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Detection of Islanding in Wind Farm Distributed Generation of Distribution System Using Wavelet Based Alienation Technique.

K. Kamala Devi, Abdul Gafoor Shaik

Abstract: ***In the present paper, a wavelet transform based alienation technique has been presented for the detection of islanding condition in a distribution system incorporate with distributed generations. A radial five bus system integrated with four doubly fed induction wind generators (DFIG) has been considered for the study. The voltage signals at various DG buses were decomposed with Daubechies wavelet transform to get approximation coefficients. The alienation coefficients of these approximate decompositions were termed as Islanding indexes. These indexes were compared with a predetermined threshold to detect Islanding condition. The same threshold value was utilized to discriminate a transient associated with sudden changes with load. The suggested algorithm was established by a few case studies involving changes in incidence angle and load. Thus, the proposed algorithm is found to be successful for Islanding detection.***

Index Terms: ***Distributed generation, Alienation coefficients, Distribution system, Islanding condition, wavelet transform, and load change.***

I. INTRODUCTION

Distributed generation (DG) is generally mentioned as decentralized source of generation of electricity. Various resources like wind, diesel, combined heat and power (CHP) and photo voltaic (PV) are used in distributed generations which are generally situated at or near consumers' homes or business establishments. If properly developed, DG can provide a lot of potential benefits to the consumers, along with economic savings, improved environmental performance and with greater reliability. A large development has been taking place in the distributed power generation worldwide. As integration of DGs in the distribution networks increases, there is possibility of increasing in hazard and risk of power system events. It contains some drawbacks such as intimidating safety of the line worker, fail to sustain voltage levels and frequency within the standard permissible limits. Islanding operation of DG normally occurs due to the power supply disconnection from the mains because of various reasons but the DG keeps supplying power into the loads and distribution networks.

In the case of islanding condition, DG should be disconnected immediately from the grid and in all utilities. There is a demand for the disconnection of DG from the system as per IEEE 929-1988 standard once islanding takes place [8] and a maximum holdup of 2 sec is needed for the detection of an unintentional islanding in [9]. As number of technical issues associated with unintentional islanding are higher, all DGs have to be ceased to energize the distribution systems very quickly. Several Islanding detection techniques were proposed in recent years. A detailed review on different methods of islanding detection for DG had been discussed elsewhere [6], [22]. If DG is energizing the loads without the utility supply, a negative impact is resulted on power system utility and also on DG such as safety risks to utility personal as well as to the public. Furthermore, wrong restoration of utility power leads to poor quality of electric service to the customers and serious damage to the DG [1], [21]. An artificial neural network (ANN) based method has been presented by [11] for detection of islanding of distributed synchronous generators which took the benefit of ANN as pattern classifiers. By taking into account the rate of change of exciter voltage over rate of change of reactive power at the DG-side, [3] proposed a novel passive islanding detection scheme for synchronous based DG. A detailed review on islanding detection methods which have been classified as remote and local methods was given by [4]. Recently; M. Mishra and M. Sahani used an algorithm based on the Hilbert-Huang transform and on extreme learning machine to track islanding condition [12]. [14] Presented a combining method based on the rate of change in active, reactive power, frequency and voltage angle. A novel approach was proposed by [15] to detect islanding condition in a DG by extracting negative sequence components of voltages and currents and processed by wavelets at targeted bus. Furthermore, [2] demonstrated using voltage index to detect islanding operation, which was suited for multiple DG units. Numerous techniques were discussed to detect islanding condition in DG such as synchronized measurement technology, optimal artificial neural network (ANN), wavelet based neuro-fuzzy algorithm proposed by [20], [16] and [19]. Similarly, proportional power spectral density, variable impedance at the Grid low voltage strategy, dqo transform based algorithm, discrete wavelet transform and combination of neural network and wavelet transform are the other approaches used for islanding detection [10], [5], [7], [13], [17], [18]. However, still there exists a need of exploring a high speed and efficient islanding detection scheme.

