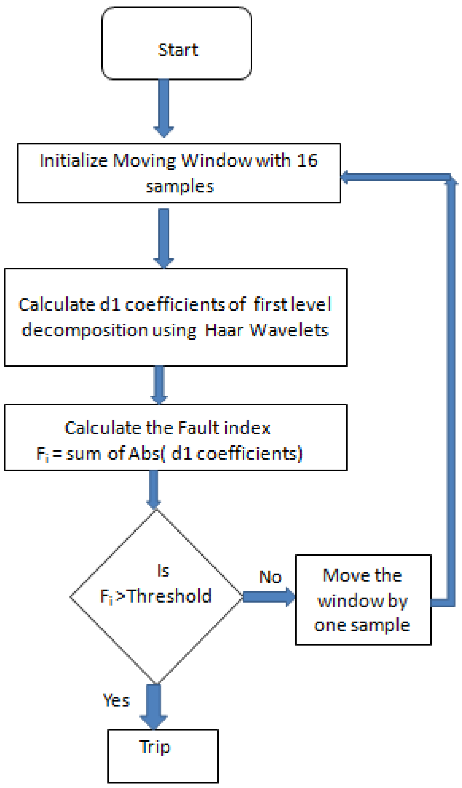

Fig 6. Flow chart of the proposed protection scheme

The simulation data considered has an ideal source with the following generation data as: RMS vault =10.27 kV (phase to phase), f=50 Hz (R&Lseries sources Rs=0.00893 Ω - Ls= 16.52e-5H).

All the studied cases consider the load at distribution nodes as:
Load 1: 1.85 MW Load 2: 0.901 MW Load 3: 0.9 MW
Load 4: 0.857MW Load 5: 0.92 MW Load 6: 0.91 MW

The **DG** unit is inserted to the simulation model at the same voltage with R&L series parameters as R_{DG}=0.08829 Ω & L_{DG} = 15.92 mH. The location and the capacity of DG is varied so as to study their effect on the proposed protection scheme

D. Effect of Location of DG

The Introduction of Distributed Generator into the network will change the fault levels. However the proposed scheme is affected only by the transients of the current. Hence, a DG of 4 MW capacity is introduced at various buses to study the variations in the fault index. Faults have been simulated at all the buses and fault index of these buses are found to be greater than threshold. A case study of which is illustrated from figures 7 to 9 for the faults at buses 4,9 and 15.

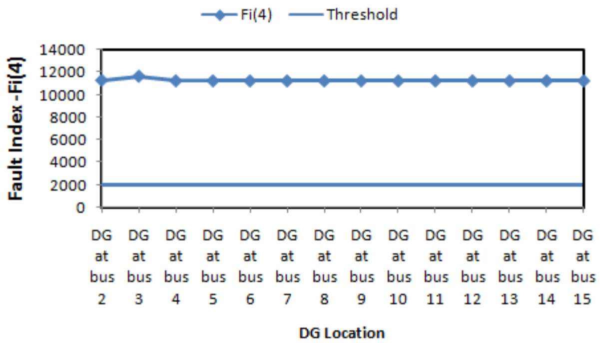

Fig 7: Fault Index F_i (4) of bus 4 , Fault at Bus 4

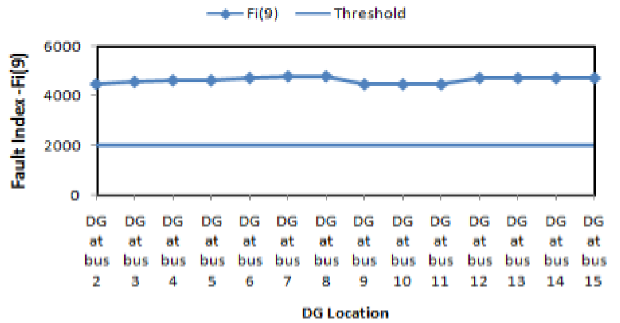

Fig 8: Fault index F_i (9) for bus 9, Fault at Bus 9

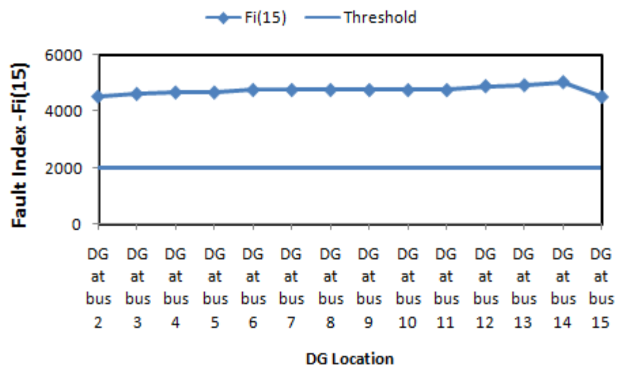

Fig 9: Fault index F_i (15) for bus 15 , Fault at Bus 15

Fig. 7 represents the variation in the fault index with DG locations for the fault at bus 4. Fig. 8 depicts the variation in the fault index with DG locations for the fault at bus 9. The variations of fault index with the DG location for a fault at bus 15 are shown in Fig. 9. Thus the proposed scheme has been successful in detecting the faults even in the presence of distributed generator at all the locations.

