Provide new protection system for the management of energy resources with regard to the use of distributed generation sources in smart grids

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ABSTRACT

In distribution networks, energy from the source is transmitted radially to load points and has a very simple protection system. The linkage of distributed generation resources to distribution networks has created challenges, such as protecting it. The short-circuit current is variable due to the presence of distribution generation sources and the flow direction can be two-way. Properly network configuration to provide consumers with high reliability and quality of energy is one of the important activities in distribution networks. In this paper a new central protection system is offerred, which it uses a wide communication for network monitoring, Distributed Generation sources, and updating relay error currents according to shifts in the system and by central control system to open and close keys in DG, main network keys and etc. The suggested method is put to use in a network in cluding wind turbine equipped with steady magnetism synchro generator, by using PSCAD/EMTDC software.

Keywords: wind turbine, island effect, wide protection, Wide Area Measurement Systems (WAMS), Phasor measurement unit (PMU)

1. INTRODUCTION

With the performance of the DG in the islands, the quality of power supplied to consumers decreases and the potential for damage to the DG during the non-synchronous closure of the reboot keys [1]. So far, many methods have been proposed for detecting DG islands. In a general category, these methods can be divided into two telecommunication and local categories. Local methods use DG location. information to identify the island. These methods are also divided into two active and passive categories [2]. Telecommunication methods, unlike local methods, are independent of the output and behavior of DGs in island conditions and have high reliability and a less recognizable area than local methods [3-7]. Using three phasor measurement unit (PMUs) and measuring voltage changes [8,9], measuring voltage and frequency changes using PMUs [10], determining the islands with optimization of minimum PMUs [11,12], using the neural network and PMU [13] There are some ways that they can be mentioned.

In this paper, we propose a method that uses simultaneous phasor measurement in two separate points of the network to protect the islands of DG. By this suggested method and using WAMS system technology there is a wide and intelligent protection of DG with a wide wiev of system condition.

In this method, using the concept of voltage jump and practical relay algorithm, vector relays, Positive Sequence Voltage Angle (PSVA) are selected as the island index parameter. This method, which is a combination of telecommunication and passive methods, uses a change in the phase angle of the positive voltage component in the DG terminal and the nearest bus from the main network to the DG.

2. Problem

One of the practical methods used to detect islands in power grids is the use of vector relays[13]. Depending on the nature of the decision parameters in these relays, the distance and proximity of the fault location to the DG and, consequently, the error resistance, can affect the performance of these relays in identifying the island's conditions of the DG[14]. Therefore, in this paper, a new approach to isotropic protection is proposed. In this way, the relay decision is based on the collection of data from two distinct points of the system and their sharing. The proposed method has a high degree of security and reliability due to the use of data sharing. Figure 1 shows the location of the PMUs in the power grid to achieve such a goal.

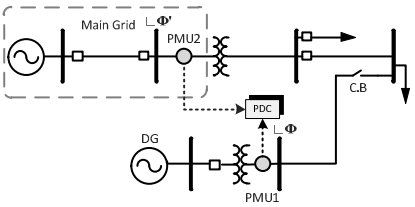


Figure. 1. The location of the PMU to create extensive island protection

3. Suggested Method

The suggested method uses measurement of two important parameters for the identification of DG islands. The first parameter is obtained from measuring the magnitude of the change in the angle of the phase of the positive component of the voltage in the DG bus. This parameter is defined by (1) as follows:

$$|\Delta\varphi_t| = \left|(\varphi_t - \varphi_{t-T}) + (\varphi_t - \varphi_{t-2T})\right| / 2 \quad (1)$$

In which φ_t is the phase angle of positive component of measured voltage by PMU1 in DG bus (as shown in Figure 1) in

t second. Also φ_{t-T} and φ_{t-2T} in order are measured phases angle in cycles first and second time before t second. T is equal to one cycle time in power system frequency (20 mili seconds)
The second parameter is to measure the magnitude of the angular change of the positive voltage component at the nearest bus from the main network to DG, which is defined in accordance with equation (2) below:

$$\left|\frac{\Delta\varphi'_t}{\Delta t}\right| = \frac{\left|(\varphi'_t - \varphi'_{t-T}) + (\varphi'_t - \varphi'_{t-2T})\right|/2}{T} \qquad (2)$$

In which φ'_t is the measured voltage positive component plase angle by PMU2 in the closest lous of main network to DG (according to picture 1) in t second. Logical model of the suggested algorithm in top is shown in picture 2 in which the last out put of AND gate, shows the occurrence of island effect in DG. In this model if $\left|\Delta\varphi'_t/\Delta t\right|$ amount goes beyond the defined threshold (1/5 degree/sec) relay is blocked in power system frequency (6T) for 6 cycles and there will be no trip. Figure 2 shows a single-line diagram of a power system including DG, which is distributed in parallel with the distribution network.