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Therefore, in the present work, alienation technique based on wavelet is used to develop an algorithm which can detect islanding condition effectively with high speed.

II. MATHEMATICAL TOOLS

A. *Wavelet Transform*

In frequency as well as time domain, a Wavelet Transform (WT) is an efficient way of detecting current transients and voltage transients. WT is described as a function {h (n)} (a low pass filter) and {g (n)} (a high pass filter). The functions of wavelet and scaling are described by the equations given below.

$$\emptyset(t) = \sqrt{2}\ \sum h(n)\,\varphi(2t-n) \quad (1)$$

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

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

The factor √2 maintains the norm of the function for the time compression factor 2.. A sequential component of {h (n)} defines a Wavelet Transform. The selection of a mother wavelet depends on the type of application.

B. *Alienations Based on Approximation Coefficients*

In this present algorithm voltage signals have been composed across a half cycle. Wavelets have been applied to these samples and disintegrate for acquiring desired approximation coefficients. The coefficient of alienation based on approximation decomposition (Coefficients) has been calculated by the following equation.

$$1 - r_a^2 = A_A \quad (3)$$

Where, r_a is the calculated correlate ion coefficient on the basis of approximation coefficients. It has been calculated as follows,

$$r_a = \frac{N_s(\sum p_a q_a) - (\sum p_a \sum q_a)}{\sqrt{[N_s \sum p_a^2 - (\sum p_a)^2][N_s \sum {q_a}^2 - (\sum q_a)^2]}} \quad (4)$$

Where, N_s *is* the number of samples per half cycle

p_a is the absolute value of samples at t_0

q_a is the absolute value of samples consider in previous moving window of half cycle

The divergence between these signals has been called as alienation coefficient. The value of it is existed in between 0 and 1.

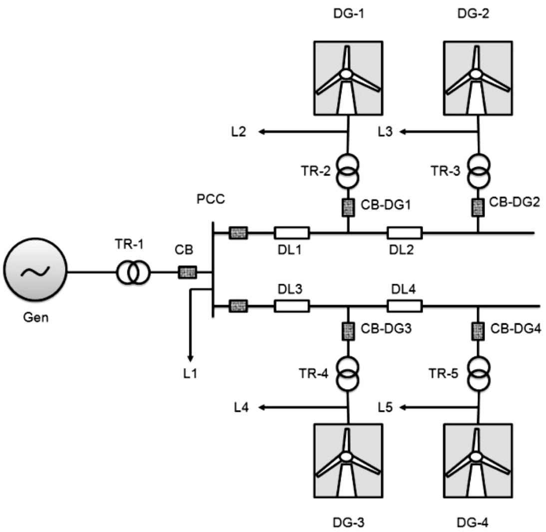

Fig. 1. Single line diagram of the system

III. PROPOSED ALGORITHM

Fig. 1 illustrates the line diagram of studied system in the present work. This system consists of radial distribution system with four DG units (wind farms) which are connected to the main supply through the Point of Common Coupling (PCC) and it is operated at a frequency of 50 Hz. The base power is chosen as 10 MVA. The DG units are kept at a distance of 30 km from each other and with distribution lines of pi-sections. The system parameters of the DGs, generator, distribution lines, transformers and loads are considered from [15]. Three phase voltages at DGs and PCC of distribution line are sampled at a frequency of 6400 Hz. These voltage samples are processed with db1 wavelet to obtain approximation coefficients of third level. The Alienation coefficient is obtained by comparing the approximate coefficients of two successive windows of same polarity.

The value of approximate coefficient remains zero under normal conditions since the two consecutive windows have similar set of approximations. But in the case of islanding or any other abnormal condition, the approximate coefficient of one window would differ from that of preceding window of same polarity. Hence there is an increase in alienation coefficient from zero to a certain value and it indicates Islanding or any other disturbance. Alienation coefficients are also termed as islanding index. These islanding indexes are compared with a threshold value to detect islanding and transients with load.