E. Effect of Size of DG

The capacity of the distributed generator would also influence the protection scheme due to changes in fault current magnitudes. Hence, the performance of the proposed scheme needs to be tested by considering the changes in the capacity of the DG installed. Hence, the capacity of DGs has been varied from 0-10 MW at each bus. The Fault Indices for various bus faults have been calculated. Faults have been simulated at all the buses by varying capacity of the DGs from 0(without DG) to 10 MW. Fault Index have been calculated and compared with the same threshold value. A case study of which is illustrated from figures 10 to 12 for the DG location at bus 5.

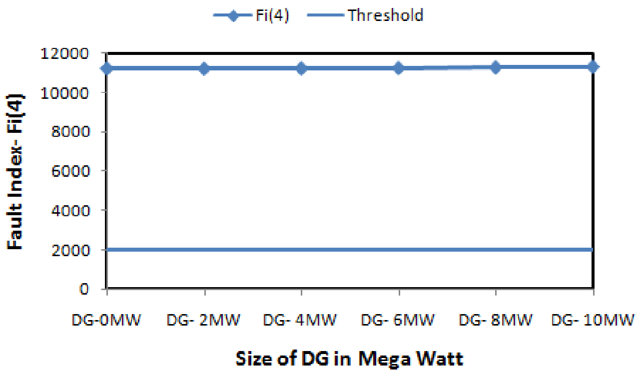

Fig 10: Fault index F_i (4) - DG at Bus 5 & Fault at Bus 4

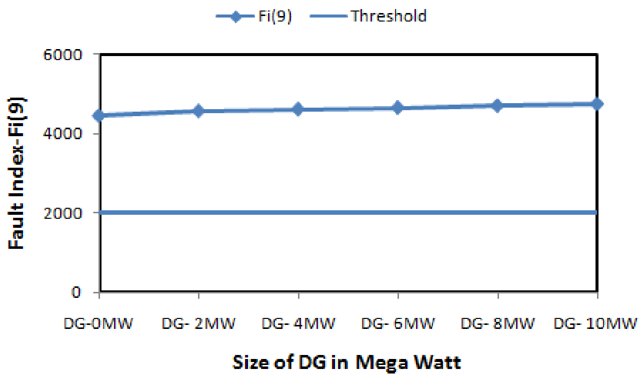

Fig 11: Fault Index F_i(9) with DG at Bus 5 and Fault at Bus 9

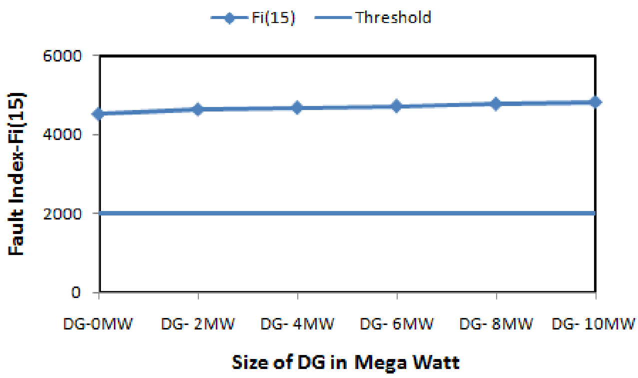

Fig 12: Fault Index F_i(15) with DG at Bus 5 and Fault at Bus 15

Fig. 10 represents the variation of the fault index with the size of DG when fault is at bus 4 and DG located at Bus 5. Fig .11 depicts the changes in the fault index with the change in the capacity of DG when fault is simulated at bus 9 with DG location at Bus 5. The variation in the fault index when the DG capacity is changed from 0 to 10 MW when fault is considered at bus 15 is shown in Fig 12. The simulation results prove that the proposed scheme has been effective in detecting the faults in the presence of DG as well as in the absence of DG i.e., with zero capacity.

F. Selection of Threshold

An extensive study has been made by simulating faults at all the buses and calculating the fault index at all the buses for each fault. The same study has been repeated by introducing a DG with variable capacity at each bus. In this study the buses are classified as *affected buses* (between source(s) and fault) and *Unaffected buses* (beyond the fault and source(s)). The fault index for both affected and unaffected buses form two regions i.e., Tripping region and Blocking region. The range which separates these two regions is selected to fix the threshold value.

IV. Conclusions

WT based multi resolution analysis approach can be successfully applied for effective detection of faults in distribution networks with and without distributed generation. Fault detection can be accomplished within half a cycle using detail coefficients of currents. The proposed protection scheme is found to be fast and reliable for various fault locations. The protection scheme has been proved to be successful in detecting the faults for various locations of DG and variations in its capacity.

V. References

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BIOGRAPHY

Mahmood Shaik, is pursuing M.Tech from University College of Engineering, Jawaharlal Nehru Technological University, Kakinada. He is interested in power systems protection, Distributed generation.

M. Nageswara Rao is Assistant Professor in the Department of Electrical Engineering, Jawaharlal Nehru Technological University, and Kakinada, India. His areas of interest include electric power distribution systems and AI Techniques applied to power systems.

Shaik Abdul Gafoor is Professor and Head of Electrical and Electronics Engineering Department in St. Ann's College of Engineering, Chirala. He graduated from Regional Engineering College, Warangal, India in 1989 and received M.Tech from Indian Institute of Technology, Kanpur, India in 1991. He obtained Ph.D from NIT Warangal. His areas of interest include wavelet applications on power system protection and ANN.