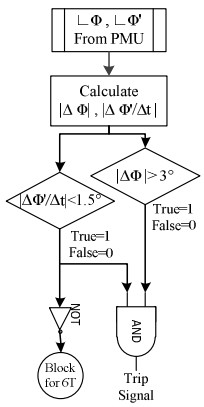


Figure .2. Logical model of the proposed algorithm

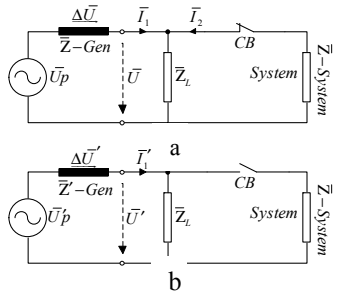


Figure.3. Diagram Single-line power system including DG: (a) before opening the circuit breaker. (b) after the opening circuit breaker

there is a phase difference φ ، between the terminal voltage and the internal voltage of the generator, the phase diagram of which is given in Fig. 4a. Assuming the torque switch is opened in the moment t = to, if the angle of the rotor in the moment before the key is opened with a constant value δ_{t_0} and after opening breaker to consider it with $\delta(t)$ and the difference

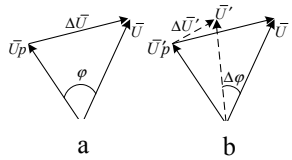


Figure.4. internal voltage phasor diagrams and terminal: (a) before opening the circuit breaker. (b) after opening the circuit breaker.

between them with $\Delta\delta(t')$ in the duration of $t' = t - t_0$ The voltage $\Delta\varphi(t')$ ، at the times after the opening of the key is defined in accordance with formula (3) below:

$$\Delta\varphi(t') = \Delta\delta(t') + (\angle Z_{Gen}(t) - \angle Z_{Gen-t_0}) + \left\{\arctan(Q(t)/P(t)) - \arctan(Q_{t_0}/P_{t_0})\right\} \qquad (3)$$

In which p(t) and Q(t) in order, are active and reactive powers produced from generator after occurring island effect, after the generator has arrived at a new stable working point, they will have a difference, equals to active and reactive power produced from network for feeding charge $(P_{S\_t_0}, Q_{S\_t_0})$, with P_{t_0} and Q_{t_0}. In this equation, given the relationship $X_{Gen} >> R_{Gen}$ and and small changes in frequency at times after the occurrence of islands, assumption is assumed $\angle Z_{Gen}(t) - \angle Z_{Gen-t_0} \approx 0$.
Therefore, relation (4) is simplified as an approximate relation (4):

$$\Delta\varphi(t') = \Delta\delta(t') + \Delta\theta(t')$$
$$\begin{cases} \Delta\delta(t') = \dfrac{\omega_0 \Delta P}{4H}(t')^2, \Delta P = -P_S \\ \Delta\theta(t') = \arctan(Q(t)/P(t)) - \arctan(Q_{t_0}/P_{t_0}) \end{cases} \qquad (4)$$

In which ω_0 is the synchronous speed, H is the constant inertia of the generator, and the other parameters are as described in the above. The relationship $\Delta\delta(t')$ between the generator oscillation equation is obtained.
According to Equation (4), and regarding that t – t0 amount is small in the first secends of breaker cut off, $\Delta\delta(t')$ has small range $\Delta\varphi(t') = \Delta\theta(t')$. After finishing temporary modes (100 milli second), P(t) and Q(t) parameters , range inorder reach to its final amount $P_{S\_t_0}$ and $Q_{S\_t_0}$ and $\Delta\theta(t' \geq 100ms)$ equals to (5):

$$\begin{cases} \Delta\theta(t') = \mathrm{K} \qquad t' = t - t_0 \geq 100ms \\ \mathrm{K} = \arctan(Q_{S\_t_0}/P_{S\_t_0}) - \arctan(Q_{t_0}/P_{t_0}) \end{cases} \qquad (5)$$

There fore $\Delta\varphi(t')$ increases with time square $\Delta\varphi \propto (t - t_0)^2$. Relationship (6) shows $\Delta\varphi(t')$ the changes in time difference:

$$\begin{cases} \Delta\varphi(t') \approx 0 & t' = t - t_0 \le 0 \\ \Delta\varphi(t') = \arctan(Q(t)/P(t)) - \arctan(Q_{t_0}/P_{t_0}) & 0 < t - t_0 \le 100ms \\ \Delta\varphi(t') = \dfrac{-\omega_0 P_{s-t_0}}{4H}(t - t_0) + K & t - t_0 > 100ms \end{cases} \quad (6)$$

In order to calculate the range of the indexes for the islands identification algorithm $|\Delta\varphi_t|$, we can use the obtained relations for $\Delta\varphi(t')$ in (6) and according to (7):

$$|\Delta\varphi_t| = \left(|\Delta\varphi(t') - \Delta\varphi(t' - T)| + |\Delta\varphi(t') - \Delta\varphi(t' - 2T)|\right)/2 \quad (7)$$

The above relations can also be repeated to express a mathematical relation to calculate the range of parameter variations $|\Delta\varphi'_t / \Delta t|$.

