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Current Signals based Wavelet Alienation Approach Islanding Detection and Load changing in a Distribution Line with Wind Distributed Generation

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Abstract: ***Distributed generation is significantly gaining attention due to increase in the electricity demand. Distributed generations are mostly used with the association of power distribution systems to energize local loads and network. Islanding is technically an undesirable condition which demands necessary steps to reduce negative effects which helps in maintaining stability of the system. In the present work, alienation technique has been applied to detect and differentiate islanding, and sudden load change. A radial system with four Distributed Generations (DFIG wind generator) connected to the source through common coupling point (PCC) has been used for comprehensive study of this technique. The current signals were decomposed with Daubechies (db1) wavelet to obtain approximate coefficients at each bus. The approximate wavelet coefficient over a moving window of half cycle was used to compute alienation coefficients. The alienation coefficients were used to compute Islanding index and fault index. The same indices were compared with threshold to differentiate Islanding and sudden load change. The proposed algorithm has been tested for various incidence angles for both islanding condition and faults. This technique is found to be robust, effective to detect islanding condition and impact of sudden load change.***

Keywords: Alienation coefficients, Distributed generation, Distribution network, Islanding index, Wavelet transform, load change.

I. INTRODUCTION

Penetration of distributed generation in power distribution networks increases rapidly in the present days. Distributed generation (DG) is also known as non centralized power generation or dispersed generation refers to the production of Electricity near the consumption place. The resources used in distributed generation are renewable energy sources and cogeneration i.e., production of heat and electricity simultaneously. DGs are having some advantageous characteristics like free location in the network area, relatively small generated power, increased reliability of the Grid, reduced transmission and distribution line losses, better voltage support and power quality improvement [1]. The backup (standby) generation, utility grid enhancement, peak shaving, load management etc are the various applications of distributed generation. However many technical issues and difficulties arise in the association of DG units with the Grid. Islanding condition is one of the most undesirable conditions intentionally or accidentally takes place in DGs. According to IEEE STD 1547-2003, in islanding condition, the grid is accidentally or intentionally disconnected from distribution network system but the distributed generation continuously feed the local loads and network [2]. Due to this Islanding condition, various operational problems arise related to power quality, safety hazard, voltage and frequency instability and damage to system equipment. The unsynchronized reclosing of the grid to the distribution system may cause damage to the power electronic conditioning equipment of the DG. IEEE 929-2000 standard specifies the disconnection of DG once it is islanded [3] and IEEE STD 1547-2003 address this issue. Islanding detection techniques are broadly classified into remote (central) and local techniques. A detailed review on islanding has been given by Khamis, Aziah et al., [4]. Remote methods are associated with islanding detection methods on the utility side where as local methods are associated with detection of islanding on DG side. Remote methods are used to detect unintentional islanding by monitoring voltage and frequency parameters [5]. Remote or central methods are independent of number of inverters, generator type, and system size and penetration level. Local techniques for islanding detection are based on the measurement of the system parameters on DG side such as voltage, frequency, current and

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harmonic distortion. Comparative analysis of anti islanding technique depends on application and cost and ability of occurrence of islanding on feeder has been presented by P. Deshbhratar, R. Somalwar and S. G. Kadwane. Local Islanding detection techniques are further classified into active technique methods, passive technique methods and hybrid technique methods [6, 7]. J. Yim, C.P. Diduch, L. Chang introduced anti islanding technique based on the proportional power spectral density as a normalized measure [8]. S. R Samantha Ray and Trupti Mayee Pujhari presented a new approach to islanding detection by extracting the negative sequence component of the voltage and current [9]. K. Narayana presented a scheme on a priority based load shedding to detect islanding in case of multiple DG units [10]. Ahmad G. Abd Elkadar reported a new islanding technique for DFIG wind turbine by using artificial neural network [11]. R. K. Ray, N. Kishore et al., proposed a wavelet and S-transform based scheme by considering a negative sequence component of the voltage signal extracted at point of common coupling. J. A. Laghari et al., developed an islanding detection technique by using average rate of change of reactive power and load shift strategy.[12] In deed there is a need to investigate a protective scheme which requires fast detection with less computational complex. In this present work the proposed algorithm can detect islanding and faults within quarter cycle.In the present paper current signals at each bus are decomposed with Daubechies wavelet up to third level to get approximation coefficients. The alienation values of approximation coefficients over a half cycle clearly localize the islanding, and load change and are calculated to obtain the islanding and fault index. These indexes are compared with the predetermined threshold value of islanding and load change. The currents at each bus are sampled at a frequency of 6400Hz.