IV. DETECTION OF ISLANDING

The system has been simulated using MATLAB / SIMULINK software. The sampling frequency of 6400 Hz is considered with 128 samples per cycle. The simulation was carried out for 25 cycles and run for 0.5 sec (25 cycles) and islanding is created after 20 cycles (at 0.4sec). Fig.2 illustrates the detection of islanding at various DGs by opening circuit breaker at 0.4 sec at PCC. For islanding condition the comparison of islanding index is done with the threshold value. It can be perceived that the islanding index of islanding is greater than the threshold value.

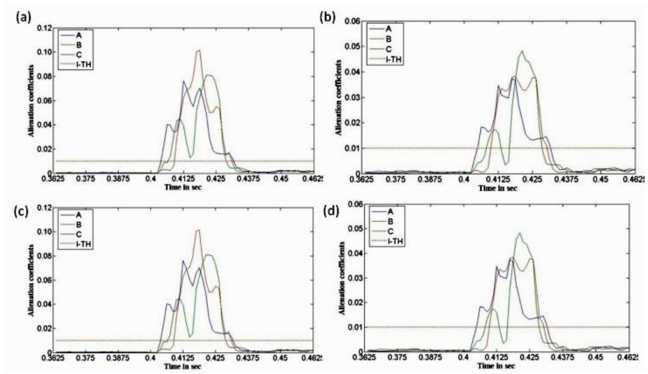

Fig. 2. a) variation of islanding indices at DG-1, b) variation of islanding indices at DG-2, c) variation of islanding indices at DG-3, d) variation of islanding indices at DG-4.

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Fig. 2(a), 2(b), 2(c), and 2(d) illustrates variation of islanding indices of three phases which are above the threshold that indicates islanding condition at DG-1, DG-2, DG-3, and DG-4 respectively. Fig. 2(a) illustrates variation of islanding indices of DG-1over 5cycles in three phases. It is observed that the variation in alienation coefficients of phase A, phase B and phase C exceeds threshold value (I-TH=0.01). Hence, it is evident that DG-1 is in islanding condition. Fig. 2(b), (c) and (d) illustrate variation of islanding indexes of three phases with time at DG-2, DG-3 and DG-4 respectively. Similar to the earlier case (DG1), islanding indices exceed the threshold value, which indicate that DG-2, DG-3 and DG-4 are in islanding condition. Fig.3 demonstrates variation of islanding indices at DG-2 and DG-3 by changing DL-2 and DL-3 as 50 km and 40 km respectively. From the results, it can be understood that the proposed algorithm is efficient to detect islanding conditions irrespective of the distribution lengths.

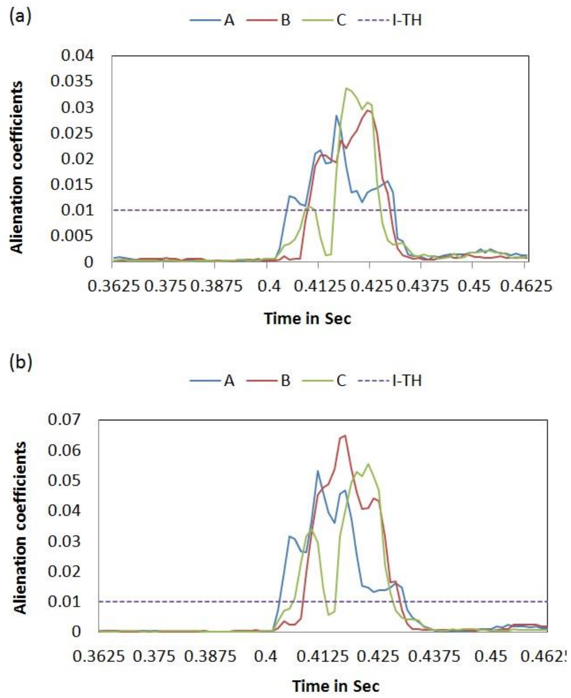

Fig. 3. a) Variation of islanding indices at DG-2 (DL-2=50 km) and b) variation of islanding indices at DG-3 (DL-3=40 km)