4. Determining thresholds

The final output of the proposed algorithm is the function of the two equations. In the first equation, the magnitude of the change in the voltage positive component phase angle of DG bus with the reference amount, and if $|\Delta\varphi_t|$ goes beyond the defined threshold , there is a possibility of DG's island effect or occurring error in input feeder of DG. This threshold is set to 3 degrees, and is configured so that the algorithm can even detect small inequalities in the island part.Second equation, absolute value of shifts pace in phase angle of voltage positive component in the closest bus of main network to DG. The second equation, determines the magnitude of the phase change of the phase angle of the voltage positive component at the nearest bus from the main network to the DG with the reference value and, by keeping the threshold of $|\Delta\varphi'_t / \Delta t|$ below the threshold, determines that the reason for the violation of $|\Delta\varphi_t|$ from the threshold caused by the islands of DG Not error. This threshold is set at 1.5 degrees per second, and it is configured that the algorithm does not make mistakes in distinguishing between large power unbalances and switching large capacitive banks in line. In the second equation, if the positive value of $|\Delta\varphi'_t / \Delta t|$ exceeds its threshold, that is, the extreme changes created in $|\Delta\varphi_t|$ and exceeded by 3 degrees due to error in the feeder. Therefore, the final output of the logical model shown in Fig. 2 blocks the relay for 120 milliseconds, during which time no command is produced from the relay.

5. Studied network

The Studied network is a continuous distribution network with voltage level of 20 KV, that has connected by 63/20KV transformer to main network with voltage level of 63 KV. This network has been implemented in the PSCAD / EMTDC software environment. The overall network schema is shown in Fig. 5, which includes a wind farm consisting of five wind turbines equipped with a permanent magnet synchronous generator with total power of MVA3. The wind farm has connected to distribution network by PWM power converter and feeds local charge connected to Bus 2. In order to do Phasor measurement, two PMU1 systems have been installed in two separated points from PMU in DG Bus and PMU2 in the nearest Bus from main network to DG (main Bus). By opening the RC key, the DG individually feeds the local load, and its island conditions occur. In this case, using the proposed algorithm, island conditions are detected in real time. It should be noted that this method can be used to detect the islands of different types of dispersed products, but since today wind turbines have become more permanent magnetism and do not have an excitation control system, so this method is based on this The type of DGs has been implemented. For other DG it is necessary to consider threshold values and modeling their stimulation system. The information on the main network, transmissions, wind system specifications, and lengths of the lines are presented in Tables (1), (2) and (3), respectively. The impedance of all lines in this network is equal to 0.2+j0.4Ω/km.

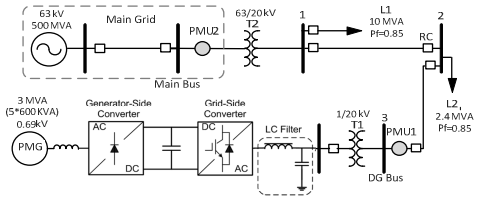


Figure.5. a single-line diagram of the network studied

Table1. Specification of the main network and trans

Amounts	Trancs	Amounts	Main Network
MVA 3	S_{T1}	kV 63	V_{L-L}
MVA 500	S_{T2}	MVA 500	S_{SC}
6	$\%X_{T1}$	20	X/R
10	$\% X_{T2}$		

Table.2. specifications of wind system

Amounts	Turbine	Amounts	Generator
MW 3.6	S_{out}	0.69kV	V_{L-G}
m 46.5	r	MVA 3	S_{nom}
m/s 13	V_W	Hz 0.416	f_{nom}
		120	p
		4.3 sec	H
		pu 0.4	X_d
		pu 0.51	X_q

Table.3. Information on lines and loads

Amounts	Loads	First-end bus	length of lines
MVA 10	S_{L1}	2-1	5Km
MVA 2.4	S_{L2}	2-3	1.5Km
0.85	$\cos\varphi_{L1}$		
0.85	$\cos\varphi_{L2}$		

6. Simulation

In this section, different simulations for DG island operating conditions are made for different load variations

6-1 study the insular operation condition of DG

In first simulation, islanding of DG is done with opening of recloser switch in 30 th second for per 11.2% changes in its charge (Δp= -7.6%, ΔQ=-8.3%). In figures (6) and (7) parameter changes in proposed method and relay shift before and after islanding of DG are shown respectively.

