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Wavelet-Ann Based Fault Location Identification in Micro Gridinter Connected Transmission System

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Abstract: This paper presents a novel protection scheme for the protection of transmission system with microgrid (MG) having of wind energy, solar PV energy and fuel cell sources. MGs provide environmental, economical benefits for the end consumers, power usages and society. However, transmission line and MGs poses major technical challenges. Protection system must respond both MG and utility grid failures. Technical challenges of MG protection are to respond to main and MG faults. A MG model is designed and it is connected to a transmission line. Later, for detection and classification of faults wavelet Analysis (WT) is used. Faults are detected by the fault indices and compared with defined threshold value. The location of fault is done by artificial neural networks (ANN) on MG connected transmission system using detailed (D_1) coefficients of energy current signals. This proposed algorithm is tested and more effective for the detection, classification and location of faults on MG interconnected transmission system. This algorithm is accurate and independent of fault inception angle (FIA), fault impedance and fault distance on line.

Keywords: Islanded microgrid, inverter– interfaced microgrids, Microgrid protection.

I. INTRODUCTION

Distributed energy resources (DERs) are very nearer to load centre has benefits of reducing network congestions and transmission losses. DERs like solar, fuel energy and wind includes different techniques allows generations in micro sources. Micro sources can be placed nearer to loads which reduce the investments due to lesser network capacity requirements, operation losses and operation costs which increase reliability [1]. However, MGs raise number of issues the main issue is protection [2]. There are 2 challenges: Firstly, during abnormal conditions the time of islanding of MG from the maingrid. Secondly, proper coordination and reliability protection system for effective tripping during the fault [3]. A D_1 coefficient of current energy signals using Biorthogonal1.5 (Bior 1.5) level-1 wavelets are usedful for fault analysis. A MG model is designed and it is interconnected to a transmission line. A fault is applied on the transmission environment and then obtain D_1 coefficients with the help of these energy values the fault can be identified with the comparison with defined threshold value. This novel scheme is applied on on MG interconnected transmission system for different faults with varying FIA and fault distances.

II. TECHNICAL CHALLENGES IN MICRO-GRID PROTECTION

Protection scheme for MG should respond to main grid and MG faults. Firstly, the protection-scheme must separate the MG from main grid rapidly for protecting the MG connected loads. Secondly, the protection-scheme should separate the low capacity part of MG very early to clear the fault. Few issues related to a protection of DERs and MGs connected to system are the short circuit (SC) current calculations for radial feeders with DERs under fault conditions. SC currents settings used in OC protection relay systems depend on a PCC, feeding power from DERs and source capacities. Because of this effect the amplitudes and directions of SC currents change according to the system abnormalities. In fact, because of the irregular DERs like solar, wind power, non-linear loads the conditions of operation of MG are constantly changing. Also the network in the field is regularly changing and aimed at achievement of economical or operational targets or loss minimization. In order to deal with low short-circuit current levels and bi-directional power flows in MGs due to presence of interfacing power electronic devices in DERs a new protection-schemes are required, where relays setting parameters must be checked/updated thoroughly to make sure that they are still deserved. A new adaptive MG protection concept is presented in this work [4,5] using advanced communication system [6], data from off-line SC analysis and real-time measurements. This concept is based on settings of protective relays with respect to a MG network type, generation capacity and load nonlinearity. The MG concept must be overcome protection, control and dispatch issues [7]. Bidirectional power flow may occur in both low- voltage (LV) and medium-voltage (MV) generation systems.

III. WAVELET TRANSFORM ANALYSIS

WT is like Fourier transform, the only difference is it allows different components frequency time localization for a given signal.

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It is the process of signal analysis through mathematical techniques where the transients signals have to be analyzed a wavelet tool more efficient, e.g., the post faults current/voltage waveform. Wavelet tool breaks up functions or data or operators into different frequency components signal, and then analyses with to its scale of each component of resolution matched [8,12].

After DWT, the input signal is analyzed into wavelet D_1 coefficients. The wavelet D_1 coefficients are processed and produced into the output data. There are 4 filters in this whole process: LPF (L and L'), HPF (H and H').

