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NDZ Analysis of Various Passive Islanding Detection Methods for Integrated DG System over Balanced Islanding

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Abstract: In this paper different passive islanding detection (PID) schemes for synchronous distributed generation (DG) is presented and their performance is evaluated. Renewable DG systems place a vital role in the smart grids. One of the important problems due to such renewable DG system is an unintentional islanding. The islanding is caused if DG still supplies power to load after disconnecting from the grid. As per the DG interconnection standards, it is required to detect the islanding within 2 seconds after islanding with the equipments connected to it. In this paper different PID methods are compared and their performance is evaluated for wind DG systems. The combined changes of rate of change of positive sequence voltage (ROCOPSV) and current, the rate of change of negative sequence voltage (ROCONSV) and current, rate of change of frequency over reactive power (ROCOFORP) are evaluated as the better methods for islanding detection at low or zero power balanced islanding. The sensitivity analysis of these methods is simulated in MATLAB for different load variations of islanding and non islanding events. The passive methods which work under zero power imbalances with zero non detection zone (NDZ) are finalized. This analysis indicates each method has different sensitivity for islanding and non islanding events.

Keywords: Distributed Generation (DG), Balanced islanding, Multiple passive islanding detection methods, Sensitivity analysis, ROCOPSV, ROCONSV, NDZ.

1. Introduction

To meet the global energy consumption demand it is better to look towards renewable power generation. Renewable power generation system which is connected at the consumer level is called DG [1]. The main problem with such DG is islanding. Islanding is caused if DG supplies power to load after disconnecting from the grid. [2]. The islanding is unsafe to field persons and equipments connected because the servicing persons are not mindful that the frame up is connected and supplying with DG near. The main causes of such unintentional islanding are the failures detected by the grid, accidental opening of circuit breaker (CB) at the grid, intentional opening of CB for maintenance, human errors and an act of nature [3]. The basic grid interfacing rules listed in the Table. I, needs that it is necessary to disconnect the DG source within 2 seconds, because if the island load is more or less, then it leads to variations in the voltage, frequency, current, THD, active, reactive powers outside the standards, which may hazardous to customer loads connected to it and sometimes for DG [4, 5]. The islanding detection methods are classified as local and remote

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techniques; again the local techniques are classified as passive, active and hybrid techniques. Rate of change of frequency (ROCOF) [6], the rate of change of active power (ROCOAP) [7], phase angle difference [8], rate of change of voltage ROCOV [9], rate of change of reactive power ROCORP [10], over under voltage / over under frequency (OUV/OUF) [11] are some passive methods, they are suffering with the large NDZ, and fails to detect islanding at low or zero power imbalance conditions. The range of values where a PID method fails to detect islanding is called NDZ [12-14]. The combination of any two passive parameters is used to reduce the NDZ, like ROCOF and output power [15], ROCOV and THD [16], ROCOV and power factor [17], ROCOV and ROCOF [18], ROCOAP combination with ROCORP [19]. These methods will reduce the NDZ to less compare to single parameter passive techniques. Different control systems and inverters are implemented to connect DG sources to grid with proper synchronization and to inject high quality power into the grid [20-21]. PLCC and SCADA are the remote ID techniques [22-23]; they detect the islanding by gathering information from DG side and utility side. Utility side signals are monitored by the PLCC [24]. If these signals are not appearing then islanding is detected. On the other hand, islanding was detected by SCADA with information from CB auxiliary contacts. The exertion of these methods is very difficult because the cost and exertion of other monitoring devices, transmitters and receivers are more [25]. By injecting some disturbance at PCC for some cycles and observing the deviations in the output signal active methods will detect the islanding. In the grid connected system, the system absorbs the local disturbance and considerable deviations are not observed. However, more deviations are observed in the output signal if the system is islanded. [26-32]. The active methods are more efficient than passive methods, but they degrade the power quality [33-35]. Large samples of data collected from non-islanding and islanding events, machine learning detection techniques detect islanding [36-42]. Some popular algorithms such as ANN [43], DTM [44], and SVM [45] are used to differentiate between islanding and non islanding incidents. In passive techniques, regional parameters such as voltage, frequency, current, phase angle, THD are monitored at the PCC, if there are changes beyond a certain threshold level then islanding is detected [46-50, 6-19]. The NDZ of these methods is higher than active and hybrid methods [51-54].

To reduce the NDZ of PID methods, in this paper multiple passive methods are presented and their performance is evaluated in a double DG system during islanding and non islanding events such as balanced islanding, LG fault, LL fault, LLG fault, load switching at different bus. Some of the methods which work at low power mismatch and balanced generation are finalized as ROCOF over reactive power (df/dQ), rate of change of negative sequence voltage (ROCONSV) and current (dV_2/dt) and rate of change of positive sequence voltage (ROCOPSV) and current. The rest of the paper is structured accordingly, materials and method that explain the modeling of test system, load model and grid interfacing controllers is presented in section II. In Section III, twenty different types of passive parameters are presented. Results discussion and comparison with existing methods are presented in section IV. Lastly, the conclusion is drawn in section V.

Table: I. Islanding detection time, frequency and voltage ranges of various standards

Standard	Quality factor	Island detection	Range of frequency	Voltage range
IEEE 1547	1	t < 2000	$59.3 \leq f \leq 60.5$	$88\% \leq V \leq 110\%$
IEC 62116	1	t < 2000	f_0 - 1.5 Hz $\leq f_0$ +1.5 Hz	$85\% \leq V \leq 115\%$
Korean Standards	1	t < [illegible]	$59.3 \leq f \leq 60.5$	$88\% \leq V \leq 110\%$
UL 1741	≤1.8	t < 2000	Setting value	Setting value
VDE 0126-1-1	2	t < [illegible]	47.5 Hz $\leq f \leq$ 50.2 Hz	$80\% \leq V \leq 115\%$
IEEE 929-2000	2	t < 2000	$59.3 \leq f \leq 60.5$	$88\% \leq V \leq 110\%$
AS47773-2005	1	t < 2000	Setting value	Setting value

2. Test system under study

The DG supplying power to load connected, after disconnecting from main grid is called islanding. The principle of islanding is shown in Fig.1. The DG is integrated into the grid with transformers and CB. When the inter-tie CB is opened, the islanding is caused with industrial area shown with inner circle with dotted lines.