According to bar graph drawn in figure(6-a), positive voltage component angle phase variation absolute value in DG terminal $|\Delta\varphi_t|$, is almost zero before opening time of recloser switch and after switch opening in 30 th second due to the sudden variation in generator productive power, according to mentioned relations in (6) and (7) equations, first it has increasing- decreasing state and after finishing transient states from 30.1 th second it starts to increase regularly. According to figure(6-a), Phasor voltage variation amplitude in 30.2 th second with reaching to 6.22 degrees, has exceeded the specified threshold (3 degrees). While according to figure(6-b), positive voltage component angle phase variation rate absolute value in main network Bus $|\Delta\varphi'_t/\Delta t|$, in this moment with 0.031 amplitude degree/sec is in lower value of the specified threshold for it (0.06 degree/sec). So the proposed algorithm, despite the unbalanced power in insulation unit (%15.9), can be detect insulation condition with 20 mil/ sec delay. Also figure(7-a) shows positive voltage component angle phase variation absolute value in DG terminal $|\Delta\varphi_t|$ that calculated once in each cycle by relay shift. this parameter that is as an island detection indicator in V_S relays, follows the rules of equation (6). So, its changes before the island occurred is almost zero and after the key has been opened in 30 th second first it has increasing- decreasing state and after 30.1 th second it has regular increasing state.as you see in figure(8-a), Phasor voltage variation amplitude in 30.2 th second with reaching to 3.35 degrees, has exceeded the specified threshold (3 degrees). At this moment, due to holding on positive frequency and voltage component amplitude in the specified limits, (0.8<Vpu<1.3) (47<f<53 Hz), according to figures (7-b) and (7-c) respectively, relay in 30.02 th second and with a 20mil/sec delay is issued the command of DG outage.

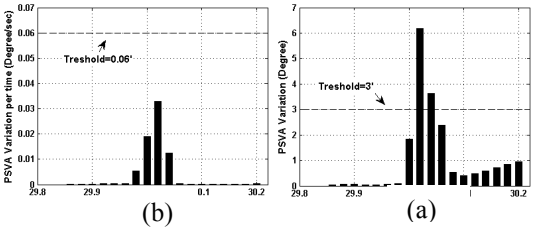


Figure.6. The proposed algorithm parameters for conditions of island DG. a) $|\Delta\varphi_t|$(degree), b) $|\Delta\varphi'_t/\Delta t|$(degree/sec)

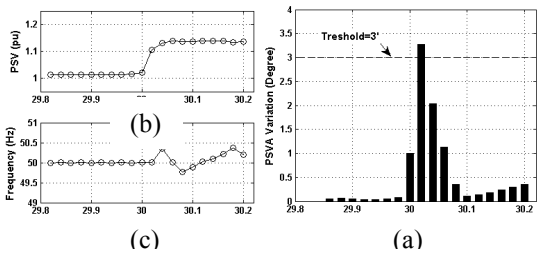


Figure.7. Relay parameters V_s for conditions of island DG. a) $|\Delta\varphi_t|$(degree), b) (pu)+ V,c) (Hz).

6-2 study the occurrence of errors in the network

With the occurrence of errors in line (symmetric and asymmetric), due to impedance variation in DG terminal, there is a sudden variation in the generation of generator $\overline{I}_1$.

6-2-1 Three-phase error

To study this state, a three-phase error to ground placed with error resistance of 5 Ohms at the end DG input feeder in 30 th second for 0.1 second. Bar graph drawn in figures (8-a) and (9-a) show positive voltage component angle phase variation absolute value in DG terminal $|\Delta\varphi_t|$ for each cycle for proposed algorithm and V_S relay. In both figures $|\Delta\varphi_t|$ was almost zero before occurrence of error and after 30 th second has twice intense increase –decrease. The first increase –decrease happens in 30 th second due to sudden variation in $\overline{I}_1$ current with error occurrence in line and second increase –decrease happens in 30.1 th second due to second sudden variation in $\overline{I}_1$ current due to error handling from network.

In proposed algorithm, Phasor voltage variation amplitude (according to figure (8-a)) at 30 and 30.12 seconds with reaching to 5.3 and 19.4 degrees respectively, has exceeded the specified threshold (3 degrees). But according to figure (8-b), in these moments, due to reaching to positive voltage component angle phase variation rate absolute value amplitude in main network Bus $|\Delta\varphi'_t/\Delta t|$ to 0.59 and 1.17 degrees/sec respectively and exceeding the specified threshold (0.06 degree/sec), according to logical model shown in figure 3, relay operation blocked each time for 20 seconds. So we prevent proposed relay wrong trip for occurrence of a three-phase error in network. Also, according to figure (9-a), Phasor voltage variation amplitude in V_S relay in 30 and 30.12 seconds has exceeded the specified threshold (3 degrees) by reaching to 3.2 and 13.2 amounts.