II. ALIENATION ALGORITHM BASED ON WAVELETS

A. *Wavelet Transform*

Wavelet transform is effectively used to analyze transients of current and voltage signals in both frequency and time-band. A set of basic functions called Wavelets, are used to decompose the signal in high frequency and low frequency bands, which are obtained from a mother wavelet by dilation and translation. Hence the amplitude and incidence of each frequency can be found precisely. Wavelet Transform is defined as a sequence of a function {h (n)} (high pass filter) and {g (n)} (low pass filter). The scaling function and wavelet function can be described in equations as follows.

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

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

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

The factor √2 maintains the norm of the function for the time compression factor 2. The time compression factor generally corresponds to the scale. The selection of mother wavelet is based on the type of application. This paper used Daubachies wavelet which is suited for this application to get best results.

B. *Alienation Coefficients based on Approximation Coefficients*

In the proposed algorithm current signals are sampled over a half cycle. Wavelets are applied to these samples and decomposed to obtain approximation coefficients. The alienation coefficient based on approximation decomposition (Coefficients) is calculated as:

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

Where, p_a is the correlation coefficient calculated based on approximation coefficients. The correlation coefficient based on approximation coefficient is calculated as

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

Where, N_s the number of samples per half cycle, absolute value of samples at t_0 is denoted by r_a. Absolute value of samples consider in previous moving window of half cycle is denoted by s_a. The variance between two signals is defined as the alienation coefficient. Its value is between 0 and 1.

C. *Weighted Alienation Coefficients*

It is needed to apply the concept of weighted alienation coefficients to detect the transients of load changes occurred at DGs. Simple arithmetic gives equal importance to all values in a series. In some cases, all the values in a series do not give same weight age. In such cases weighted average is more suitable for calculations. The concept of average of weighted Alienation coefficients is as follows. It is used to increase the relative importance of any quantity (of our interest) with respect to other quantities. For which each value is multiplied by a weight according to its importance. The weighted average for any input x can be computed by using the following equation (5) and procedure.

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$$\bar{x} = avg \sum_{i=1}^{i=5} WiXi \qquad (5)$$

i= Total number of inputs.

x_i is alienation coefficient at each bus of four DGs and PCC where, i = 1,2,3,4,5.

Get Max (x_1, x_2, x_3, x_4, x_5) = n.

Divide each alienation value of DGs and PCC by n to get weights. The weights will be $x_i/n=w_i$ where i=1 to 5.

Multiply every alienation coefficient of four DGs and PCC with their respective weights (wi). Then get average of these values for all three phases.