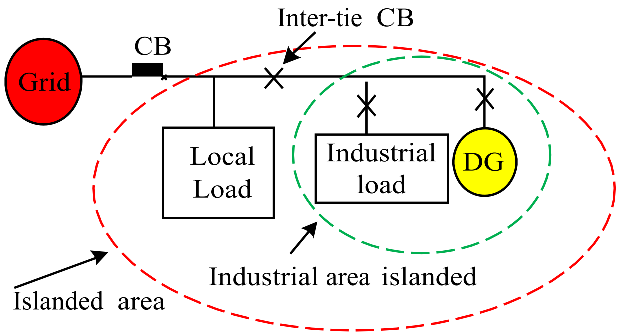

Fig. 1. Principle of islanding detection

If the main CB is opened, the islanding is occurred with local load and industrial area. The voltage and currents are input to the proposed detection process. The passive parameters at PCC are used to detect islanding. In the grid connected mode, no variations are observed in the passive parameters. During the islanding the change of these passive parameters is more and is used to detect islanding. One or two parameters are taken as input to the proposed method. The simulation study of the proposed multiple passive methods is performed on 11 KV distribution network connected to the grid using MATLAB shown in Fig.2. It consists of two hydro DG systems of 2 MVA capacity, 9 loads and 7 buses. The 2 MVA DG units increases the voltage to 11 KV to the distribution system by two 2 MVA, 3.3/11 KV transformers. From the distribution system, it is synchronized to the grid through 20 MVA, 33/11 KV transformers. One of the DG is DFIG type and the other is synchronous generator. In the distributed generator to keep the voltage in the allowable limits, it is set up with the excitation control. To regulate the mechanical force of the water flow, the mini hydro generator is additionally driven by a hydraulic rotary engine. The rotary engine model employed in this work is that the non elastic water column while not surge tank, whereas the excitation system model is an IEEE type AC1A standard. Different types of controllers like, rotating reference frame, constant reference frame controllers are used to synchronize the DG with the grid. The function of these controllers is to inject high quality power into the grid [20]. The dq/abc, synchronous reference frame controller shown in Fig. 3. is used to synchronize the DG with the grid, and to control active and reactive powers [21].

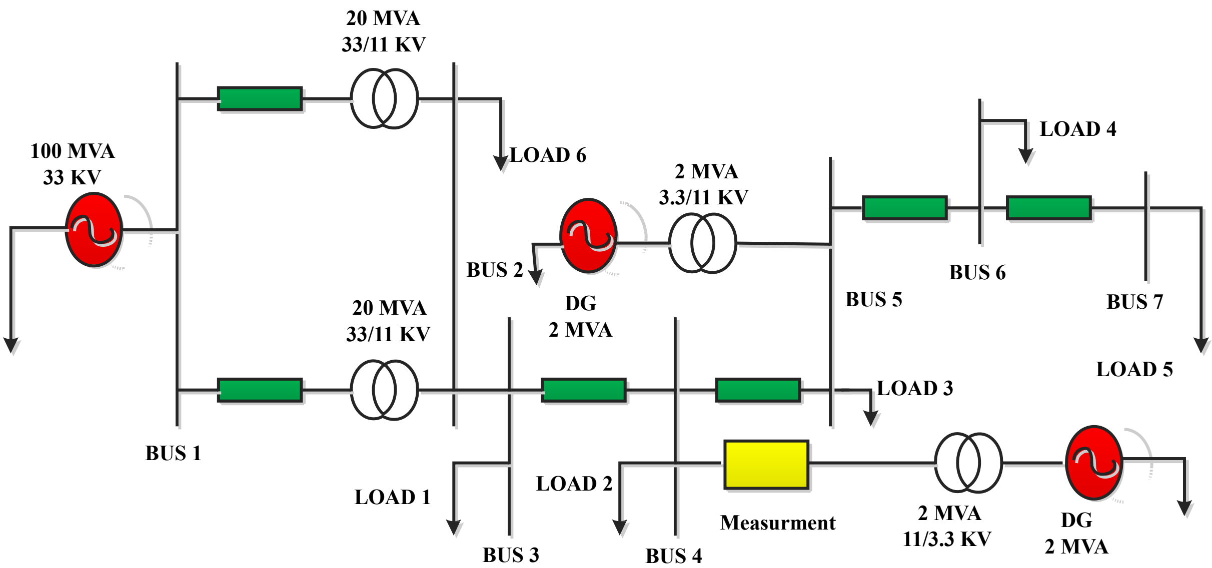

Fig.2. Test system under study for performance evaluation of all methods

3. Passive methods considered for evaluation

PID technique measures the local parameters such as voltage, active power, reactive power, frequency, negative sequence voltage, positive sequence voltage and their combinations to detect the islanding. The detection parameter may be with rate of change of single parameter or ratio of rate of change of multiple parameters.