A. Variation of islanding incidence angle

The testing of proposed algorithm has been done successfully by varying Islanding incidence angle. Islanding has been applied at regular intervals of 30^0 for testing the proposed algorithm. The variation of islanding indexes of three phases is given in Fig. 3 with different incidence angle. The variation of alienation coefficients of all three phases was observed as above the threshold value. Thus, it is evident from Fig. 4 (a), (b), (c), and (d) that the islanding index is always above the threshold at DG-1, DG-2, DG-3, and DG-4 for various incidence angles at PCC. Hence, it can be said that four DGs are in islanding condition.

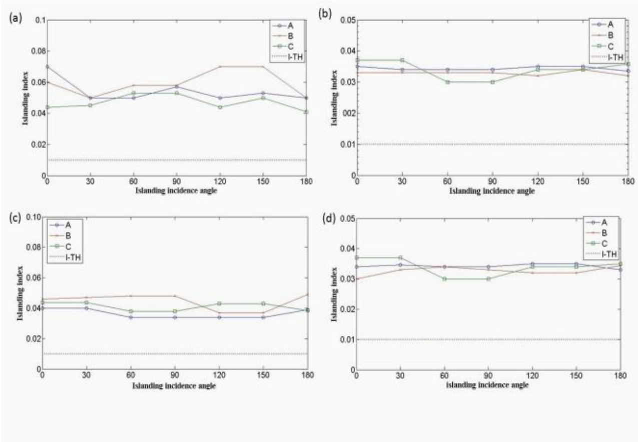

Fig. 4. a) variation of islanding index for varying islanding incidence angle at DG-1, b).Variation of islanding index for different incidence angles at DG-2, c).Variation of islanding index for different islanding incidence angles at DG-3, d).Variation of islanding index for different incidence angles at DG-4.

B. Load changing

The effect of variation of load on distribution system which is considered as non-islanding event has also been studied. Fig. 5 shows the effect of sudden load changing in a distribution line at DG-1 at 0.4sec. Load at different levels of increments such as 5%, 10%, 15%, 20%, 25%, 50% and 70% on 3MVAR and 0.8 p.f base has been added to the existing system load at same time (0.4 sec). Fig.5(a) illustrates variation of alienation coefficients for 5% ,10%,15%, 20%, 25%, 50% and 70% load increment added to existing load at DG-1 for phase A. Similarly Fig. 5 (b) shows the alienation coefficients variation with respective to time of phase A for load changing at PCC. From Fig. 5 (a) and 5 (b), it is evident that the transients associated with different load changing are below the threshold value. Similarly from Fig. 6 (a) and 6 (b), the variation of alienation coefficients for phase B and from Fig. 7 (a) and 7 (b), the variation of alienation coefficients of phase C were observed as lower than the threshold value. From these results, it is evident that transients associated with load changing are lower than the threshold value where as transients associated with islanding condition is greater than the threshold value and these two events can be discriminated efficiently by using this technique.

Fig. 8 shows the flowchart of the algorithm used in the present work. Time to detect islanding condition at the two DGs for different islanding incidence angles is shown in Table 1. From the data, it is evident that time required to detect islanding condition of every DG is within half cycle.