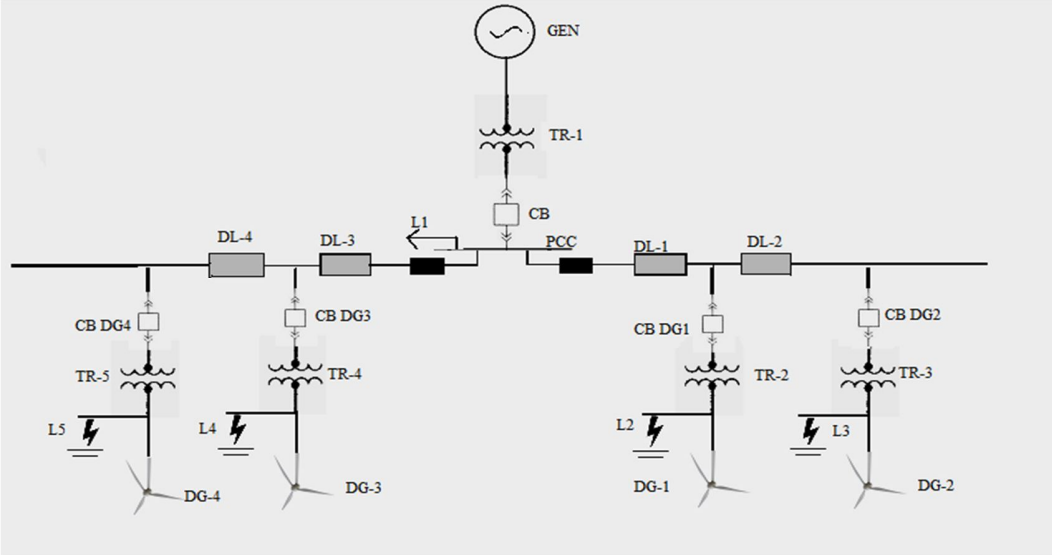


Figure 1: Line diagram of the system

III. PROPOSED ALGORITHM

TABLE 1 Parameters adopted in the present work

S.NO	COMPONENT	SPECIFICATION
1.	Generator	Rated short circuit MVA=1000 Rated KV=120,Vbase=120kv,f=50Hz
2.	Distributed generations(DGs) (DG-1 to DG-4)	Six Doubly fed induction generators (9MW) of each 1.5MW wind turbines are connected to a 25kv grid through a30km,25kv feeder.
3.	Distribution lines DL-1 to DL-4	PI-Section,30km each, rated MVA= 20, Rated KV=25,Vbase=25kv, R0= 0.1153Ω/km,R1=0.413Ω/km,L0= 1.05e-3H/km, L1=3.32e-3H/km, C0=11.33e-009F/km,X1=5.01e-009 F/km.
4.	Transformer T1	Rated MVA=25,Vbase=25kv,Rated KV=120/25, X1=0.1p.u, R1=0.00375 p.u, Rm=500 p.u, Xm=500 p.u.
5.	TransformerT2 to Transformer T5.	Rated MVA=10,rated kv=575v/25kv, Vbase=25KV, X1=0.1, R1=0.00375 p.u, Rm=500 p.u, Xm=500 p.u,f=50hz
6.	Load L-1	15MW,5MVAR.
7.	Load L-2 to Load L-5	8.0MW,3MVAR.

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The single line diagram of proposed system is shown in Fig. 1. The base power is 10 MVA. The studied system consists of radial distribution system with 4 DG units (wind farms), connected to the main supply system through Point of Common Coupling (PCC) and operates at a power frequency of 50 Hz. The DG units are placed at a distance of 30 km with distribution lines of pi-sections. The data of the generator, DGs, transformers, distribution lines and loads are considered.

Three phase currents at DGs and point of common coupling of distribution line are sampled at 6400 Hz. These samples are obtained over a moving window of half cycle length. These current samples are decomposed with db1 wavelet to obtain approximation coefficients of third level (A_3). Alienation coefficient C_A is computed by comparing the approximate coefficients of current window, with those of previous window of same polarity.

Under normal conditions, the two consecutive windows have similar set of approximations, hence A_a remains zero. But in case of islanding, fault or any other abnormal condition, the approximate coefficient of current window should differ from those of previous window of same polarity. Hence alienation coefficient would increase from zero to a certain value indicating disturbances.