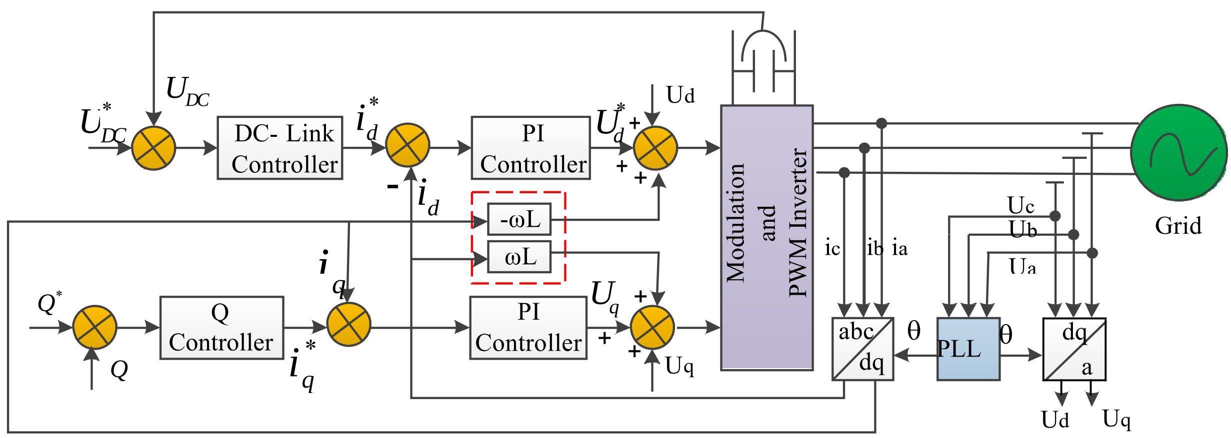

Fig. 3. Control circuit used for grid integration of renewable energy resources

This study focuses on islanding detection with one and two passive parameters under different islanding and non islanding events. Each parameter is selected based on its sensitivity for islanding and non islanding events.

3.1 OUV/OUF passive method

The first passive islanding technique is over OUV/OUF method [11]. In this method the voltage and frequency of the system at PCC are observed to decide whether islanding is taken or not. The voltage and frequency threshold values can be calculated as equation (1) and (2)

$$\left(\frac{V}{V_{max}}\right)^2 - 1 \le \frac{\Delta P}{P_{DG}} \le \left(\frac{V}{V_{min}}\right)^2 - 1 \qquad (1)$$

$$Q_f\left(1-\left(\frac{f}{f_{min}}\right)^2\right) \le \frac{\Delta Q}{P_{DG}} \le Q_f\left(1-\left(\frac{f}{f_{max}}\right)^2\right) \qquad (2)$$

Where V_{max}, V_{min} f_{max} and f_{min} are the maximum voltage, minimum voltage, maximum frequency and minimum frequency respectively. Generally the values of V_{max}, V_{min}, f_{max} and f_{min} are 110%, 88%, 60.5 and 59.5 Hz respectively [11]. It can detect islanding, when the voltage and frequency exceeds the thresholds. The NDZ of this method is more and is shown in Fig. 4. From which this method fails to detect islanding inside the box. From equations (3) and (4) the variation in active power leads to variation in voltage and change in reactive power modifies the frequency. During zero power imbalance condition △P and △Q are zero due to which there is no variation in voltage and frequency and islanding is not detectable.

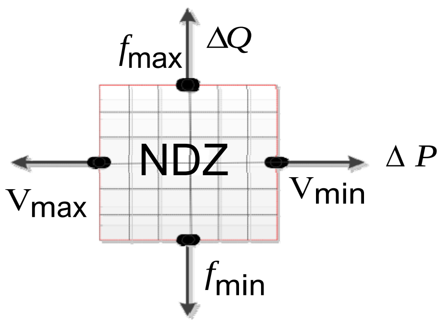

Fig.4. Non detection zone of OUV/OUF method

3.2. Rate of change of active power (ROCOAP) (dP/dt)

In this method of ID the active power at PCC is calculated and derivated to get dP/dt. If it is more than the set value, then it is taken as islanding [7]. From Fig. 1 we can write

$$P_{Load}=\frac{V^2}{R}=P+\Delta P \tag{3}$$

From equation (3) if △P = 0, the active power cannot change and also the voltage. This shows that this method fails to detect islanding in the worst case of islanding. The NDZ of this method is high.

3.3. Rate of change of voltage (ROCOV) (dV/dt)

In this method the ROCOV is calculated for five cycles as per equation (4). If the ROCOV is more than a minimum voltage set point, then islanding is doubtable. If it is more than a maximum voltage set value, which indicates the huge power difference between load and generation and an islanding is confirmed [9]. But if the ROCOV is in between maximum and minimum voltage set points then we will suspect an islanding may be non islanding events. From equation (1) and (3) if △P = 0 or small mismatch between DG and load there is no change in power which leads no considerable variations in voltage and the ROCOV passive method declines to detect islanding.

$$ROCOV=\left|\frac{1}{5}\sum_{i=1}^{5}\left(\frac{dV}{dt}\right)_i\right| \tag{4}$$

3.4. Rate of change of reactive power (ROCORP) (dQ/dt)

The ROCORP passive method will detect islanding, if the ROCORP at PCC is more than a specified threshold value [10]. The net reactive power received by the load can be written as, form Fig.1 is an equation (5). From equation (2) and (5) if △Q = 0, the net flow of reactive power between load and DG is zero. Now the ROCORP cannot go beyond the specified value as a large power mismatch and this method fails to detect islanding at small power or zero power imbalances between load and DG.

$$Q_{Load}=\frac{V^2}{2\Pi fL}=Q+\Delta Q \tag{5}$$

3.5. Rate of change of frequency (ROCOF) (df/dt)

The performance of the ROCOF passive method is based on the measurement of frequency at PCC [6]. The frequency measurement is done through Phase locked loop. In the cases when the grid system is lost, a change in DG's loading is happening and its instantaneous output frequency is changing called as ROCOF. The Expression for the ROCOF is given by [15]

$$\frac{df}{dt}\left(k\right)=\frac{f\left(t_k\right)-f\left(t_k-\Delta t\right)}{\Delta t} \tag{6}$$

Where $f(t_K)$is, the frequency at the time of k^{th} sample $f(t_k-\triangle t)$is the measured value of frequency, $\triangle t$ before the k^{th} segment time i.e. $t_k-\triangle t$. But at zero or small power mismatch condition from the equation (2) and (4) the change in frequency is less and fails to detect islanding. The NDZ of this method is less compared to OUV/OUF passive method.