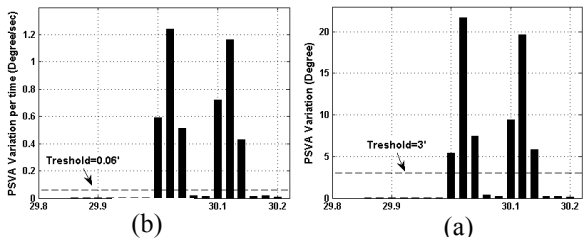


Figure. 8. Parameters of the proposed algorithm for three-phase to ground fault with fault resistance of 5 Ω.
a) $|\Delta\varphi_t|$(degree), b) $|\Delta\varphi'_t/\Delta t|$(degree/sec)

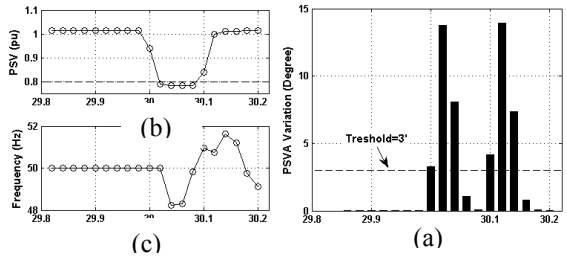


Figure.9. Parameters V_S relay for three-phase to ground fault with fault resistance of5 Ω. a) $|\Delta\varphi_t|$(degree), b) (pu)+ V,c) Hz.

In this moment, due to holding over positive frequency and voltage component amplitude in the specified threshold

(0.8<Vpu<1.3 , 47<f<53Hz) respectively , V_S relay is issued the wrong command of DG outage in 30 th second with first increasing in Phasor voltage amplitude according to shown figures in (9-b) and (9-c).

In table 4, we are given the values of parameters and results of proposed algorithm operation and V_S relay in critical moments (when Phasor voltage variation amplitude has exceeded 3 degrees) for occurrence of a three-phase error to ground with error resistance of 1, 10, 15 and 50 Ohms.

Table4. values of parameters and relay function results in 30 seconds, for three-phase errors

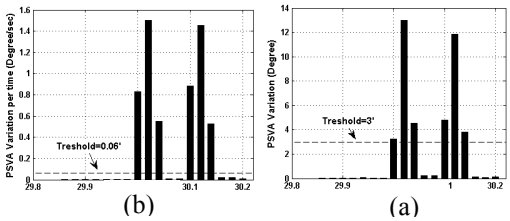
Resistance Error	Relay parameters V_s			The proposed algorithm parameters		
	$\lvert\Delta\varphi_t\rvert$ Deg	$V+$ per-unit	Trip	$\lvert\Delta\varphi_t\rvert$ Deg	$\lvert\Delta\varphi'_t/\Delta t\rvert$ (Degrees per second)	Trip
1Ω	4.34	0.832	YES	6.16	2.39	NO
10Ω	8.06	0.9	YES	3.8	0.21	NO
15Ω	5.51	0.94	YES	8.36	0.157	NO
50Ω	1.77	0.99	NO	2.74	0.016	NO

According to this table, proposed algorithm operation for all states with amplitude exceeding | $\Delta\varphi'_t/\Delta t$ | from specified threshold has been blocked correctly and any incorrect command has been issued. While, V_S relay with issuing outage command for all states has been have wrong operation.

6-2-2 two-phase error

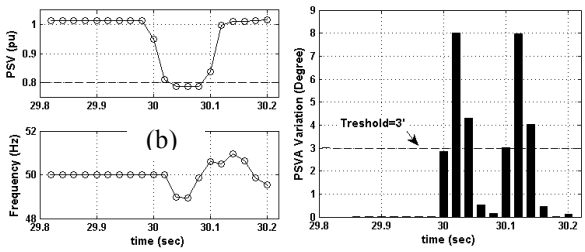
In this state, a two-phase error was placed with error resistance of 5 Ohms at the end DG input feeder in 30 th second for 0.1 second. In proposed algorithm, Phasor voltage variation amplitude (according to figure (10-a)) has exceeded the specified threshold (3 degrees) at 30 and 30.12 seconds with reaching to 3.4 and 11.9 degrees respectively. But according to figure (10-b), in these moments, due to reaching to positive voltage component angle phase variation rate absolute value amplitude in main network Bus | $\Delta\varphi'_t/\Delta t$ | to 0.83 and 1.47 degrees/sec respectively and exceeding the specified threshold (0.06 degree/sec), relay operation has been blocked each time for 120 mil/sec. So in this way, it is prevented a proposed relay wrong trip for occurrence of a two-phase error in network.

Also, according to figure (11-a), Phasor voltage variation amplitude in V_S relay in 30.02 and 30.14 seconds has exceeded the specified threshold (3 degrees) by reaching to 8.0and 4.1 amounts respectively. In these moments, due to holding over positive frequency and voltage component amplitude in the specified threshold (0.8<Vpu<1.3, 47<f<53Hz) respectively, V_S relay is issued the wrong command of DG outage in 30 th second with first increasing in Phasor voltage amplitude according to shown figures in (11-b) and (11-c).



(b) (a)

Figure.10. Parameters of the proposed algorithm for two-phase to ground fault with fault resistance of 5 Ω.
a) $\lvert\Delta\varphi_t\rvert$(degree), b) $\lvert\Delta\varphi'_t/\Delta t\rvert$(degree/sec)



(c) (a)

Figure. 11. Parameters V_S relay for two-phase to ground fault with fault resistance of 5 Ω.
a) $\lvert\Delta\varphi_t\rvert$(degree), b) (pu)+ V,c) (Hz).