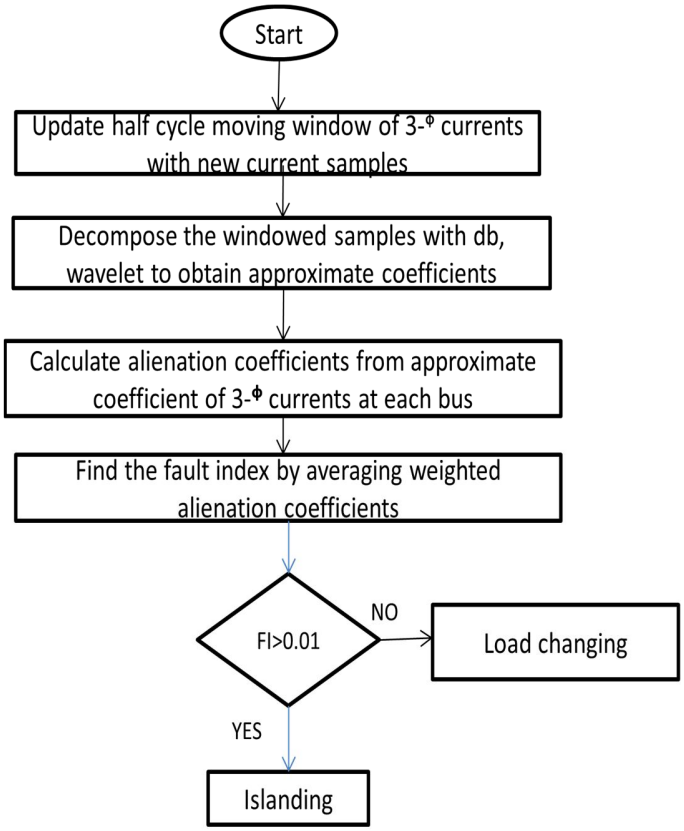


Figure 2: Flow chart of the proposed algorithm.

IV. RESULTS AND DISCUSSIONS

A. Detection of Islanding

The single line diagram is modelled in MATLAB/ SIMULINK environment as per Fig.1. The flow chart of the present work is shown in Fig 2. 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 simulated after 20 cycles (at 0.4sec). Fig.3 illustrates the detection of islanding at various DGs by opening circuit breaker at 0.4sec at PCC. In islanding, and load changing the islanding index and fault indexes are compared with threshold value. The threshold value is set as 0.01 in case of islanding and load change. It can be observed that the islanding index of islanding at every DG is greater than the threshold and fault index of load change at every DG is found to be lesser than the threshold. The fault index was observed as higher than the threshold for the fault as and lowers than the threshold for islanding. Fig. 3(a), (b), (c), (d), (e), (f) illustrate variation of islanding index above the threshold which indicate islanding condition at DG-1, DG-2, DG-3, DG-4 for current signals which satisfies proposed algorithm.

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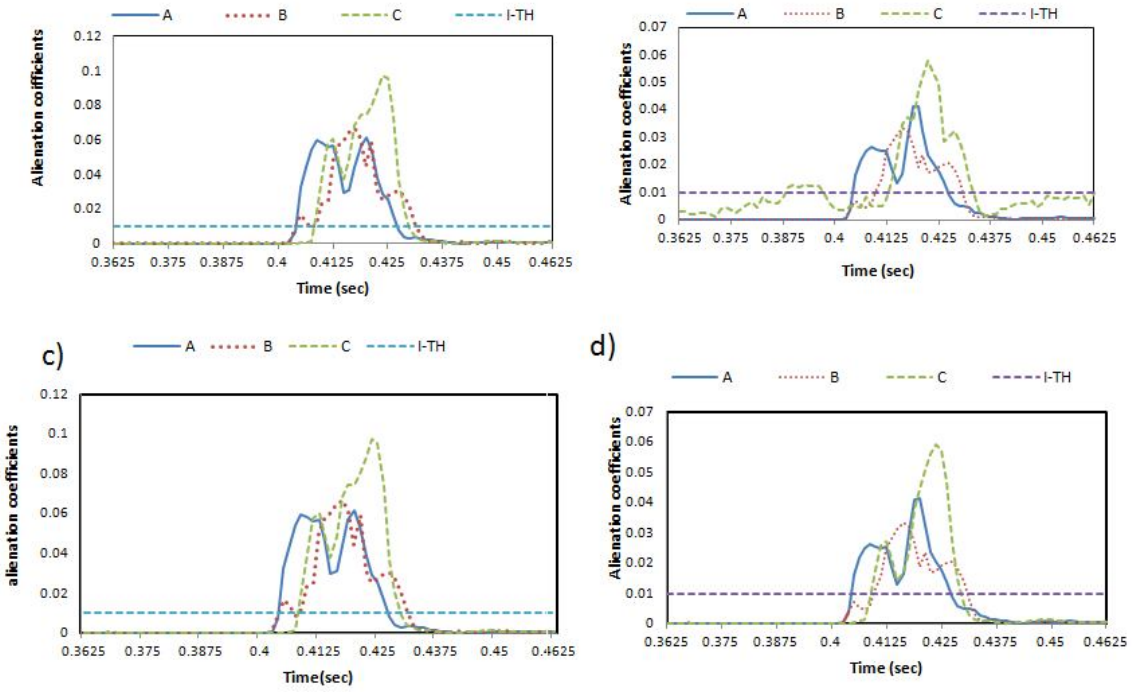