3.6. Rate of change of frequency over reactive power (ROCOFORP) (df/dQ)

In this method the ROCOF shown in equation (6) and ROCORP of the equation (5) are calculated independently. If ROCOF is more than a maximum threshold value, then islanding is confirmed. If it is more than a minimum threshold value, and lesser than a maximum threshold value, the case may be islanding or non islanding. To confirm the islanding and to differentiate the islanding with non islanding events, reactive power is injected into the system [55].

The injected power is selected as 1% of rated DG capacity, which cannot harm to power quality. From equation (4) the frequency and reactive power are inversely proportional to each other. After a few more cycles, if ROCOF is more than a minimum threshold value, then islanding is confirmed.

3.7. Rate of change of frequency over voltage (ROCOFOV) (df/dV)

In this method the ROCOF and ROCOV are calculated independently [18]. If ROCOF and ROCOV both are, more than a specified threshold value, then islanding is confirmed. Otherwise, if anyone is more than a specified threshold value and another is less, then non islanding is confirmed.

3.8. Rate of change of voltage over active power (ROCOVOAP) (dV/dP)

In this method the ROCOV is calculated for five cycles of the equation (4). If the ROCOV is more than a minimum voltage set point, then islanding is doubtable. If it is more than a maximum voltage set value, which indicates the huge power operation between load and generation and an islanding is confirmed. But, when the ROCOV is in between maximum and minimum voltage set points, then an islanding is suspected or may be a non islanding event. In this case to confirm the islanding and to separate between non islanding events the real power of any one DG is increased or decreased. Now again the ROCOV over another twenty cycles is calculated and is compared with ROCOV after each five cycles. If it is same or more, then islanding is confirmed, otherwise a non islanding case [17].

$$\text{ROCOV}=\left|\frac{1}{20}\sum_{i=1}^{20}\left(\frac{dV}{dt}\right)_i\right| \qquad (7)$$

3.9. Rate of change of active power over reactive power (ROCOAPORP) (dP/dQ)

The active power and reactive power at PCC are found with PQ measurement and are presented in equation (3) and (4). Equation (3) and (4) are differentiated to ROCOAP and ROCORP. When there is a huge power difference between load and DG, the variations in the ROCOAP and ROCORP are observed more [19]. If the mismatch is less, the variations are also less. To find weather islanding or non islanding is caused in the system, the threshold values are fixed. If both are more than a specified threshold value, then it is considered as islanding. If anyone is more than a specified value, but not other in this case we can treat it as non islanding. In this method, it is difficult to fix threshold values under low power mismatch conditions and zero power imbalance conditions.

3.10. Rate of change of active power over voltage (ROCOAPOV) (dP/dV)

The active power and voltage are proportional to each other. These two parameters depend on the inertial component of the machine used. Under a small power variation, the ROCOAP and ROCOV variations are less. When there is a huge power difference, the variations are observed more. The ROCOAP and ROCOV are independently calculated [17]. If both the values specify more than the threshold value, then islanding is detected. Otherwise, non islanding.

3.11. Rate of change of reactive power over frequency (ROCORPOF) (dQ/df)

The reactive power depends on the variation of excitation, but the frequency depends on the inertia constant of the machine. Hence the sensitivity of the reactive power is more than the frequency. ROCORP and ROCOF both are calculated separately and if their values are more than a specified threshold value, then islanding is confirmed [55].

3.12. Rate of change of voltage over reactive power (ROCOVORP) (dV/dQ)

At PCC the voltage is found by using voltage measurement. The deviations in the voltage are used to detect islanding. Two threshold values are selected as maximum voltage and minimum voltage. During islanding of huge power difference the ROCOV variations are more than the specified maximum threshold value and are confirmed as islanding. For non islanding and small power mismatch islanding situations, the ROCOV variations are in between maximum and minimum threshold values. In these cases, to separate the islanding and non islanding events, reactive power is force into the system, and also the variations are observed for another few cycles. If these variations are more than the minimum set value, it is considered as islanding. If they are less than the minimum threshold value, then it is selected as non islanding [55].

3.13. Rate of change of reactive power over voltage (ROCORPOV) (dQ/dV)

At PCC the voltage is found by using voltage and reactive power are found by using suitable measurement. The deviations in the voltage and reactive power are used to detect islanding. The ROCORP and ROCOV combinations are used to detect the case of islanding [9]. If these changes are more than the minimum set value, it is considered as islanding, otherwise non islanding. This method capable to detect islanding at the huge power mismatch situation, but fails to detect islanding under low power variations. The NDZ of this method is high.

3.14. Rate of change of frequency over active power (ROCOFOAP) (df/dP)

At PCC the frequency is found by using a phase locked loop (PLL). The deviations in the frequency are used to detect islanding. Two threshold values are selected as maximum ROCOF and minimum ROCOF. During islanding of huge power difference the ROCOF variations are more than the specified maximum threshold value and are confirmed as islanding. For non islanding and small power mismatch islanding situations, the ROCOF variations are in between maximum and minimum threshold values [16-19]. In these cases, to separate the islanding and non islanding events, active power of any one DG is increased or decreased, and also the variations are observed for another twenty cycles. If these variations are more than the minimum threshold value, it is considered as islanding. If they are less than the minimum threshold value, for another twenty cycles then it is selected as non islanding.

