A NEW METHOD FOR ISLANDING DETECTION IN DISTRIBUTED GENERATION

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ABSTRACT

This paper presents a new reliable algorithm of loss of mains detection for distributed generation. One of the technical issues created by DG interconnection is inadvertent islanding. Islanding occurs when a portion of the distributed system becomes electrically isolated from the remainder of the power system, yet continues to be energized by DG connected to the isolated subsystem. It can be desirable to permit such islanded operation to increase customer reliability, and this is often done where the DG provides backup power to the facility where it is installed. The proposed algorithm utilizes multi-criteria approach with fuzzy logic decision- making.

I. INTRODUCTION

The increased expanding of distributed (dispersed) generation (DG) in utility systems has been mainly caused by the liberalization of the electricity markets, recent advances in energy conversion systems and the environmental drive to promote green energy. These recent advances in energy conversion include the emergence of cheaper and more efficient power generation systems using renewable and hybrid power schemes. The attractions of 'green energy' have been and will continue to be a powerful force in the expansion of distributed generation.

The increasing presence of dispersed generators in utility networks creates problems with regards to the operation and control of the distribution system. If DG is feeding the power to the networks without the utility supply, then it produces several negative impacts on utility power system and the DG itself, such as the safety hazards to utility personnel and the public, the quality problems of electric service to the utility customers, and serious damages to the DG if utility power is wrongly restored [2], [3]. Therefore, during the interruptions of utility power, the connected DG must detect the loss of utility power and disconnect itself from the power grid as soon as possible.

Islanding operations of DG usually occur when power supply from the main utility is interrupted due to several reasons but the DG keeps supplying power into the distribution networks. These kinds of islanding conditions cause negative impacts on protection, operation, and management of distribution systems; therefore, it is necessary to effectively detect the islanding conditions and swiftly disconnect DG from distribution network. Moreover, the islanded operation should be avoided because of safety reasons for maintenance man and power quality reasons of distributed lines.

Generally, if there are large changes in loading for DG after loss of the main power supply, then islanding conditions are easily detected by monitoring several parameters: voltage magnitude, phase displacement, and frequency change. However, in case of small changes in loading for DG, the conventional methods have some difficulty in detecting such a particular islanding condition.

The islanding protection for DG becomes an important and emerging issue in power system protection since the distributed resources installations are rapidly increasing and most of the installed systems are interconnected with distribution network. In order to avoid the negative impacts from islanding operations of DG to protection, operation, and management of distribution system, it is necessary to effectively detect the islanding operations of DG and disconnect it from distribution network rapidly.

This paper gives an overview of islanding detection algorithms for DG effectively working in the most of loading conditions. A new method which utilizing the multi-criteria approach is also presented.

II. ISLANDING OPERATION

Opening the utility grid breaker causes a potential power island fed from the embedded generator and isolated from the grid supply (Figure 1). If loss of grid remains undetected, the embedded generator may quickly loose synchronism with the utility grid supply. This introduces the possibility of reconnection of the two systems while their generators are out of phase. The consequences of out-of-phase re-closing are severe stresses on the embedded generator and disruption of the utility supply. There are also safety and health issues. It is possible that the remaining load from the utility system in the island would be greater than the capacity of the embedded generator. This would cause the embedded generator to be dragged down, along with the industrial process, leading to a complete outage. When embedded induction or synchronous generators are used in the system, a further consequence of loss of grid can be self-excitation. Loss of grid, or 'islanding' protection involves the automatic detection of a situation when the connection to the grid supply is lost. This allows of a dispersed generator to supply the local, isolated grid.