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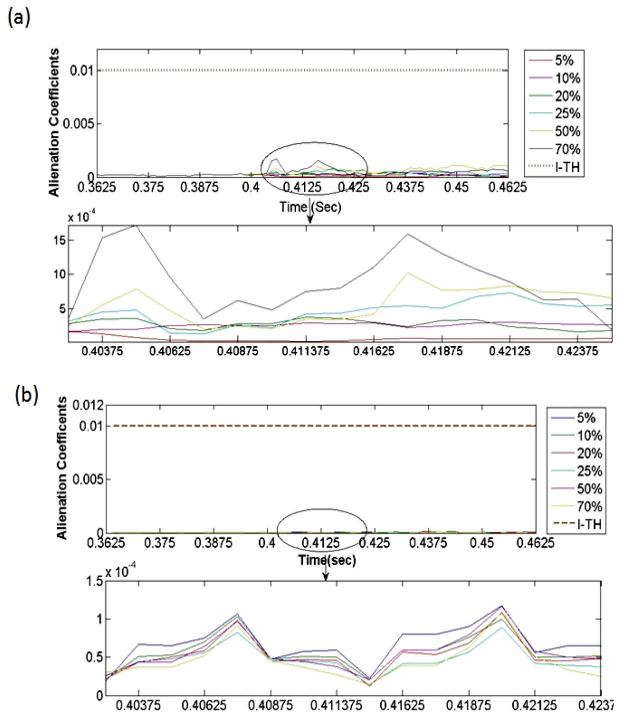

Fig.5. (a) Variation of alienation coefficients for phase-A with load changing at DG-1 and b) at PCC.

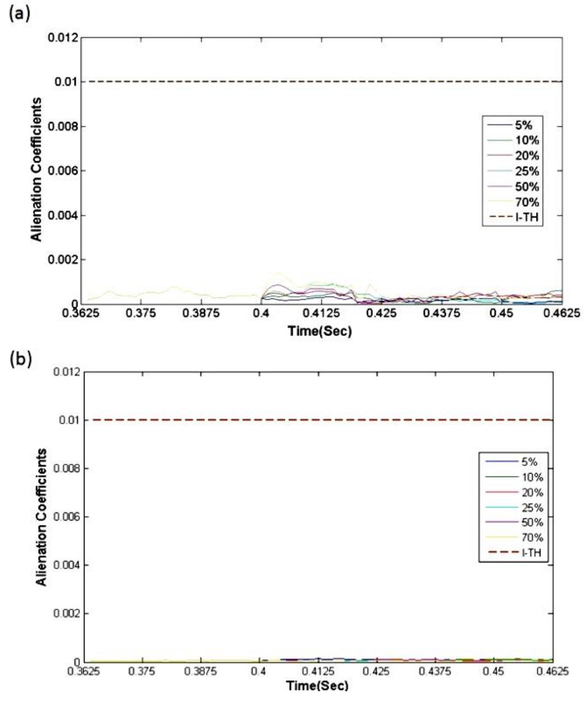

Fig. 6. (a) Variation of alienation coefficients for phase-B with load changing at DG-1 and b) at PCC

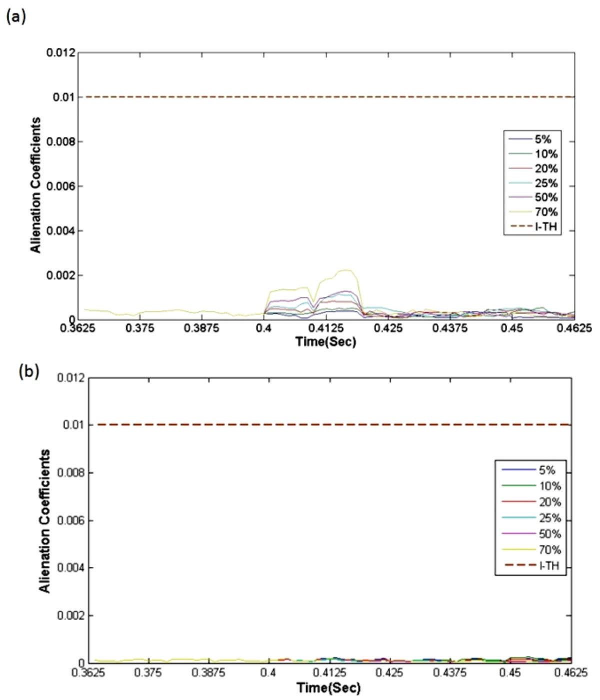

Fig. 7. (a) Variation of alienation coefficients for phase-C with load changing at DG-1 and b) at PCC.

