Islanding Detection of a Distributed Generation System using angle between Negative Sequence voltage and current

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Abstract: This paper proposes a new passive local islanding detection technique for a distributed generation (DG) system connected to a utility grid. In the proposed method the absolute value of angle between the negative sequence components of voltage and current is estimated at the DG end and is used to recognize the islanding condition. The conventional passive methods have the drawback of non-detection zone (NDZ). The active islanding detection methods introduce disturbance in power system. A micro grid system is simulated using PSCAD/EMTDC software. Several test cases are generated to test the performance of the proposed technique.

Keywords: Active power mismatch, distributed generation (DG), micro-grid, rate of change of frequency (ROCOF).

I. INTRODUCTION

Distributed power generation systems are becoming more common as a result of the increased demand for electricity and the requirement to reduce the impact on the environment from traditional sources of power production in which fossil fuels or nuclear fuel are commonly used. With distributed generation integration with the main utility, the main issue is the islanding situation [1]. Islanding operation occurs when DG continues to supply power to the network even if power is interrupted from the main grid [2]. Islanding is a situation in which a distribution system becomes electrically isolated from the remainder of the power system, due to a fault at upstream side or any other disturbance, and yet continues to be energized by the DG connected to it.

Several researchers have proposed many methods for islanding detection. There are four types of islanding detection techniques: 1) passive, 2) active and 3) communication based and 4) hybrid techniques. Monitoring of the different system parameters like voltage, frequency, impedance, THD at any desired location comes under the passive techniques in which these parameters are compared with the pre-specified threshold to decide about the islanding. Passive methods are preferred, since they use the information that is available on the DG without influencing the normal operation of the DG. The major demerit of passive techniques is dependency on threshold values.

For higher threshold value, islanding situations may not detected properly and for lower threshold value other non-islanding conditions may be treated as islanding condition. Various passive methods that have been presented so far are over/under voltage [4]-[5], the rate of change of frequency (ROCOF) [6], the rate of change of power (ROCOF) [7]-[8], total harmonic distortion of current [9]-[10], the rate of change of voltage (ROCOV) [11] and the phase shift method [12]. In case of active method, a small disturbance is intentionally introduced into the system and upon the feedback it can be determined whether islanding occurs or not. But a large change in the system parameters will occur in case of islanding as the main utility is absent. Active islanding methods have very small NDZ. But the quality of the power is distorted due to the injection of external disturbance. Some of the islanding methods are slip-mode frequency shift, active Frequency Drift, current injection and voltage shift method [13]-[16] in case of communication based technique, communication based islanding detection methods depend on the communication links between the DGs. This method has negligible NDZs along with the highest possible accuracy but the drawback is that it is most expensive as it requires the high speed operation.

In this paper, a passive islanding detection method is presented using the absolute value of the angle between the negative sequence voltage and current at the DG end. The voltage and current data are sampled at a sampling frequency of 1 kHz. Least square based technique is used to calculate the voltage and current phasor. The negative sequence components of voltage and current are calculated. Islanding condition is identified by estimating the absolute value of the angle between negative sequence voltage and current. The proposed method work well during zero power mismatch. Performance of the technique is tested for islanding and different non-islanding conditions like capacitor switching, load switching, etc. at the DG terminals.

II. THE SYSTEM STUDIED

A radial distribution system (25 kV, 50 Hz) as shown in Fig. 1 is considered. In this system, 10 MVA is taken as the base power. The distribution system has 4 DG units which are connected to the grid through point of common coupling (PCC). 25 kV is the operating voltage at the DG units having a distance of 20 km with transmission lines of pi sections. The description of the components of the system which are taken from the reference [20] is shown in the appendix.

III. PROPOSED TECHNIQUE

The non-islanding and islanding voltage and current data are collected at a sampling rate of 1 kHz. Phasor estimation for the voltage and current is done by the least square method. The negative sequence voltage and current after the islanding are...
calculated from this information which are denoted as $r_{2island}$ and $r_{2island}$ respectively.

Finally the absolute value of angle ($\phi$) between negative sequence voltage and current after islanding is given as:

$$\phi = \left| r_{2island} - r_{2island} \right|$$  \hspace{1cm} (1)

Based on the value of this angle $\phi$, islanding is decided. The value of $\phi$ will be positive for the islanding and zero for non-islanding conditions. Fig. 2 gives the complete algorithm for the proposed technique.

The rate of change of frequency is affected with active power mismatch. The active power mismatch is varied from 0% to 80% and the performance of ROCOF is verified. For higher active power mismatches higher will be the magnitude of ROCOF and with a proper threshold it is easy to distinguish the islanding condition as the cases are shown in Figs. 3 and 4. The magnitude of ROCOF decreases for lower active power mismatch and falls below the threshold which becomes difficult to differentiate the two conditions. The performance plot for 5% to 80% active power imbalance is shown in Fig. 5. The islanding for 0% active power mismatch is not detected because the value of the ROCOF will be less even the value may be zero.

**B. Performance Evaluation of Proposed Technique**

In the proposed technique, the negative sequence component of voltage and current are calculated. For islanding condition the value of the angle between the two will be positive and will be zero for non-islanding conditions as the magnitudes of negative sequence components of voltage and current are more than for non-islanding condition (DG-2 tripping) which shown in Fig. 6. The islanding detection is obtained within 5 ms and dynamics of trip signal is consistent. Next islanding condition is simulated by tripping CB1 with 20% active power mismatch. The non-islanding condition is simulated with load switching at the PCC with a 20% active power mismatch.
Performance of islanding relay located at DG-2 end is assessed with help of the proposed method. Corresponding performance plot for islanding and non-islanding conditions is shown in Fig. 7. It is quite clear from the figure that the absolute value of the angle during islanding is positive and zero for non-islanding condition. Hence the proposed technique identifies the islanding condition. Next the non-islanding condition is simulated by taking out the section-2 completely with 0% active power mismatch. The performance plot is shown in Fig. 8. Same conclusion can be made in this case also. Power mismatch as low as 0%.