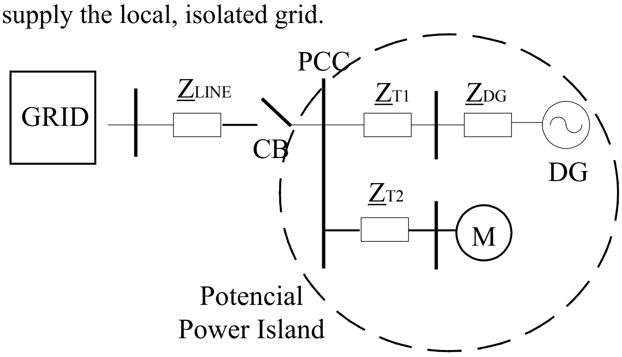

Figure 1. Typical loss of grid scenario

III. ANTI ISLANDING DETECTION METHODS

In a conventional situation after the connection between a local network and utility network is lost, the DG has to take charge of the remaining network and the connected loads; therefore, the loading condition of the DG is suddenly changed after islanding. For detection such a condition traditionally an under/over-voltage and under/over-frequency criteria are used. These (under/over-voltage and under/over-frequency) relays may, however, fail to detect loss of mains in situations where the islanded load is reasonably well matched to generator power output. The generator's AVR and speed governor controller may be able to compensate for the smaller load change, causing minimal change in the generators voltage and frequency. Therefore, changes of these parameters are to small in order to detect a loss of grid correctly.

IV. PROPOSED DETECTION ALGORITHM

To detect islanding effectively, it is necessary to have good understanding of all possible islanding conditions. Nowadays, many classical methods and novel algorithms for the islanding protection have been proposed [2]. These techniques can be divided into two categories: passive and active methods such as classical passive systems include under/over frequency and under/over voltage relays and the most widely recognized methods like the Rate of Change of Frequency (ROCOF), Voltage Vector Shift (VVS) [2-4].

The considered methods have been evaluated by using of EMTP-ATP simulations. The 5MW synchronous DG generator and local load is connected to 110 kV utility supply network. Various loss-of-grid scenarios have been simulated by adjusting the size of the site load, and the amount of power flowing from the generator into the site load.

Load changes in the modelled DG system are simulated with the use of additional load in series with the site load. Standard IEEE governor models are used together with controller fitted to the AVR.

It is intended that the generator control systems are as similar to those used in the field as possible. Equivalent scheme of the considered system is outlined in Figure 2. Measurements voltage and current are taken from the Point of Common Coupling (PCC). To facilitate comparison, a conventional rate of change of frequency signal was also implemented in the software model using volt-age samples taken from the generators terminals [8].

Fuzzy logic based relay (FLR)

Generally, it is difficult to detect islanding operation by monitoring only single system parameter. The proposed fuzzy system is based on processing of three measured parameters, namely: voltage, frequency derivative (ROCOF) and active power derivative (ROCOP) [9]. The choice between these control parameters is based on the desired actions by the protection system of the dispersed generator in response to power system conditions.

Criterion 1: change of voltage

The decision as to whether voltage following is permitted under current power system conditions can only be made if the voltage is normal, otherwise voltage control is always effected. To predict the voltage dynamics it is propose to define the Rate of Change of Voltage parameter [5].