3.15. Rate of change of voltage over frequency (ROCOVOF) (dV/df)

In this method, the ROCOV and ROCOF are calculated at PCC [16-18]. In the grid connected operation, there are no suitable variations in the ROCOV and ROCOF. When the system is islanded, the variations in the ROCOV and ROCOF are used to detect islanding. If both the values of ROCOV and ROCOF are more than a specified threshold value, then islanding is detected, on the other hand it is considered as a non islanding condition.

3.16. Rate of change of reactive power over active power (ROCORPOAP) (dQ/dP)

The sensitivity of reactive power depends on the variation of excitation; active power sensitivity depends on frequency. For islanding conditions due to changes in excitation, the reactive power variations are faster than the frequency and active powers [17-19]. In this method the ROCORP and ROCOAP are calculated to confirm the islanding. This method declines to detect the islanding events under small power variations and the islanding is confirmed when both are more than set values.

3.17. Rate of change of active power over frequency (ROCOAPOF) (dP/df)

In this method the combination of ROCOAP and ROCOF are used to detect islanding. These two parameters depend on the inertia constant of the generator, so the response of these parameters to balanced islanding is less. If both are more than a specified threshold value, then islanding is detected [17].

3.18. Rate of change of Negative sequence voltage (ROCONSV) (dV_2/dt)

The sequence analyzer will separate the positive, negative and zero sequence components from unbalanced voltages and currents obtained at PCC. The zero sequence components present only when the system is associated with ground. The negative sequence components present during the islanding operation [51]. The positive sequence components will present in all modes. The symmetrical components of voltages are at PCC are represented in equation (8)

$$v_{a1} = \frac{1}{3}(v_a + \alpha v_b + \alpha^2 v_c)$$

$$v_{a2} = \frac{1}{3}(v_a + \alpha^2 v_b + \alpha v_c) \quad (8)$$

$$v_{a0} = \frac{1}{3}(v_a + v_b + v_c)$$

Where V_{a0}, V_{a1} and V_{a2} are the zero sequence, positive sequence and negative sequence voltages

$$\alpha = 1\angle 120^0 \text{ or } \cos 120^0 + j \sin 120^0 \quad (9)$$

and also $\alpha^2 + \alpha + 1 = 0$ (10)

the ROCONSV is dV_{a2}/dt (11)

by observing ROCONSV equation (11), the islanding is detected. In the grid connected mode this deviations are not present, but in islanding condition these changes are more and an islanding is detected.

3.19. Rate of change of Positive sequence voltage (ROCOPSV) (dV_1/dt)

The positive sequence components of voltages will present in all modes of micro grid like grid connected, autonomous and islanding modes. From equation (8) the ROCOPSV is dV_1/dt. By finding the variations in the ROCOPSV, we will conclude whether the islanding case or non islanding is occured [46], [51].

3.20. Rate of change of Phase angle between NSV and NSC (dØ/dt)

At PCC the voltage and current are calculated. By using least square method the phasor of voltage and current magnitudes are calculated [8]. The sequence analyzer will calculate the NSV and NSC. The Ø between NSV and NSC can found by the equation (12) [56]

Ø $= \angle N$ [illegible] [illegible] and $\angle N$ [illegible] C (12)

If the phase angle Ø is more than the specified threshold value, then islanding is detected. This value is positive for islanding events where as it is zero for non islanding events such as fault switching, load switching etc.

3.21. Rate of change of exciter voltage, over reactive power (ROCOEVORP) (dE/dQ)

The excitation voltage and reactive power are selected for islanding detection because the excitation voltage and reactive power are directly varied with variation of excitation but not on inertia constant. The active power and frequency are depends on the inertia constant of generator, but not on the excitation. So the time taken for small changes in frequency and active power is more due to inertia. However the action of reactive power and excitation are very fast for variation of an excitation. The ROCOEVORP (dE/dQ) is calculated. When the $dE/dQ \neq 0$, its value is continuously correlated with pre defined values. If dE/dQ is higher than threshold, the islanding event is confirmed, otherwise it is considered as non islanding event [57].

4. Results and Discussion

The test system is simulated on the Matlab/Simulink environment. Various islanding and non islanding events are considered for performance evaluation of passive parameters which works under worst case of islanding.

4.1. Various cases of islanding and non islanding events

There are two major cases of islanding, they are islanding and non islanding. Again the islanding is balanced islanding and unbalanced islanding [22]. There are many non islanding cases in which so many passive methods are making wrong detections such as switching of loads, faults. Most of the methods are giving correct decision for switching of loads and wrong results for faults. In this paper various types of faults like LG, LL, LLL, LLG are considered for performance evaluation. The Common type of faults occurring in a power system is LG fault. The chance of occurrence is about 70 % on any one of the three phases. The LL faults appear when two conductors are short circuited and the chance of occurrence is 15 %. The LLG faults occur about 10 % rarely in the power system. Least chance of occurrence of fault is LLL about 2 to 3 %. Along with these faults, load switching is done to make sure that whether the method is responding to non islanding events is not. Various islanding and non islanding cases are indexed in Table.II. All these cases are individually simulated for each passive parameter evaluation. To get the correct results these are simulated with different capacity of loads.

