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# Neuro-Wavelet Based Transmission Line Protection Scheme in Presence of Microgrid

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***Abstract:*** This paper introduces a novel protection scheme for transmission line protection with microgrid comprises of wind, solar, fuel cell energy sources. Microgrids provide environmental, clear economic benefits for the end consumers, power utilities and society. However, transmission line and microgrids poses major technical challenges. Protection system must respond both microgrid and utility grid failures. The major technical challenges of microgrid protection are to respond to main and microgrid faults. After the microgrid model is developed and it is connected to a transmission line. Later, for detection, classification and location of faults, wavelet multi resolution Analysis is used. Faults are detected by the fault indices and compared with the threshold value and for the location of fault artificial neural networks is used on transmission system and microgrid resources. The proposed algorithm is tested and it is effective for the detection, classification and location of faults on transmission system with microgrid which is almost independent of fault impedance, fault inception angle and fault distance of feeder line.

***Keywords:*** Islanded microgrid, inverter-interfaced microgrids, Microgrid protection.

## 1. INTRODUCTION

Distributed energy resources are very nearer to the load centre has benefits of reducing network congestions and transmission losses. Renewable energy resources like solar, hydro energy and wind includes different techniques allows generations in micro sources. Micro sources can be placed nearer to the loads which reduce the investments due to lesser network capacity requirements, operation losses and operation costs which increase reliability [1]. However, microgrids raise number of challenges the main challenge is protection [2]. There are two challenges: Firstly, during abnormal conditions the time of islanding of microgrid from the maingrid. Secondly, proper coordination and reliable protection system for effective tripping during the fault [3]. A detail $D_1$ coefficient of current signals using Bior1.5 wavelets are used to detect, classify and location of fault using Artificial neural Networks. In this paper, the validation of wavelet based fault location methods are performed on a transmission line with microgrid comprises of fuel cell, wind, solar energy sources. After the microgrid model is developed, it is connected to an equivalent transmission system. A fault is simulated on the transmission line so that the fault description and location algorithm can be applied to detect the fault as well as location estimation with the existence of microgrid. The scheme is applied on typical transmission model for different faults with varying fault incidence angles and fault resistances.

## 2. TECHNICAL CHALLENGES IN MICRO GRID PROTECTION

Protection scheme for microgrid should respond to main grid as well as microgrid faults. Firstly, the protection system must separate the microgrid from the main grid rapidly for protecting the microgrid connected loads. Secondly, the protection system should separate the low capacity part of the microgrid as

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early as possible to clear the fault in the system. Some of the problems related to a protection of distribution grids and microgrids with a huge penetration of distributed energy resources. The short circuit current calculations for radial feeders with distributed energy resources and seen that short-circuit currents used in overcurrent protection relay systems depend on a connection point and a feed-in power from distributed energy resources. Because of these, amplitudes and directions of short circuit currents varies according to the system abnormalities. In fact, because of the intermittent micro-sources like solar ,wind and periodic load variation the operating conditions of microgrid are constantly changing. Also a network topology can be regularly changed aimed at achievement of economic or operational targets or loss minimization. Besides controllable islands of different capacity and content can be formed as a result of faults in the main grid or inside a microgrid. In order to deal with low short-circuit current levels and bi-directional power flows in microgrids dominated by micro-sources with power electronic devices interfaces a new protection schemes are required, where relays setting parameters must be checked/updated systematically to ensure that they are still deserved. A novel adaptive microgrid protection concept is presented in this paper [4, 5] using advanced communication system [6], data from off-line short circuit analysis and real-time measurements. This concept is based on protection relay settings with respect to a microgrid topology, generation and load status. The microgrid concept has to overcome a number of challenges in several fields, not only from the protection point of view, but also from the control and dispatch perspective [7]. Generation systems in both low voltage (LV) and medium voltage (MV) systems, making power flow bidirectional.