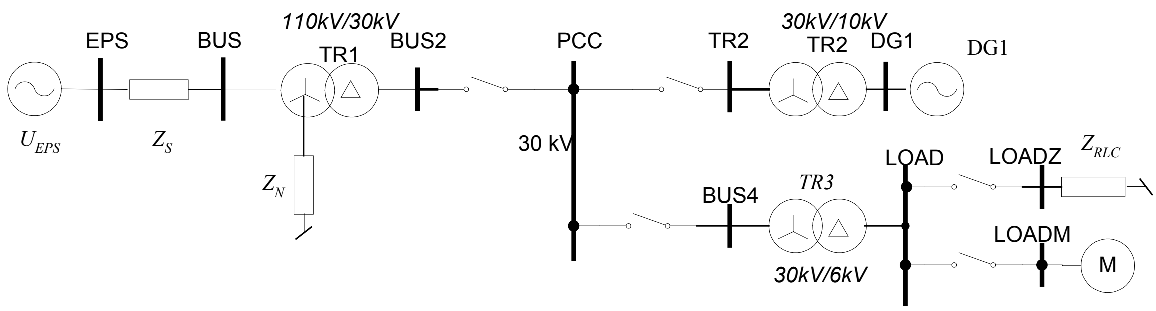

Figure 2. Equivalent scheme of the considered network

Criterion 2: ROCOF
Rate of Change of Frequency as control parameter is more stable than the voltage under grid connected conditions and therefore gives useful information about the nature of the connected network. In particular, this parameter is used to indicate the stiffness of the network system and to assess the relationship between the system frequency and the active power flow from the dispersed generator [5,7].

Criterion 3 - ROCOP
Rate of Change of Active Power is used to assess the impact that active power fluctuations have on the connected network's frequency and voltage. When the inertia of the connected system is high, such as when the dispersed generator is operating in parallel with the grid the impact is negligible. This is, however, not true under isolated operation. The rate of change of active power is used taking into account of the state of the system voltage and frequency. This algorithm remains stable during local load changes and during wide range of power system fault condition [6].

Measurement unit
The simplified block diagram of the considered FLR for power generator is presented in Figure 3. The sampled voltage and currents from PCC sides of the protected unit are measured as well as at the terminal.

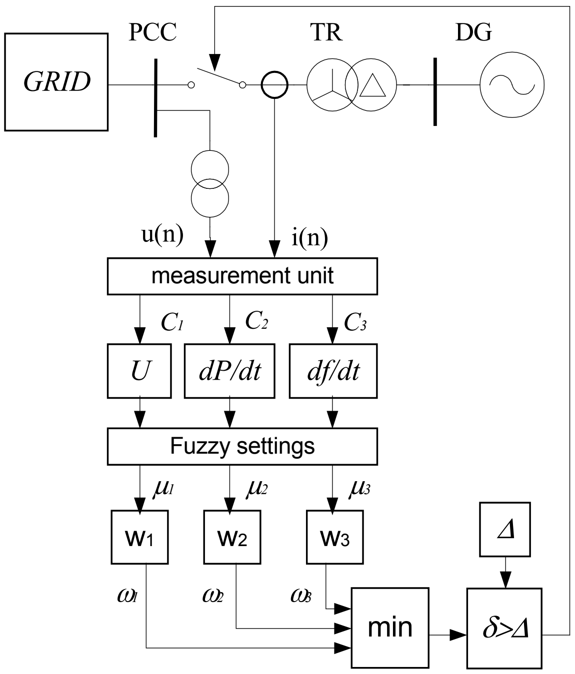

Figure 3. Block diagram of multi-criteria relay of anti-islanding protection

The measuring unit forms the signals and measurements is based on Finite Impulse Response (FIR) full-cycle orthogonal filters designed using the 1kHz sampling rate.

Fuzzy logic rules
Each of criteria (processed system parameters) can be used alone for loss of grid detection. However, no one separate criterion does not ensure that it would be able to properly detection and not nuisance operation during normal load variation. Authors put forward to fuzzy logic rule approach because of its flexibility for enhancement and update [11]. The fuzzy logic rules for islanding detection are applied only if the situation is not clear or uncertain. Voltage magnitude should consists between limits described below:

$$IF \quad U_{(n)} \geq 1.1 \cdot U_r or U_{(n)} \leq 0.9 \cdot U_r \quad THEN \quad A \qquad (1)$$

Similarly with frequency derivative, ROCOF:

$$IF \quad \left| \frac{df}{dt}(n) \right| \quad \geq ROCOF \quad THEN \quad B \qquad (2)$$

And the Rate of Change of active Power:

$$IF \quad \left| \frac{dP}{dt}(n) \right| \quad \geq ROCOP \quad THEN \quad C \qquad (3)$$

where: A,B,C are the decision criteria terms of each parameter.
The proposed multi-criteria approach is more stable and gives the correct decision for almost all possible situations.