Table II: Case studies

Cas	Classification of the event
1	Loss of Mains (LOM)
2	Line to ground fault (LG)
3	Double line to ground fault
4	Double line fault (LL)

5	Triple line fault (LLL)
6	Load switching at bus 3
7	Load switching at bus 4
8	Load switching at bus 5
9	Load switching at bus 6
1	Load switching at bus 7

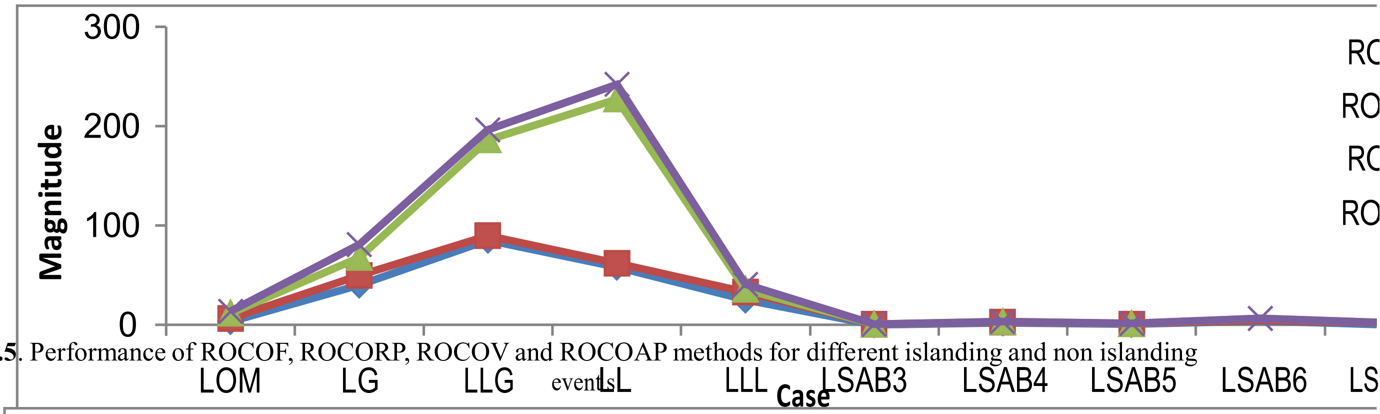

Fig.5. Performance of ROCOF, ROCORP, ROCOV and ROCOAP methods for different islanding and non islanding events

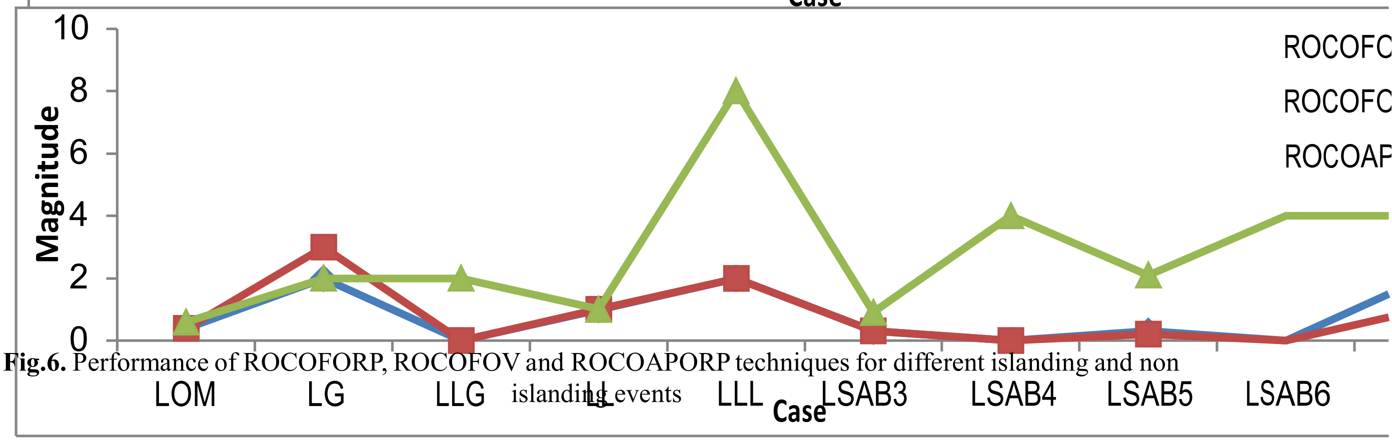

Fig.6. Performance of ROCOFORP, ROCOFOV and ROCOAPORP techniques for different islanding and non islanding events

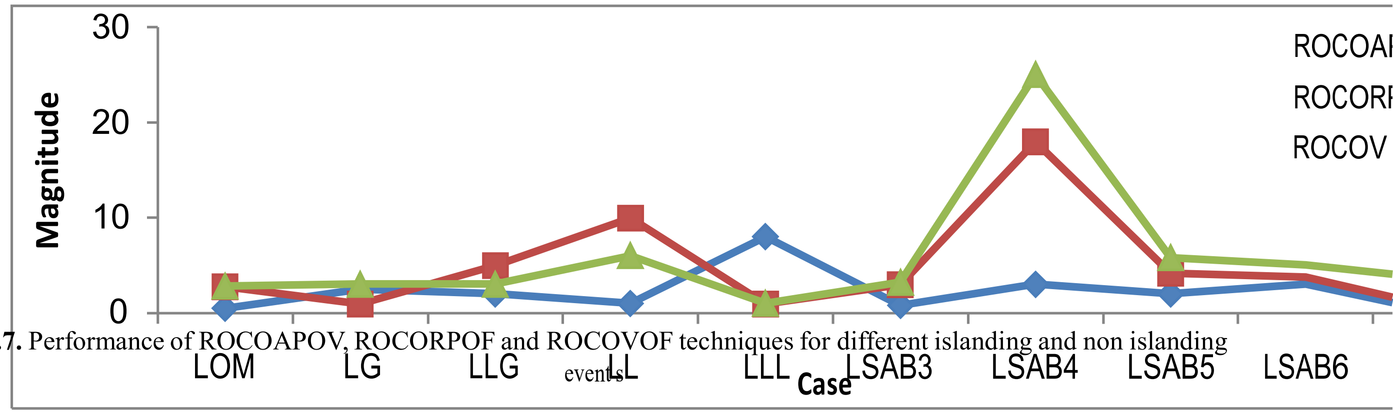

Fig.7. Performance of ROCOAPOV, ROCORPOF and ROCOVOF techniques for different islanding and non islanding events