Other important non-islanding conditions like load changes and capacitor bank switching are also checked and the performance plots are shown in Figs. 9 and 10 respectively. The proposed method clearly distinguishes the islanding condition for both the cases as the angle has some positive definite value throughout during islanding and zero during non-islanding condition.

The performance of the proposed islanding relay is evaluated during active power mismatch which is a vital concern to distributed generation system. Fig. 11 shows the performance of proposed technique for islanding detection at DG-4 end for active power mismatch of 0 and 80%. It is done by opening CB1 at t = 0.08 s. It is found that the variation of the angle (Φ) is marginal as the active power changes from 0% to 80%. This is quite evident from the same figure as the trip signals for the two cases are almost the same. The performance curve of the islanding detector (Φ) is positive and there is almost no change in magnitude for both the cases. It is found that the magnitude of Φ (angle between $V_{2f}$ and $I_{2f}$) is independent of variation in active power mismatch.
One more important factor which determines the superiority of the technique is the response time, the time taken by the any method to respond from the occurrence of the event. Fig. 12 shows the response time for the proposed technique along with widely used technique ROCOF for the purpose of comparison. Response time for the ROCOF is higher than the proposed technique and also varies as the active power mismatch changes. However, as is evident from the figure, the response time for the proposed technique is quite low (around 5 ms) and is almost independent of the active power mismatch.

![Time (ms) vs % active power mismatch](image)

Fig. 12 Active power mismatch vs operating time

V. CONCLUSION

In this work a passive islanding detection technique is proposed. The performance of the conventional technique (ROCOF) is also tested for different active power mismatch conditions. It is found that the conventional technique is dependent on active power mismatch. The proposed technique works well under wide range of active power imbalance where the ROCOF fails. The response time of proposed technique is around quarter cycle from the event inception, showing fastness of proposed algorithm compared to ROCOF relays. Another observation is the ability of the proposed technique to perform with active power imbalance of 0%, thus reducing the Non Detection Zone (NDZ) as compared to the existing ROCOF relays.

APPENDIX

The description of the components of the system as shown in Fig. 1 is given below.

**Generator:** rated short-circuit MVA = 1000, f=50 Hz, rated kV = 120, V base = 120 kV.

**Distribution Generators (DGs):**
DG-1, DG-2, DG-3: Wind farm (9 MW) consisting of six 1.5-MW wind turbines. The doubly-fed induction generator (DFIG) has been considered for the proposed study.

**Transformer TR-1:** rated MVA = 50, f = 50 Hz, rated kV = 120/25 kV, V base = 25 kV, R = 0.00375 pu, X = .1 pu, R m = 500 pu, X m = 500 pu.

**Transformer TR-2, TR-3, TR-4 and TR-5:** rated MVA = 10, f = 50 Hz, rated kV = 575 V/25 kV (except TR-5: 400V/25 kV), V base = 25 kV, R = 0.00375 pu, X = .1 pu, R m = 500 pu, X m = 500 pu.

500 pu.

**Distribution lines (DL):** DL-1, DL-2, DL-3, and DL-4: PI-Section, 20 km each, rated kV = 25, rated MVA = 25, V base = 25 kV, R 0 = 0.1153 Ω/km, R 1 = 0.413 Ω/km, L 0 = 1.05e-3 H/km, L 1 = 3.32e-3 H/km, C 0 = 11.33e-9 F/km, C 1 = 5.01e-09 F/km.

**Normal loading data:**
L1 = 15 MW, 5 Mvar.
L2, L3, L4, L5 = 8 MW, 3 Mvar.

All these results are summarized in tabular form in Table I.

<table>
<thead>
<tr>
<th>Event</th>
<th>Island current phasor Mag (A)</th>
<th>Island current phasor Angle (rad)</th>
<th>Island voltage phasor Mag (V)</th>
<th>Island voltage phasor Angle (rad)</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Islanding</td>
<td>0%</td>
<td>16.4</td>
<td>-3.0</td>
<td>192</td>
<td>-1.06</td>
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<tr>
<td></td>
<td>30%</td>
<td>15.2</td>
<td>-2.82</td>
<td>409</td>
<td>-1.65</td>
</tr>
<tr>
<td></td>
<td>60%</td>
<td>19.1</td>
<td>2.819</td>
<td>409</td>
<td>-1.25</td>
</tr>
<tr>
<td></td>
<td>80%</td>
<td>46.9</td>
<td>-2.34</td>
<td>420</td>
<td>-1.62</td>
</tr>
<tr>
<td>Non-islanding</td>
<td>DL-2 cut off</td>
<td>0.3</td>
<td>-2.397</td>
<td>5.6</td>
<td>0.662</td>
</tr>
<tr>
<td></td>
<td>Load switching</td>
<td>0.3</td>
<td>1.21</td>
<td>12</td>
<td>0.976</td>
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<tr>
<td></td>
<td>DG-2 Tripping</td>
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<td>2.028</td>
<td>9.8</td>
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<td></td>
<td>Cap. switching</td>
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<td>1.89</td>
<td>21.3</td>
<td>-0.016</td>
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</table>

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