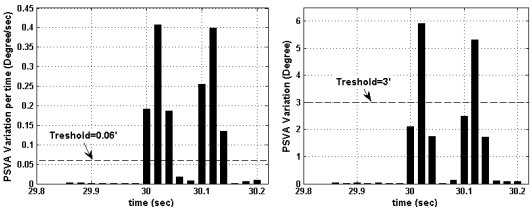
In table (5), we are given the values of parameters and results of proposed algorithm operation and V_S relay in critical moments for occurrence of a two-phase error with error resistance of 1, 10, 15 and 30 Ohms.

Table 5. values of parameters and relay function results in 30 seconds, for two-phase errors

Resistance Error	Relay parameters V_s			The proposed algorithm parameters		
	$\lvert\Delta\varphi_t\rvert$ Deg	$V+$ (per-unit)	Trip	$\lvert\Delta\varphi_t\rvert$ Deg	$\lvert\Delta\varphi'_t/\Delta t\rvert$ (Degrees per secon)	Trip
1Ω	5.3	0.6	NO	8.75	3.84	NO
10Ω	5.97	0.89	YES	9.65	0.6	NO
15Ω	4.62	0.93	YES	7.26	0.3	NO
30Ω	2.56	0.97	NO	4.14	0.09	NO
50Ω	1.62	0.99	NO	2.63	0.044	NO

6-2-3 Single – phase error

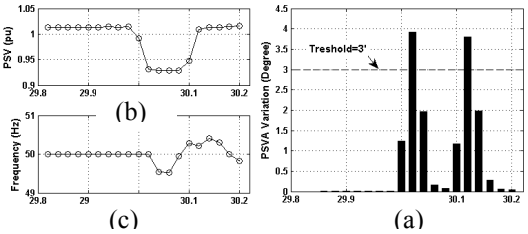
In this state, a single-phase error to ground placed with error resistance of 15 Ohms at the end DG input feeder in 30 th second for 0.1 second. In proposed algorithm, Phasor voltage variation amplitude (according to figure (12-a) has exceeded the specified threshold (3 degrees) at 30.02 seconds with reaching to 5.93 degrees.



(b) (a)

Figure.12. Parameters of the proposed algorithm for Single -phase to ground fault with fault resistance of 5 Ω.
a) $|\Delta\varphi_t|$ (degree), b) $|\Delta\varphi'_t/\Delta t|$(degree/sec)

Also, according to figure (13-a), Phasor voltage variation amplitude in Vs relay in 30.02 and 30.14 seconds has exceeded the specified threshold (3 degrees) by reaching to 3.9 degrees.



(b)
(c) (a)

Figure. 13. Parameters Vs relay for Single -phase to ground fault with fault resistance of 5 Ω.
a) $|\Delta\varphi_t|$ (degree), b) (pu)+ V,c) (Hz).

In this moment, due to holding over positive frequency and voltage component amplitude in the specified threshold (0.8<Vpu<1.3, 47<f<53Hz) respectively, Vs relay is issued the wrong command of DG outage in 30.02 th second with first increasing in Phasor voltage amplitude according to shown figures in (13-b) and (13-c).

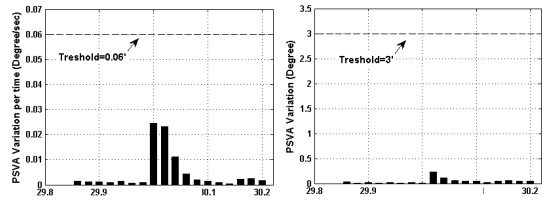
Table 6. values of parameters and relay function results in 30 seconds, for Single -phase errors

Resistance Error	Relay parameters Vs			The proposed algorithm parameters		
	$\lvert\Delta\varphi_t\rvert$ Deg	V+ (per-unit)	Trip	$\lvert\Delta\varphi_t\rvert$ Deg	$\lvert\Delta\varphi'_t/\Delta t\rvert$ (Degrees per second(	Trip
1Ω	4.5	0.78	YES	3.78	0.71	NO
10Ω	2.46	0.97	NO	3.7	0.152	NO
15Ω	1.71	0.985	NO	2.63	0.073	NO
30Ω	0.88	1	NO	1.39	0.018	NO
50Ω	0.47	1.01	NO	0.745	0.0175	NO

In table 6, we are given the values of parameters and results of proposed algorithm operation and Vs relay in critical moments for occurrence of a single-phase error with error resistance of 1, 10, 15 and 30 Ohms.