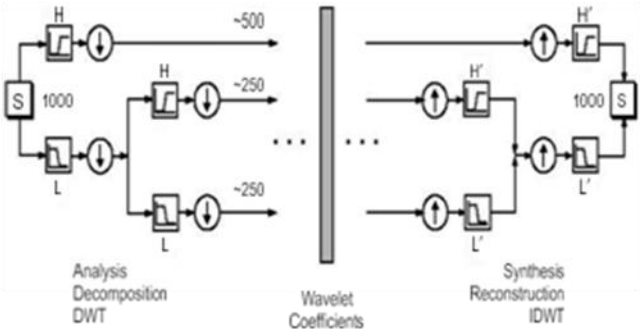


Figure 1: Wavelet transforms analysis of a signal

Transients are decomposes into wavelet detailed components by using WT containing more detailed information used for analyzing signals. These wavelet detailed components are D_1 coefficients are convenient for detecting and classifying the transients under abnormal conditions [12]. WT is defined as a function h (n) (LPF) and g (n) (HPF). The φ (t) is a scaling function and ε(t) is a wavelet are defined by the below equations:

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

$$\varepsilon(t) = \sqrt{2}\sum g(n)\varphi(2t-n)$$

Where

$$g(n) = (-1^{n})h(1-n)$$

IV ARTIFICIAL NEURAL NETWORK

ANN is simplified models of the biological nervous system. ANN is a heavy parallel distributed processor build with easy processing units which has natural ability of storing knowledge and keep it accessible for use [8-9]. It resembles the brain in two aspects (i) Inter-neuron connection strengths, known as synaptic weights to store the collected knowledge, and (ii) knowledge is collected by the network through a learning process from its environment. The use of ANN for the protection of transmission circuit has very limited consideration [6]. Fault location at various distances in transmission line circuits and also detection of fault [7], A.S. Oshaba and E.S. Ali uses radial basis function ANN.

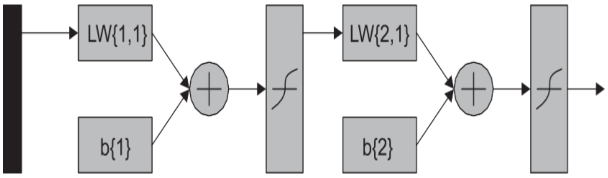


Figure 2: Neural Network Structure

The details of the ANN architecture described as follows:

1. Input layer: D1 coefficients of current signals.
2. Layers number: Two.
3. Neurons number: Ten.
4. Transfer function: Pure line.

V. MODELING OF MG CONNECTED TO UTILITY GRID

DERs like solar, wind energy and fuel cell have attracted power sectors for power generation that integrated at PCC tied with main power grid with an intention to improve reliability in PQ against the huge load demand. Both solar energy and wind energy is unsystematic and depends on changes in climatic. Fortunately, all the resources to form a MG system where the strength of capacity of one source overcomes the drawback of the other source. However, the integration of MG makes several PQ issues during islanding problems must be effectively identified.

PV energy system containing solar PV plates that converts radiation of solar into direct current. The direct current is then converted into alternating current then it is connected to main grid [10]. Maximum power obtained from PV energy has directly related to temperature and solar irradiance intensity. The output current is equal to difference of light generated current to diode current.

$I = I_{phase} - I_{diode}$

I_D = Diode current,

I = Output current of cell,

I_{phase} = Light generated current.

The wind turbine is coupled DC generator to produce DC output and a PWM technique is used to convert output DC to three phase output AC [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).

$l = Wm R/V$ (2)

$P = 1/2 C_p r V_W^3 AW$ (3)

W 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),

r = Air Density (kg/m).

VI. FAULT ANALYSIS OF MICROGRID WITH SYSTEM MODELING

Fault analysis in MG is categorized into two types one of the fault in main grid and other is in MG considered as external and internal faults. Internal fault is in LV bus and external fault is in MV bus. The MG need to be operating in both grid connecting and islanding modes.

Conventional protection-scheme is a big challenge in MG protection [11]. The protection problem of major MG is related to major difference between SC fault current in grid connecting and islanding modes. Further, there is selectivity and sensitivity issues due to change in fault currents in abnormal situations [10].

But in DERs with lower fault current levels it is essential to have high selectivity and sensitivity to isolate/sectionalize the faults. As the solution for all MG protection conventional protective system doesn't give effective result, but it needs advanced protection-scheme. The protection-scheme makes sure that secure operation of MG 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 DERs the protection coordination could be compromised [15].