Figure 3: Variation of islanding indexes with time at a) DG-1 located at 30km from PCC, b) DG-2 located at 60km from PCC, c) DG-3 located at 30km from PCC and d) DG-4 located at 60km from PCC.

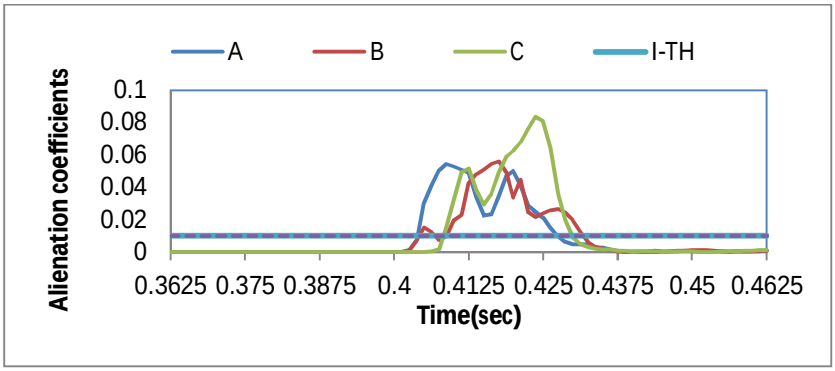


Figure 3: Variation of islanding indexes with time at e) DG-3 located at 35km from PCC

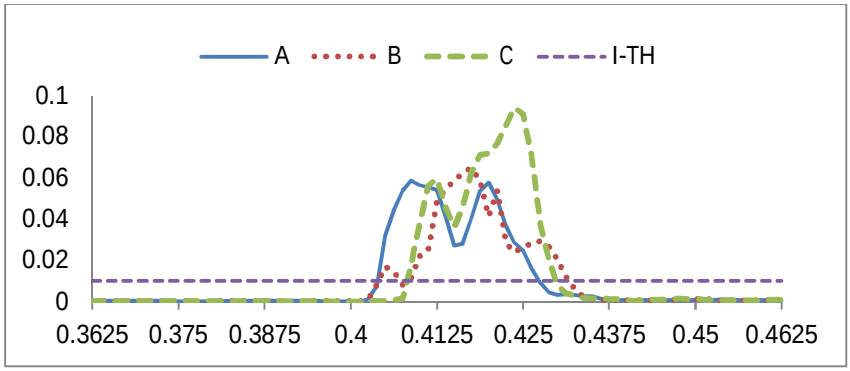


Figure 3: Variation of islanding indexes with time at f) DG-2 located at 50km from PCC.

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B. Variation of Islanding Incidence Angle

Islanding has been applied at regular interval of 30^0 to test the proposed algorithm. Fig.4 illustrates variation of islanding indexes of three phases with incidence angle. From graph it is evident that the islanding index is always greater than the threshold for various incidence angles at PCC which shows islanding condition.