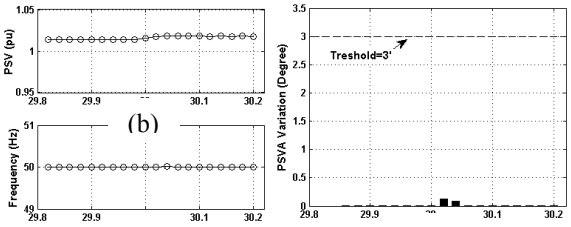
6-3 Switching capacitive banks

In this section, in order to investigate the sensitivity of the proposed method and compare its results with the Vs relay function, a capacitor bank with a capacity of 66.0 Mvar (30% of total generator load) is introduced at 30th seconds near the local loads. Bar graph drawn in figures (14-a) and (15-a) shows phase angle variation voltage positive component in DG terminal $|\Delta\varphi_t|$, for proposed algorithm and Vs relay, respectively. In both figures, $|\Delta\varphi_t|$ is almost zero before entering capacitive bank and after 30th second, due to entering capacitive bank to network and changing Q(t) amount, we have a sudden increasing- decreasing. According to figures (14-a) and (15-a), maximum Phasor voltage variation amplitude for proposed algorithm and Vs relay happens at 30th second for 0.23 and 0.11 degrees respectively. So , Phasor voltage variation amplitude for both relays for total time , holding lower than specified threshold(3 degrees) and Without concluding a relationship $(|\Delta\varphi_t|>3°)$ in logical model any command has been issued incorrectly to relay.



(b) (a)

Figure. 14. The proposed algorithm parameters for capacitor bank to the network with a capacity of 0.66Mvar.
a) $|\Delta\varphi_t|$ (degree), b) $|\Delta\varphi'_t/\Delta t|$(degree/sec)



(b)
(c) (a)

Figure. 15. Relay parameters Vs for capacitor bank to the network with a capacity of 0.66Mva .
a) $|\Delta\varphi_t|$ (degree), b) (pu)+ V,c) (Hz).

Table. 7. values of parameters and relay function results in 30 seconds for capacitor bank to the network

Capacity Bank Capacity (MVAR)	Relay parameters Vs			The proposed algorithm parameters		
	$\lvert\Delta\varphi_t\rvert$ Deg	V+ (per-unit)	Trip	$\lvert\Delta\varphi_t\rvert$ Deg	$\lvert\Delta\varphi'_t/\Delta t\rvert$ (Degrees per second)	Trip
0.11	0.012	1.01	NO	0.015	0.004	NO
0.22	0.03	1.012	NO	0.05	0.011	NO
0.33	0.047	1.015	NO	0.095	0.017	NO

In table 7, we are given values of parameters and results of proposed algorithm operation and Vs relay at 30th second for entering capacitive banks to network with capacities of 0.11, 0.22 and 0.33 MVAR. According to this table, in both relays

definite command has been issued due to holding lower maximum Phasor voltage variation amplitude from specified threshold (3 degrees).

6-4 Importing/exporting balanced charge to network

In this unit, to study sensitivity of proposed method and compare its results with V_S relay operation, a balanced –charge with 0.66 MVA capacities (30% generator total charge) enters network, near the local charges at 30th second .

Bar graph drawn in figures (16-a) and (17- a) shows phase angle variation voltage positive component in DG terminal $|\Delta\varphi_t|$, for proposed algorithm and V_S relay, respectively. In both figures, $|\Delta\varphi_t|$ is almost zero before error occurrence and after 30th second, due to entering balanced-charge to network and changing P(t) and Q(t) amounts, we have a sudden increasing-decreasing. According to figure (16-a), maximum Phasor voltage variation amplitude for proposed algorithm is 0.86 degrees that happen at 30th second . According to figure (17-a) maximum variation amplitude for this parameter for V_S relay is 0.45 degrees that happen at 30.02th second. So , Phasor voltage variation amplitude for both relays for total time , holding lower than specified threshold(3 degrees) and as a result of lacking $(|\Delta\varphi_t| > 3°)$ equation in logical model any command has been issued incorrectly.

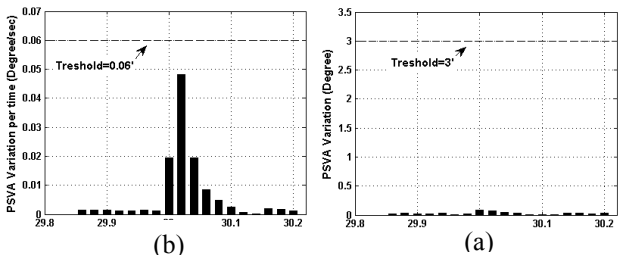


Figure. 16. Parameters of the proposed algorithm for load balancing network capacity with 0 / 66MVA.
a) $|\Delta\varphi_t|$ (degree), b) $|\Delta\varphi'_t/\Delta t|$((degree/sec)

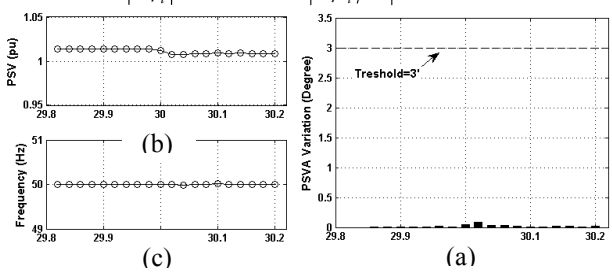


Figure. 17. Relay parameters proposed for load balancing network capacity with 0.66Mvar.
a) $|\Delta\varphi_t|$ (degree), b) (pu)+ V, c) (Hz).