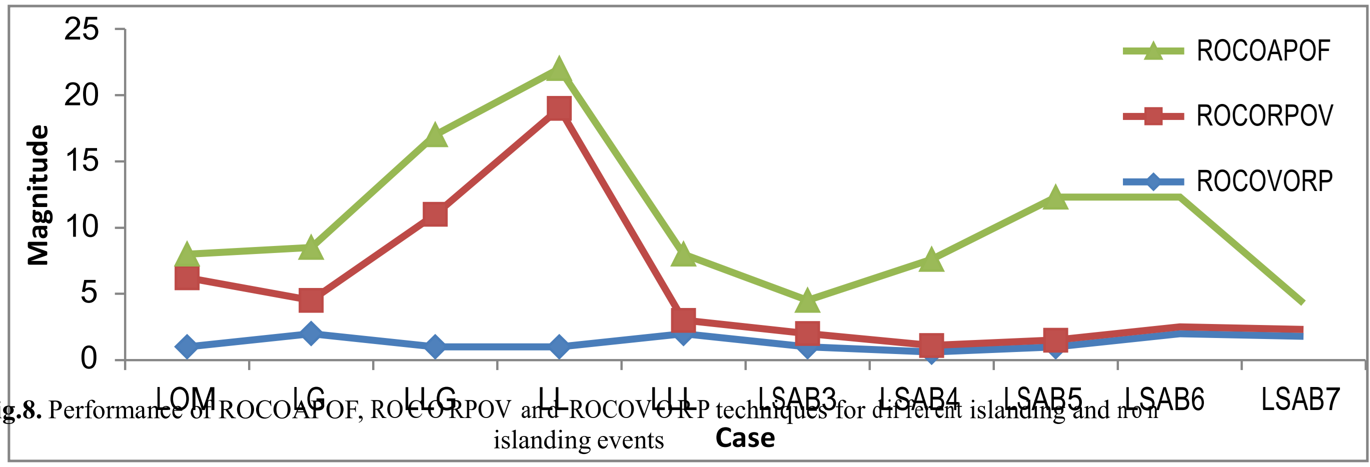

Fig.8. Performance of ROCOAPOF, ROCORPOV and ROCOVORP techniques for different islanding and non islanding events

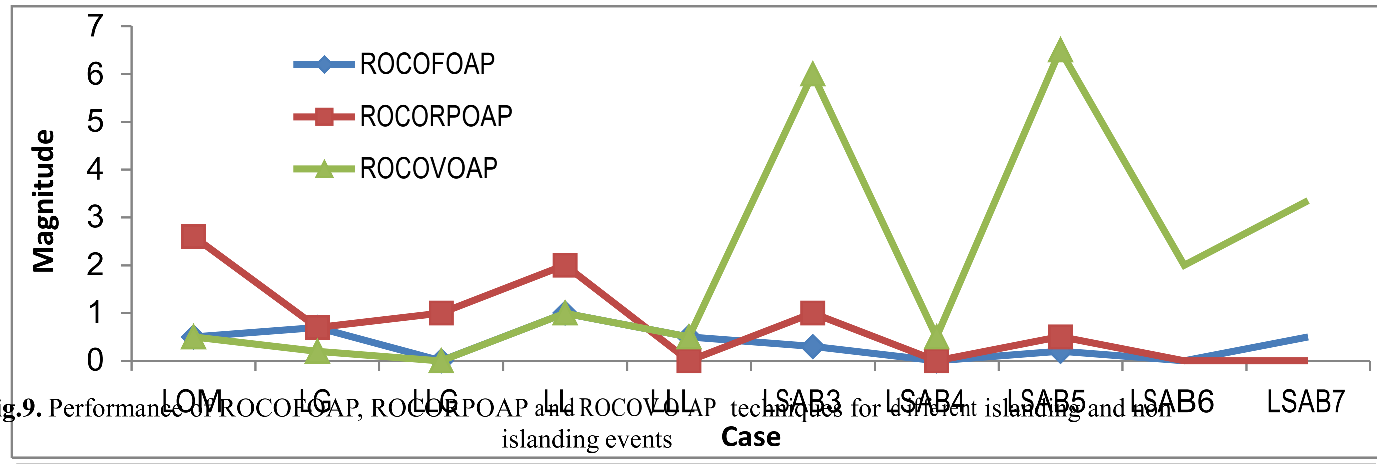

Fig.9. Performance of ROCOFOAP, ROCORPOAP and ROCOVOAP techniques for different islanding and non islanding events

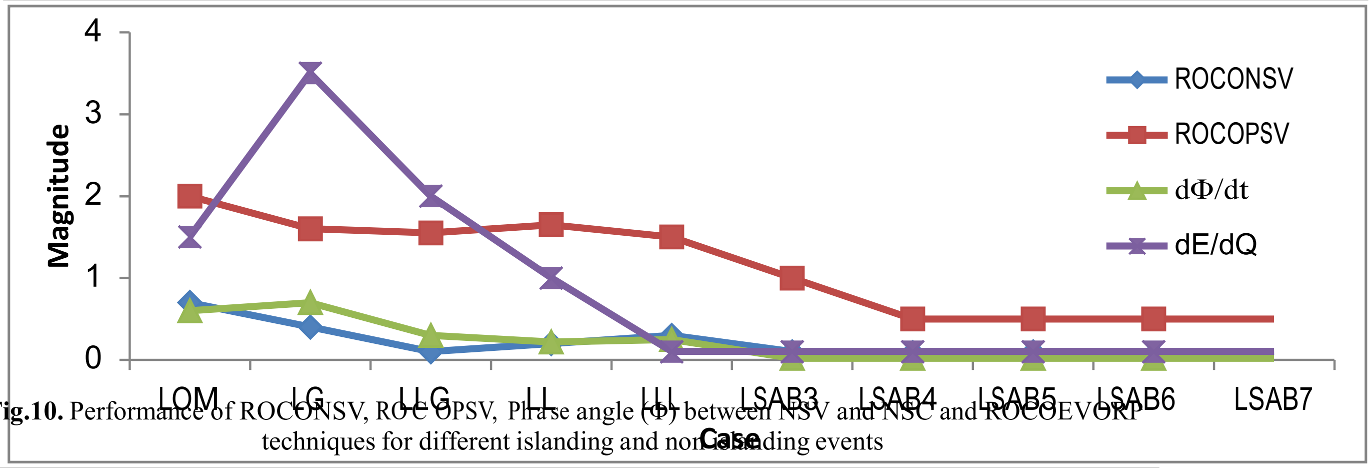

Fig.10. Performance of ROCONSV, ROCOPSV, Phrase angle (Φ) between NSV and NSC and ROCOEVORP techniques for different islanding and non islanding events