## 3. WAVELET ANALYSIS

Wavelet Transform (WT) is a linear transformation similar to Fourier transform, the only important difference is it allows for a given signal time localization of different frequency components. So, it is a mathematical technique used in signal analysis. Where the signal being analyzed has transients or discontinuities wavelet analysis is particularly efficient, e.g., the post faults current/voltage waveform. Wavelet transform is a tool that cuts up functions or data or operators into different frequency components, and then studies with a resolution [8] matched to its scale of each component [12]. The following figure shows the basic idea of the DWT. After DWT, the input signal is analyzed into wavelet coefficients. The wavelet coefficients can be processed and synthesize into the output signal. There are four filters in this whole process: low pass filters L and L′, high pass filters H and H′.

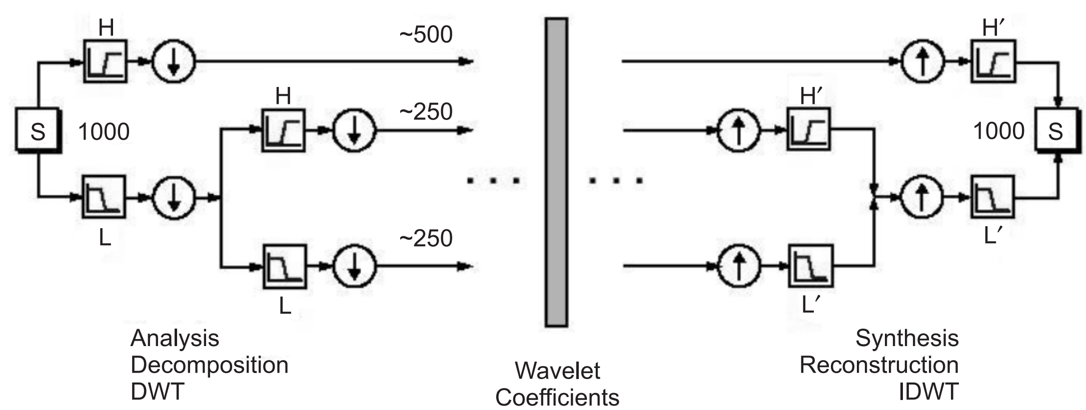


**Figure 1: Wavelet transforms analysis of a signal**

Transients are decomposes into a series of wavelet components by using wavelet transform having each of which corresponds to a time domain signal that covers a specific octave frequency band containing more detailed information. These wavelet components appear to be useful for detecting and classifying the sources of surges under abnormal conditions [12]. Hence, the Wavelet transform analysis is practical for analyzing power system transients [13]. Given, a function $f(t)$, its continuous wavelet transform (WT) be calculated as follows:

$$\text{W.T}(a, b) = \frac{1}{\sqrt{a}} \int x(t)\, g\left(\frac{t-b}{a}\right) dt$$

Where '*a*' is scaling (dilation) and '*b*' is translation (time shift) constants respectively, and ψ is the wavelet function which may not be real.

## 4. ARTIFICIAL NEUTRAL NETWORK

Neural networks are simplified models of the biological nervous system. A neural network [8-9] is a heavy parallel distributed processor build with simple processing units which has a natural ability of storing knowledge and keep it available for use. It resembles the brain in two aspects (i) Inter-neuron connection strengths, known as synaptic weights to store the acquired knowledge, and (ii) knowledge is acquired by the network from its environment through a learning process. There has been a very limited attention to the use of artificial neural network for protection of teed transmission circuit [6]. Fault distance location in transmission line circuits and also detects the fault A.S. Oshaba and E.S. Ali [7] use radial basis function neural network for but the network does not identify the phase in which the fault occurs.

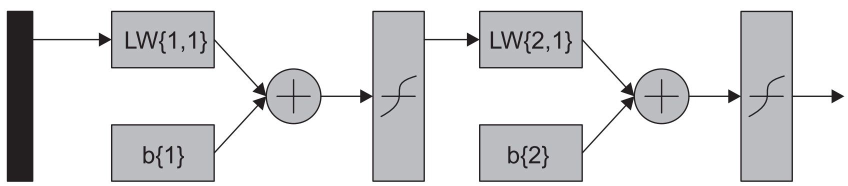


**Figure 2: Neural Network Structure**

The details of the ANN architecture described as follows:

1. Input layer: D1 coefficients of current signals are used to locate the fault.
2. Number Layers: 2,
3. Number of neurons: 10,
4. Transfer function: Pure line

## 5. MODELLING OF HYBRID MICRO GRID CONNECTED TO UTILITY GRID

Non-conventional energy resources like solar, wind energy and fuel cell have attracted power sectors for power generation that interconnected at point of common coupling to the main power grid with an aim to improve reliability in power supply against the load demand. Both solar and wind, is unsystematic and dependence on changes in climatic. Fortunately, the problems can be overcome by integrating all the resources to form a hybrid microgrid system where the strength of one source overcomes the drawback of the other source. However, the interfacing of microgrid with these energy resources makes several power quality issues and islanding problems which must be identified, analyzed and mitigated effectively.

Photovoltaic (PV) system has an array of cells containing a solar photovoltaic material that converts solar radiation into direct current .The direct current is converted into alternating current so it can be connected to main grid [10]. Maximum power obtaining from solar has directly related to solar irradiance intensity and temperature. The output current is equal to difference of light generated current to diode current.

$$I = I_{ph} - I_D \tag{1}$$

$I_D$ = Diode current,

$I$ = Output current of cell,

$I_{ph}$ = Light generated current.

The wind turbine acts as a prime mover to a coupled DC generator. A Pulse Width Modulation (PWM) technique is used to convert output of DC generator to three phase AC voltage [9]. Wind turbine extracts maximum kinetic energy from the wind, which strikes rotor blade. The power coefficient $C_p$ measures amount of energy extracted by the turbine. $C_p$ may be given as a function of the Tip Speed Ratio (TSR).

$$\lambda = \omega m \, R/V \quad (2)$$

$$P = 1/2 C_P \, \rho V^3_W \, AW \quad (3)$$

$\omega m$ = Wind turbine mechanical angular rotor speed,

P = Power (W),

$C_p$ = Power coefficient,

$V_w$ = Velocity of Wind (m/s),

A = Rotor disc Swept area ($m^2$),

$\rho$ = Air Density (kg/m).

## 6. FAULT ANALYSIS OF MICROGRID WITH SYSTEM MODELLING

Fault analysis in micro grid can be categorized into two types one of the fault in main grid and other is in micro grid considered as internal and external faults. Internal fault could be in LV feeder or LV consumer and external fault could be in MV bus or distribution transformer. The micro grid need to be operating in both grid connected mode and islanded mode. Conventional protection strategy is a big challenge in microgrid protection system [11]. The protection problem of major microgrid is related to major difference between fault current in main grid connected mode and islanded mode. Also there is a selectivity and sensitivity issues due to various different fault current in different situations [10]. But in DGs with lower fault current levels it is essential to have high sensitive to faults and selectively isolate/sectionalize. As the solution for all micro grid protection conventional protection system doesn't offer effective solution, but it needs advanced protection scheme. The protection scheme makes sure that safe operation of microgrid in both modes of operation, that is island and grid connected modes. In grid connected mode due to contribution of host grid fault currents are large. This allows employing conventional over current relay, but the fact is that due to existence of distributed resources the protection coordination may be compromised [15].