TABLE 2 Islanding Incidence Angle

Incidence Angle	PHASE A	PHASE B	PHASE C	I-TH
0°	0.03466	0.0144	0.0222	0.01
30°	0.033375	0.0255	0.0319	0.01
60°	0.013	0.0189	0.0369	0.01
90°	0.038	0.0255	0.04215	0.01
120°	0.0155	0.023	0.01442	0.01
150°	0.0331	0.0222	0.039	0.01
180°	0.0331	0.01422	0.02312	0.01

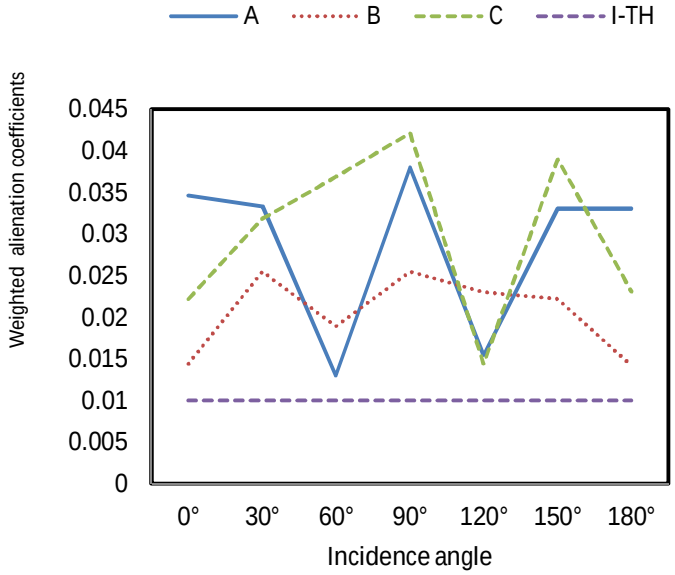


Figure 4: Variation of islanding index for different incidence angle at four DGs.

C. Load Changing

The effect of sudden change of load on distribution network at DG-1 is observed. Fig 5 shows effect of load changing in a distribution line at DG-1 at 0.4sec through a circuit breaker. System at different levels of load increment on 3 MVAR and 0.8 power factor base is added to the existing system load at similar time of 0.4 sec. Fig5 (a),5(b),5(c),5(d),5(e) show the load change of 5% , 10%, 20%, 25% and 30%. Figure 6 (a) indicates 15% load changing at DG-2, 6(b) 20% load changing at DG-3, 6(c) 25% load changing at DG-4. It is observed that the magnitude of disturbance is found to be less than that of threshold. But it is found that sudden increment of load has no impact on islanding.

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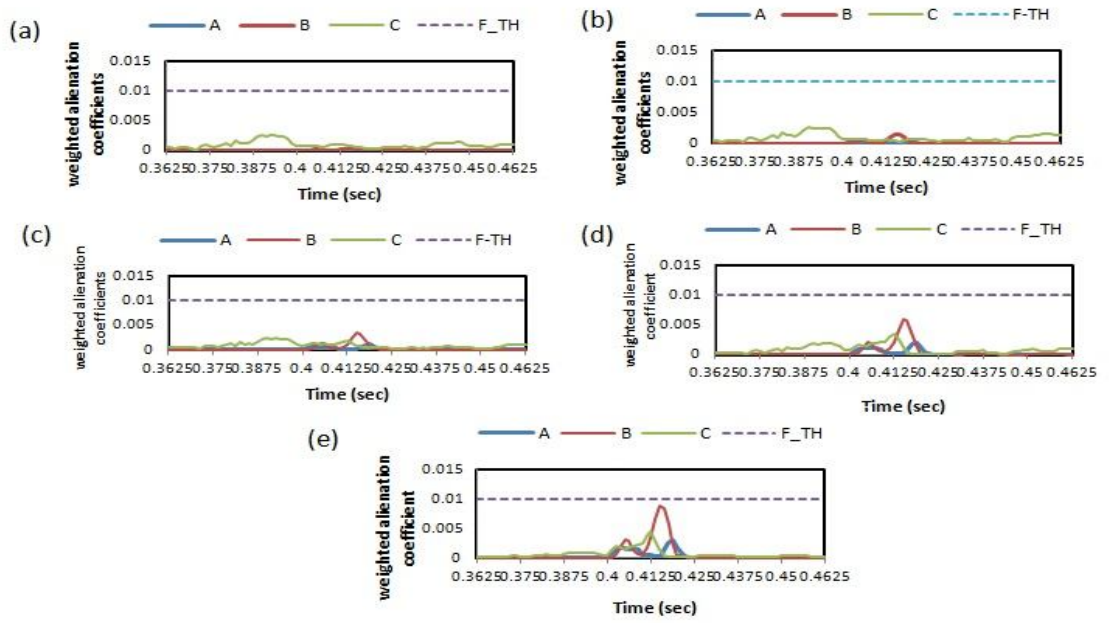