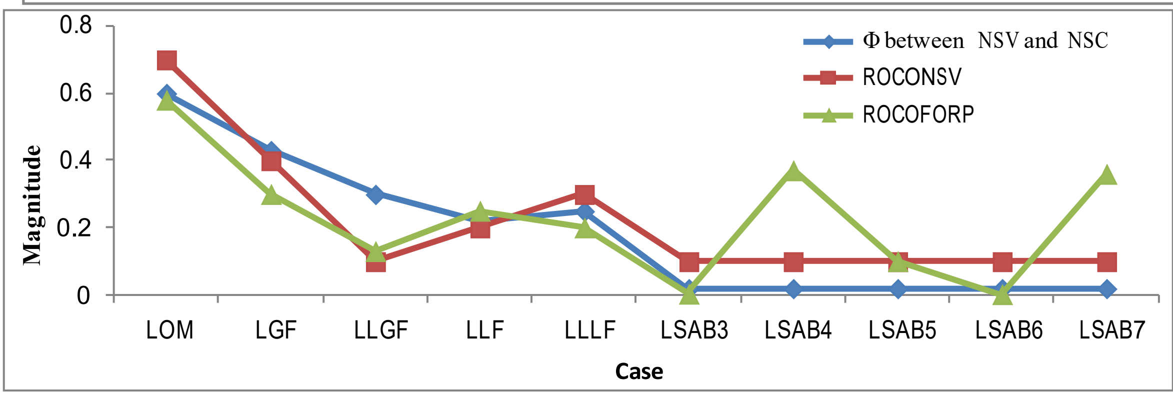

Fig.11. All cases with df/dQ, Phase angle between NSV and NSC, ROCONSV methods

It can be seen from above graphs the magnitudes are different for each parameter for each case. The magnitude of each one is compared with other all parameters magnitudes for getting the most sensitive result. The various islanding and non islanding cases are simulated which shows the variation of the proposed methods in Fig. 5-10. For cases of faults variations in this study (Fig. 5-10), it is found that the magnitude parameters of df/dQ, dQ/dP and dV/dP have lower value compared to other parameters. Meanwhile, for load switching cases as in Fig. 5-10, parameters of df/dt, dQ/dV, and df/dP have the least magnitude value. From the observation and consideration (df/dQ), (dV_1/dt) and (dV_2/dt) are the better ones compared to the other parameters. The results shown in Fig.11 indicate the same. But in these methods we have to select the threshold values carefully. The comparison with some of the existing methods, with proposed methods is shown below.

Table III: Comparison of different existing passive methods

Passive ID method	Detection time	NDZ
Voltage and current harmonic detection [27]	200 to 500 ms	Large with a large value of Q
OUV/ OUF [28]	200 ms to 2s	Large ROCOF
[22]	300 ms	Small
ROCOFOAP [30]	250 ms	Smaller than ROCOF
ROCOP [31]	400 ms	Smaller than OUV/OUF
Phase Jump Detection (PJD)	100-200 ms	Large
Voltage Unbalance (VU) [32]	53 ms	Large
Switching frequency [59]	50 ms	None
Grid voltage sensor less [35]	45 ms	None
Fuzzy and S Transform [61]	20 ms	Very small
Discrete wavelet transform [62]	20 ms	Very small
Wavelet packet transform [63]	Very small	None
Discrete wavelet transform [64]	10 ms	None
Wavelet coefficients of transient signals [66]	30 ms	None
Wavelet [65]	50 ms	Very small
Wavelet transform &S-transform method [67]	Very small	None
Combination of voltage amplitude and frequency [68]	170 ms	Very small
Combination of voltage unbalance and THD [16]	2 sec	Large
Fast Gauss Newton algorithm [69]	40 ms	Small
Voltage and frequency [79]	150 ms	Very small
ROCOFORP [70-71]	Not mentioned, better than 16 existing passive parameters	Zero
ROCOPAD [72]	< ROCOF	Small
ROCONSVAC [73]	80 ms	Zero
ROCOPSVAC [74]	10 ms	Zero
PNSVNSC [75]	Within quarter cycle (4.16 ms)	Zero
ROCOEVORP [76]	Not mentioned	Zero
Transient component based [77]	< One cycle (20 ms)	Very small
Forced Helmholtz oscillator [78]	Maximum 440 ms	Very small

5. Conclusion

In this paper the behavior of twenty passive parameters is evaluated for synchronous double DG system. Different islanding and non islanding events are simulated for different capacity loads. The islanding situations like balanced islanding, 50% of active power mismatch, 30% active power mismatch are simulated. The non islanding events like LG, LL, LLG faults and switching of loads at various buses are presented with results. The ROCOFORP, combination of ROCOPSV and current, ROCONSV and current PID parameters are selected as the most effective passive parameters for islanding and non islanding evaluation. So these three methods are selected as the most efficient passive methods for future islanding detection. These methods are clearly differentiating between islanding and non islanding events and they have the capacity to detect islanding in the worst case of islanding which is small power imbalance conditions and also their NDZ is almost zero.

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