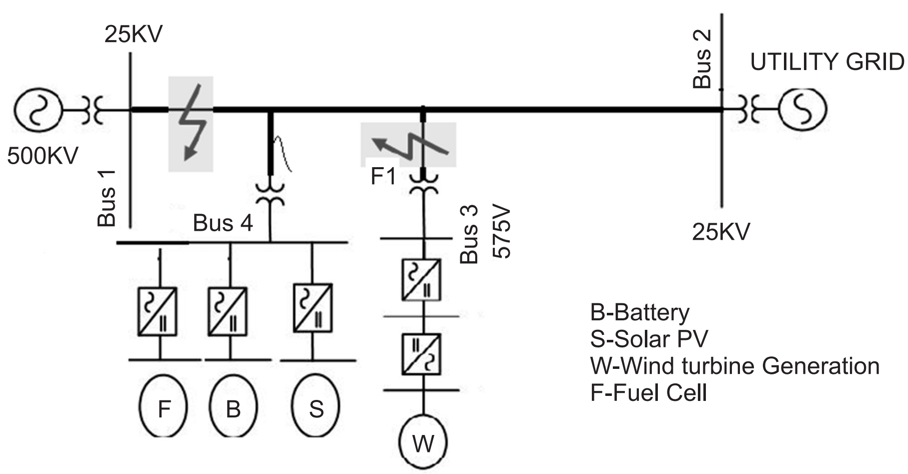


**Figure 3: Single line diagram for microgrid connected to utility grid**

A 60 km length transmission line is considered in between Bus 1 and Bus 2 as test case in this paper. At 10 km distance of the transmission line at Bus 3 formulated with wind energy source of capacity 9 MVA, 575 V through a transformer of 575 V/25 KV is connected. A Bus 4 formulated with battery, solar PV and Fuel cell energy source of capacity 400 KVA connected through transformer of 575 V/25 KV. Figure 3 Represents the Single line diagram for microgrid connected to utility grid.

## 7. ESTIMATION OF FAULT LOCATION

Fault location estimation is determined using artificial neural networks subsequent to detection and classification of fault. For this purpose a Bior. 1.5 mother wavelet is used to decompose the local terminal of three phase currents over a half cycle window. A decomposition $D_1$ is used for fault detection and classification to speed up to assess the fault location. To estimate fault location for an LG, LL, LLG and LLLG fault, $D_1$ decomposition of any one faulty phase can be used.

The details of the artificial neural networks architecture described as follows:

1. Input layer: Current signals detail $D_1$ coefficients using Bior. 1.5 wavelets at both the ends are used for location of fault.
2. Number Layers: 2,
3. Number of neurons: 10,
4. Transfer function: pure line.

## 8. RESULT ANALYSIS

Bior. 1.5 mother wavelet is used to analyze the local terminal three phase currents to obtain the detail coefficients over a half cycle length of moving window. The detail coefficients are calculated from the Bus1, Bus 2, Bus 3 and Bus 4 to obtain effective D1 coefficients ($D1_E$). Each phase Fault Index ($If_1$) is then calculated. The results are plotted for different faults are given below.