Figure 5: Effect of load changing in a distribution line at DG-1: (a). 5% load changing at DG-1, (b). 10% load changing at DG-1, (c). 20% load changing at DG-1, (d). 25% load changing at DG-1, (e). 30% load changing at DG-1

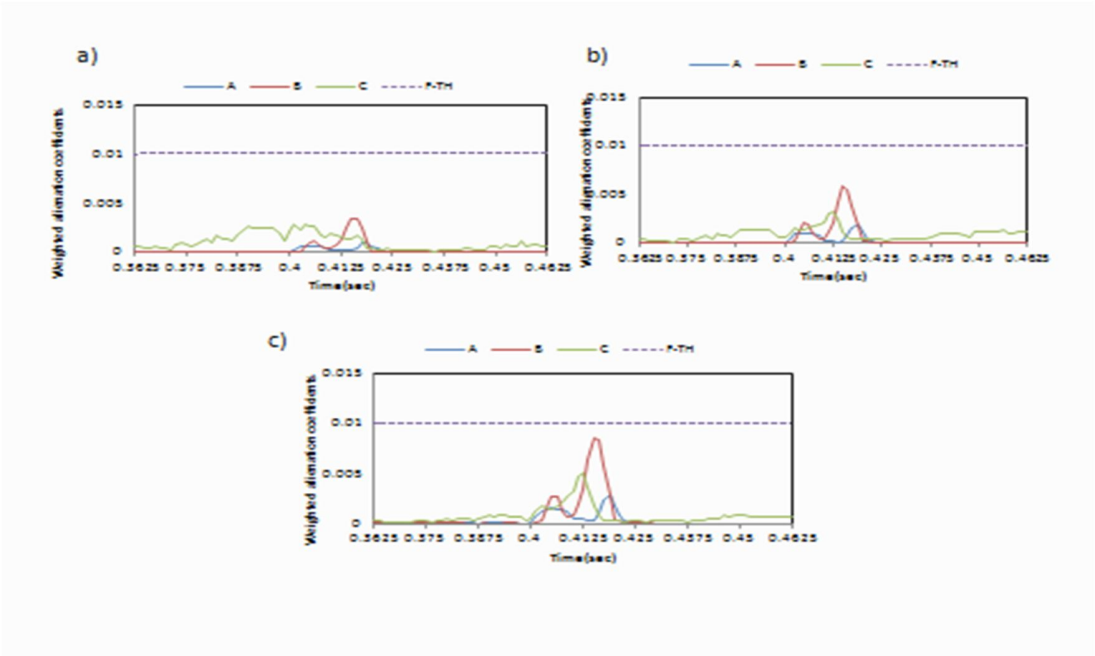


Figure 6: Effect of load changing in a distribution line at DGs: (a). 15% load changing at DG-2, (b). 20% load changing at DG-3, (c). 25% load changing at DG-4.