These results strongly suggest that the proposed algorithm can be successfully implemented to detect islanding condition efficiently with high speed. Thus islanding condition of distributed generation in a distribution system can be detected successfully under various load changing conditions by using this wavelet based alienation coefficients.

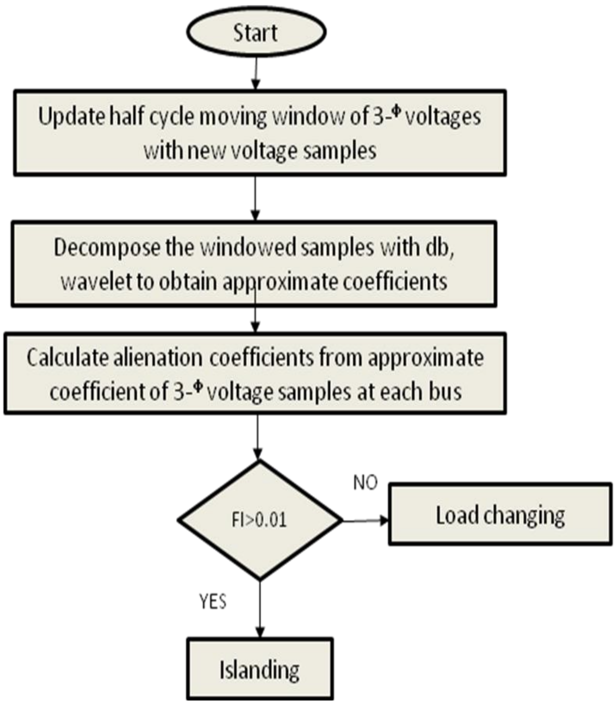

Fig. 8. Flowchart of the proposed algorithm

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Table 1. Time to detect islanding condition at four DGs for different islanding incidence angles

Islanding incidence angle (°)	Time to detect islanding condition (sec)											
	DG1			DG2			DG3			DG4		
	Phase A	Phase B	Phase C	Phase A	Phase B	Phase C	Phase A	Phase B	Phase C	Phase A	Phase B	Phase C
0	0.00375	0.00875	0.00625	0.005	0.00875	0.0075	0.00375	0.00875	0.00625	0.005	0.00875	0.0075
30	0.00375	0.0075	0.005	0.00375	0.0075	0.00625	0.0025	0.0075	0.005	0.0025	0.0075	0.0075
60	0.00875	0.00375	0.0025	0.00875	0.005	0.00375	0.00875	0.00375	0.0025	0.0087	0.005	0.0037
90	0.0075	0.0025	0.00125	0.0075	0.00375	0.0025	0.0075	0.00375	0.00125	0.0075	0.005	0.0025
120	0.00625	0.00375	0.01	0.0075	0.005	0.01	0.00625	0.00375	0.01	0.0075	0.005	0.01
150	0.00375	0.00125	0.0075	0.005	0.0025	0.00875	0.00375	0.00125	0.0075	0.005	0.0025	0.0087
180	0.00375	0.00875	0.00625	0.005	0.00875	0.00875	0.00375	0.00875	0.00625	0.005	0.0087	0.0087

V. CONCLUSIONS

The proposed algorithm investigates the successful implementation of the wavelet transform based alienation coefficient approach for effective detection of islanding using voltage signals in distribution network with penetration of DGs under sudden load changing conditions. The proposed technique is tested for various islanding incidence angles effectively. It has been observed that for islanding, the islanding index was greater than the threshold and for load changing the islanding index was less than the threshold. Thus the proposed algorithm is reliable and fast for the detection of islanding as well as to discriminate transients associated with islanding condition and load changing.

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