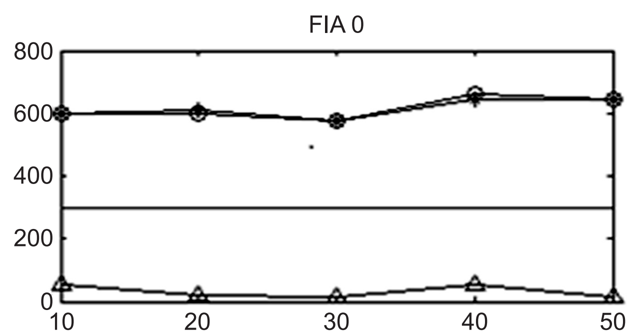


**Figure 4: Variation of fault index from Bus 1 at LL Fault on phase AB for transmission line at FIA 0°**

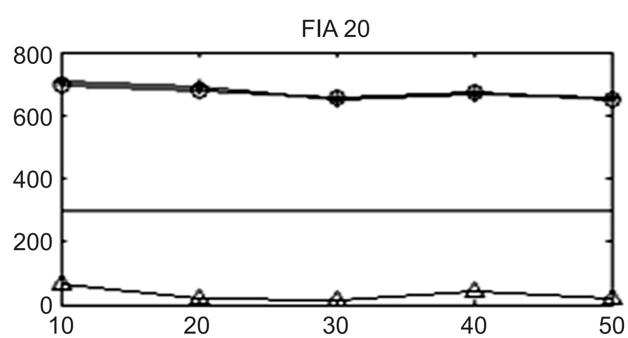


**Figure 5: Variation of fault index from Bus 1 at LL Fault on Phase AB for transmission line at FIA 20°**

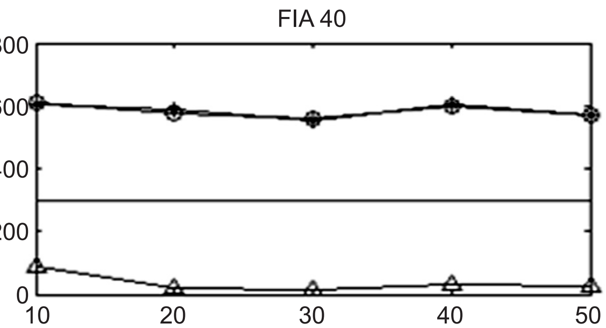


**Figure 6: Variation of fault index from Bus 1 at LL Fault on Phase AB for transmission line at FIA 40°**

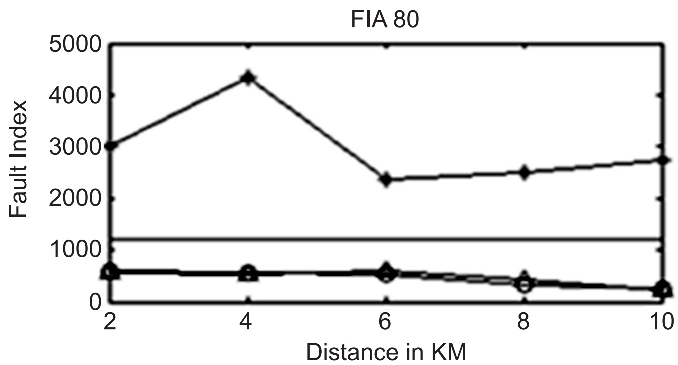


**Figure 7: Variation of fault index from Bus 2 at LG Fault on Phase AG for transmission line at FIA 80°**

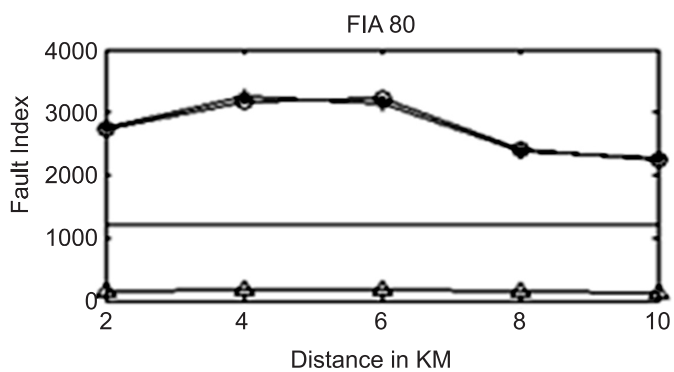


**Figure 8: Variation of fault index from Bus 2 at LLG Fault on Phase ABCG for transmission line at FIA 80°**

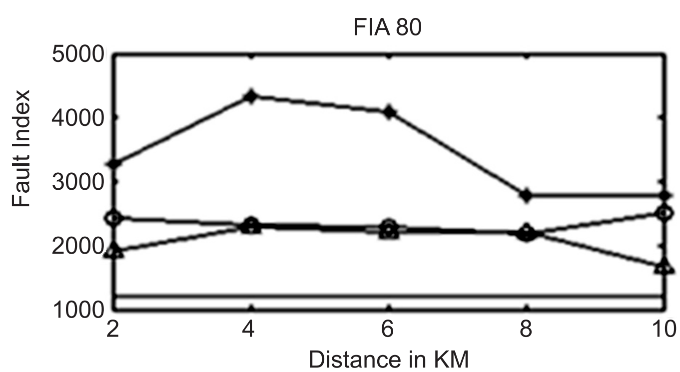


**Figure 9: Variation of fault index from Bus 2 at LLLG Fault on Phase ABCG for transmission line FIA 80°**

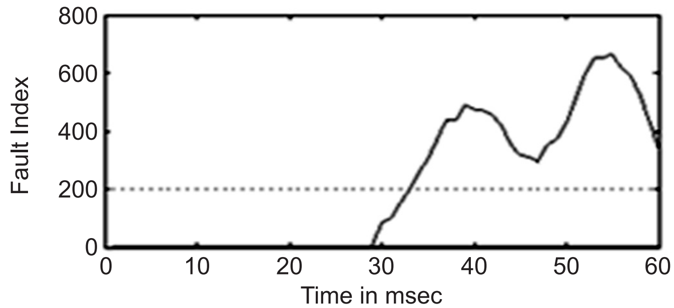


**Figure 10: Detection of LG fault at PV generation**

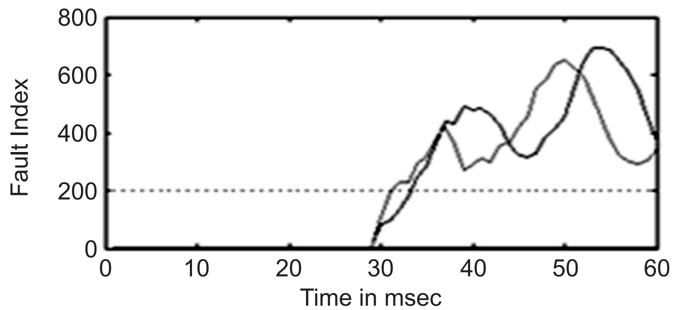


**Figure 11: Detection of LLG at PV generation**

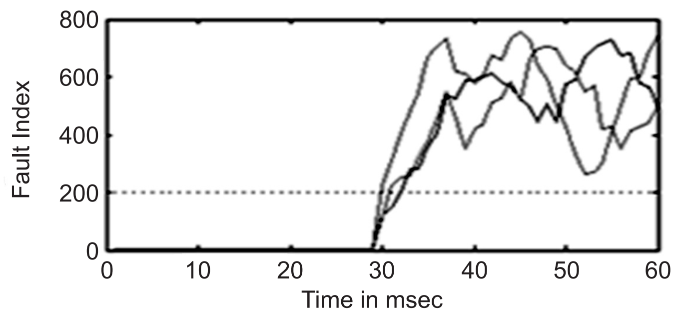


**Figure 12: Detection of LLLG fault at PV generation**

The described algorithm has been explained for all types of faults at various locations by simulating LG fault, LL fault, LLG fault and LLLG faults at different locations of transmission line with STATCOM. The variation of fault Index If1 with the location varying with step size for all types of faults of transmission line in presence of STATCOM. The fault index If1 of all faulty phases varies with the