V. CONCLUSION

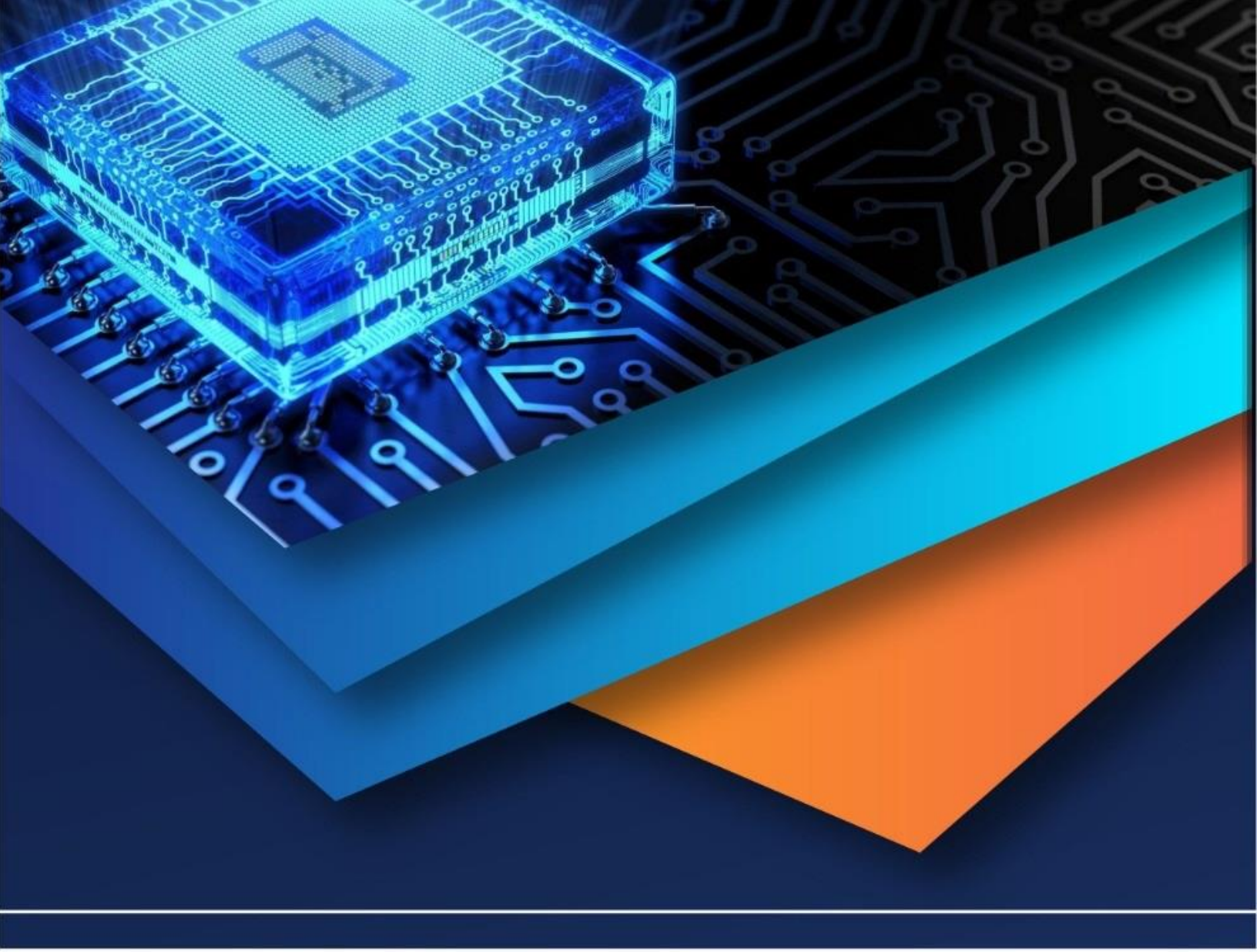
The proposed algorithm investigates the successful implementation of the wavelet transform based alienation coefficient approach for effective detection of islanding and effect of load changing in distribution system with penetration of DGs. Alienation coefficients over a half cycle clearly detect and localize the event. It is found that the islanding is greater than threshold value and load changing in a distribution line is less than threshold. Thus the proposed method is successful, fast and reliable for the detection of islanding and for load changing.

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