In table 8, we are given values of parameters and results of proposed algorithm operation and V_S relay in critical moments, for Load arrived balanced with capacity of 0.32 MVA and balanced load departure with capacity of 0.66 MVA. According to this table, in both relays any definite command has been issued due to holding lower maximum Phasor voltage variation amplitude from specified threshold (3 degrees).

Table 8. parameter values and performance results relays at the moment 30.02 seconds, to enter / exit load-balanced network

enter / exit load-balanced (MVA)	Relay parameters V_S			The proposed algorithm parameters		
	$\lvert\Delta\varphi_t\rvert$ Deg	V+ (per-unit)	Trip	$\lvert\Delta\varphi'_t/\Delta t\rvert$ Degrees per second		Trip
0.32 enter	0.032	1.01	NO	0.027	0.027	NO
0.32 exit	0.027	0.013	NO	0.047	0.012	NO
0.66 exit	0.03	1.014	NO	0.055	0.031	NO

7. Conclusion

In this paper, a new method introduced for island identification according to phase angle variation in sampled voltage by PMU in both separate network buses. This new method makes possible an extensive and reliable protection in smart networks that uses sharing Phasor data in data processing center for decision making. Proposed method is able to distinguish between island and non-island conditions and has triped unbalanced small power with 20 mil/sec delay. Results of simulation unlike relay shift show that proposed method makes any mistake and does not triped for symmetric and asymmetric errors away from DG with different resistance errors.

8. Reference

[1] H. Laaksonen, "Advanced Islanding Detection Functionality for Future Electricity Distribution Networks",IEEE Transactions on Power Delivery, Vol. 28, No. 4, pp. 2056–2064, (2013).

[3] D. Velasco, C. L. Trujillo, G. Garcera , E. Figueres, "Review of Anti-Islanding Techniques in Distributed Generators Renewable and Sustainable Energy Reviews", Vol.14, pp.1608-1614, (2010).

[5] B. Bahrani, H. Karimi, R. Iravani, "Non-Detection Zone Assessment of an Active Islanding Detection Method and Its Experimental Evaluation". IEEE Trans. on Power Delivery, Vol. 26, No. 2, pp. 517–525, (2011).

[6] A. Etxegarai, P. Eguía, I. Zamora, "Analysis of Remote Islanding Detection Methods for Distributed Resources", International Conference on Renewable Energies and Power Quality (ICREPQ'11), pp.1-7, (2011).

[7] A. G. Phadke, J.S. Thorp,"Synchronized Phasor Measurements and Their Applications", Springer publishing, (2008).

[8] A. Mazloomzadeh, Cintuglu, "Islanding Detection Using Synchronized Measurement in Smart Microgrids", Innovative Smart Grid Technologies Latin America (ISGT LA), IEEE PES Conference , pp. 1–7, (2013).

[9] Z. Lin, T. Xia , Y. Ye, Y. Zhan., L. Chen, Y.Liu, K. Tomsovic, T. Bilke, "Application of Wide Area Measurement Systems to Islanding Detection of Bulk Power Systems", IEEE Trans. On Power Systems, Vol. 28 , No. 2, pp. 2006–2015, (2013).

[10] L. Huang, Y. Sun, J. Xu, W. Gao, J. Zhang, Z. Wu, "Optimal PMU Placement Considering Controlled Islanding of Power System", IEEE Trans. on Power Systems, Vol. No. 99, pp. 1–14, (2014).

[11] N. Granda, D. G. Colome, "A New Strategy for Controlled Power System Islanding", Transmission and Distribution: Latin

America Conference and Exposition (T&D-LA), 2012 Sixth IEEE/PES pp. 1–8, (2012).
[12] F. Galvan, R. Matthew, "Using Phasor Measurement Units in Power System Island Restoration", Power and Energy Society General Meetin. 2012 IEEE pp. 1–3, (2012).
[13] W. Wang, W. Kliber, G. Zhang, W. XU, W. Howell, W. Palladino, "A Power Line Signaling Based Scheme for Anti-Islanding Protection of Distributed Generators – Part II: Field Test Results", IEEE Trans. on Power Deliver, Vol. 22, No. 2, pp. 1767–1772, (2007).
[14] F. Hashiesh, H. Mostafa, A. Khatib, I. Helal, M. Mansour "An Intelligent Wide Area Synchrophasor Based System for Predicting and Mitigating Transient Instabilities",IEEE Trans. on Smart Grid, Vol. 3 , No. 2 pp. 645-652, (2012).