type of fault. However its value remains greater than Threshold Th1. The fault Index of healthy phases remains less than the threshold value. The location of the fault in the system is described by comparing with ANN distance and actual distance at fault is occurred is illustrated in table-1

**Table 1**
**ANN based fault location Analysis**

| *Type Fault* | *Actual Distance* | *ANN Distance* | | | |
|---|---|---|---|---|---|
| | | *T1* | *%Error* | *T2* | *%Error* |
| | 24 | 24.4 | 0.8 | 23.9 | 0.2 |
| LG | 36 | 35.2 | –1.6 | 36.6 | 1.2 |
| | 45 | 45.4 | 0.8 | 43.8 | 2.4 |

| *Type Fault* | *Actual Distance* | *ANN Distance* | | | |
|---|---|---|---|---|---|
| | | *T1* | *%Error* | *T2* | *%Error* |
| LLG | 24 | 23.8 | –0.4 | 24.3 | 0.6 |
| | 36 | 35.7 | –0.6 | 36.4 | 0.8 |
| | 45 | 45.9 | 1.8 | 46.2 | 2.4 |
| LL | 24 | 23.8 | –0.4 | 24.2 | 0.4 |
| | 36 | 36.2 | 0.4 | 35.2 | 1.6 |
| | 45 | 45.6 | 1.2 | 45.3 | 0.6 |

## 9. CONCLUSIONS

This paper describes an innovative technique based on wavelet multi resolution analysis is used to detection, discrimination and location of the fault in the transmission line with microgrid comprising of solar, wind turbine, and fuel cell generation using artificial neural network analysis. The test system is created and simulated using the power system block set with SIMULINK software. The proposed protection scheme tested and found to be fast, reliable and accurate for different types of faults on transmission lines with various fault impedances, inception angles and locations of the fault.

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