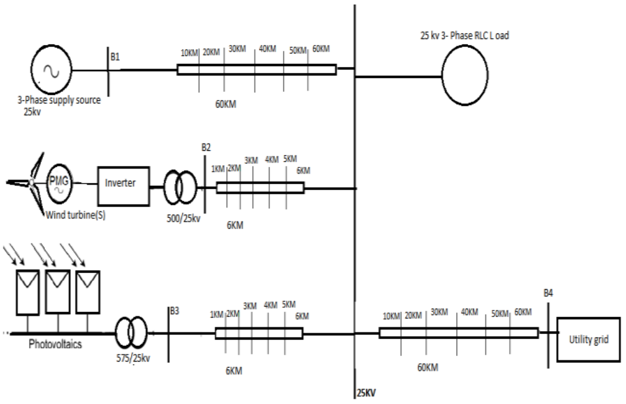


Figure 3: Single line diagram for MG integrated to utility grid

A 60 km distance transmission line is considered at Bus 1 and Bus 2 as test case in this paper. At 6 km distance of the transmission line at Bus 3 formulated with wind energy source with a capacity of 10MVA, 575V through a transformer of 575V/25 KV is connected. At Bus 4 fuel cell of capacity 50kW and solar PV of capacity 1MW are connected via transformer of 575V/25KV shown inFigure3.

VII. ESTIMATION OF FAULT LOCATION

Fault location estimation is determined using ANN after the fault detection and fault classification. For this purpose a Bior1.5 mother level-1 wavelet is used for current signals decomposition over a ½ cycle window. After decomposition current energy signals are obtained as D_1 coefficients is used for fault analysis. To estimate fault location for an L-G, LL, LL-G and LLL-G fault, D_1 coefficients of faulty phase can be used.

VIII. RESULT ANALYSIS

Bior1.5 mother level-1 wavelet is used to analyze the local terminal three phase currents to obtain the D_1 coefficients over a ½ cycle window. The D_1 coefficients are calculated from the Bus1, Bus 2, Bus 3 and Bus 4 to obtain effective detailed D1 coefficients. Each Fault phase Index (If_1) results are plotted for different FIA are given below.

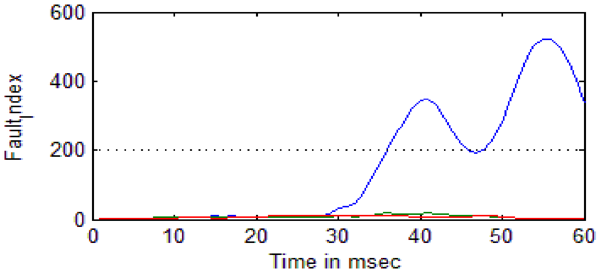


Figure 4: Line-ground fault at terminal 2.

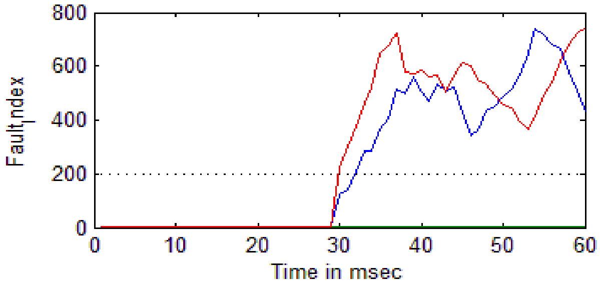


Figure 5: Line-Line-ground fault at terminal 3.

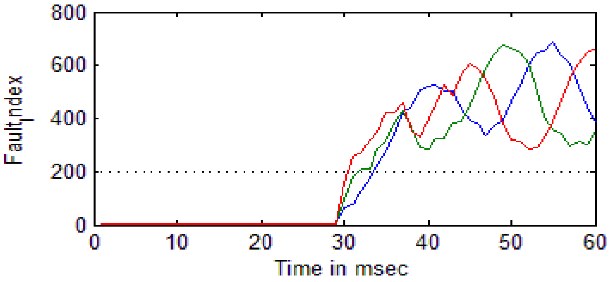
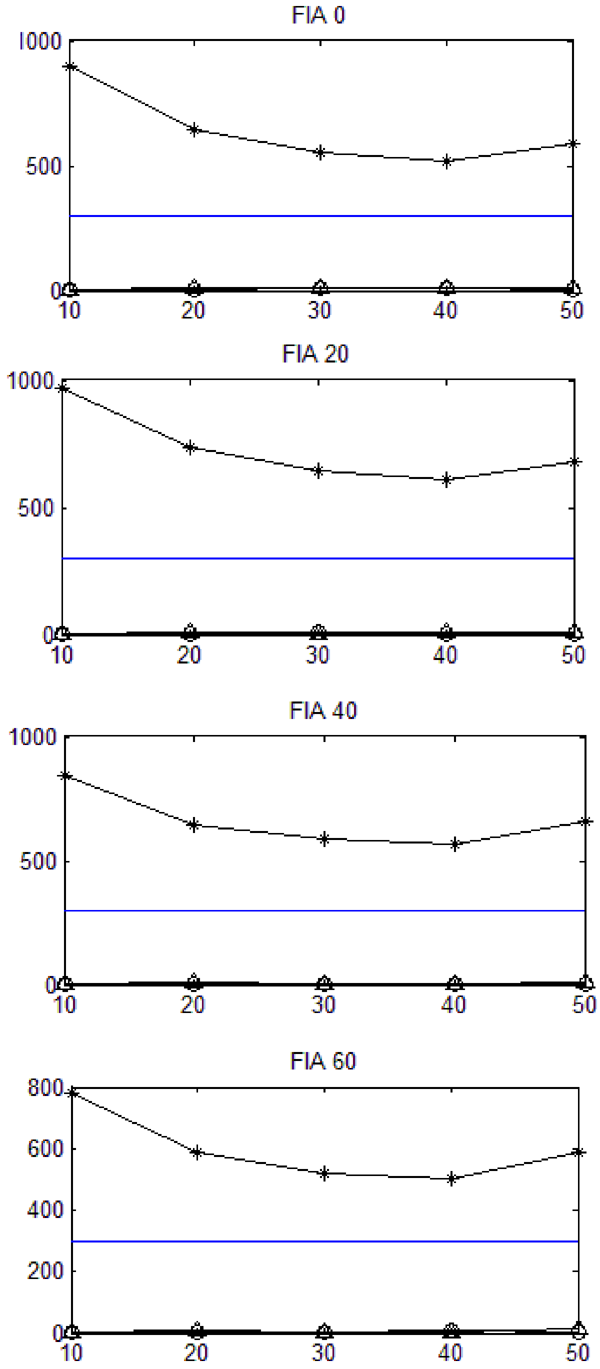


Figure 6: Line-Line-Line-ground fault at terminal 4.

FIA /KM	0^0	20^0	40^0	60^0	80^0
10	895.69	968.55	842.90	782.01	804.44
20	645.93	738.02	642.39	584.50	582.28
30	553.65	646.61	585.73	518.92	502.61
40	521.04	608.91	569.49	500.15	482.66
50	589.26	682.023	659.84	586.27	560.77
FIA /KM	0^0	20^0	40^0	60^0	80^0
10	3.6156	3.5277	2.7611	2.1519	2.3378
20	5.6032	4.4373	5.1871	4.9242	4.3186
30	9.4980	8.5115	6.8898	5.2289	4.3620
40	9.1490	6.9017	5.5280	5.8568	5.3089
50	3.7676	4.1267	5.4772	4.3055	5.9513

FIA /KM	0^0	20^0	40^0	60^0	80^0
10	4.9799	5.3140	4.4563	4.3786	3.8207
20	9.0125	8.6357	7.5999	7.0119	4.9115
30	8.1995	5.3848	4.5009	5.2927	4.498
40	9.3938	9.1337	6.4700	5.2799	2.5269
50	7.0904	10.369	10.1715	11.6617	10.906

Figure 7: Detailed coefficients of terminal 1 Line-Ground fault with distances and FIAs.



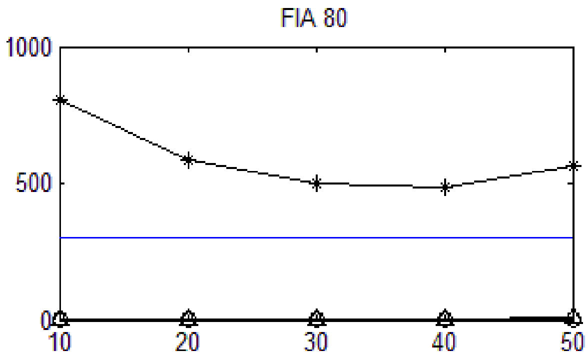


Figure 8: Variation of fault index at bus1 on phase A-G with distances and FIAs.

Table 1: ANN based fault location Analysis.

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

IX. CONCLUSIONS

This paper describes an innovative technique based on WT analysis is used to detection and discrimination of the fault in the MG interconnected transmission line using D_1 coefficients of current energy signals. All phase currents of D1 coefficients are compared with defined threshold value. All phases above threshold value are identified as fault phases and below are healthy phases. All phase currents of D1 coefficients are used for input data for ANN to estimate the location.. The test system is developed created and simulated using the PS block-set with SIMULINK software. The proposed protection-scheme tested and found to be very fast detection of fault, shows accuracy and independent of capacities of sources including DERs for all types of faults on MG interconnected transmission lines with different FIA and locations.

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