Multi-criteria decision making
If the situation is clear, the signals μ1, μ2, μ3 called the member functions are reduced to Boolean logic variables and equal either 0 or 1. Under uncertain conditions, however, they may take values from the interval 0-1, and thus, partly support certain hypotheses. Moreover, there may be contradictions between the recognition given by the particular criteria. In addition, the criteria in terms of quality of provided recognition are in some cases more, and in another less reliable. In order to resolve this and balance the decisions made by the criteria with the criteria powers, the multi-criteria decision-making methods are recommended [10]. The algorithm should rule-out all the non-islanding conditions, the signals ω_1, ω_2, ω_3 are aggregated into the overall tripping support d, by means of a kind of continuous logic AND-operator:

$$\delta = \min(\omega_1, \omega_2, \omega_3) \qquad (4)$$

The tripping is initiated if d overreaches a constant time-varying or tripping threshold Δ:

$$TRIP = (\delta \geq \Delta) \qquad (5)$$

V. SIMULATION STUDIES

To demonstrate the performance of a loss of mains algorithm, a number of studies are required. The simulation studies were carried out using EMTP-ATP program [8]. Standard EMTP libraries were used. The test of investigated algorithm was conducted with several network condition. There was simulated specific kind of islanding conditions - with neglecting changes in the load of DG after islanding operation (Figures 4, 5). The islanding was initiating after changing of 2.5% of the nominal DG power (Figure 4).

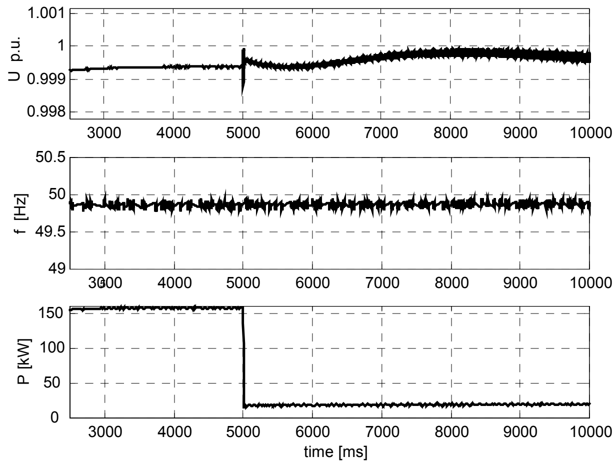

Figure 4. Loss of grid with small variation in DG loading

The algorithm was tested not only with islanding operation condition of DG but also with normal network load variation (Figure 6), induction motor starting (Figures 7, 8) which are sometimes confused with islanding condition to show that the algorithm works correctly.

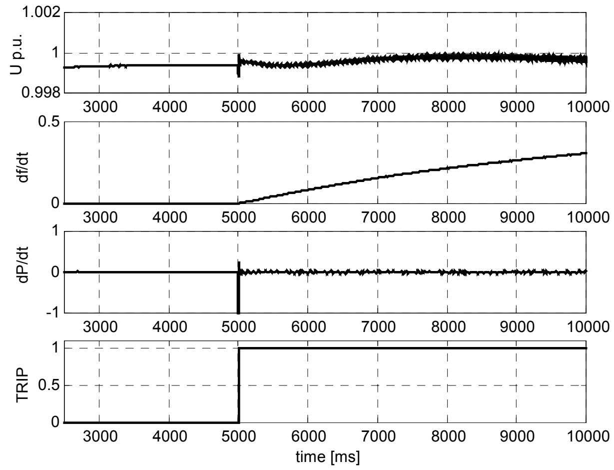

Figure 5 The response of algorithm during loss of grid with small variation in DG loading

A normal operation condition during load fluctuation, causing voltage and frequency dip, during parallel operation of DG with the grid.

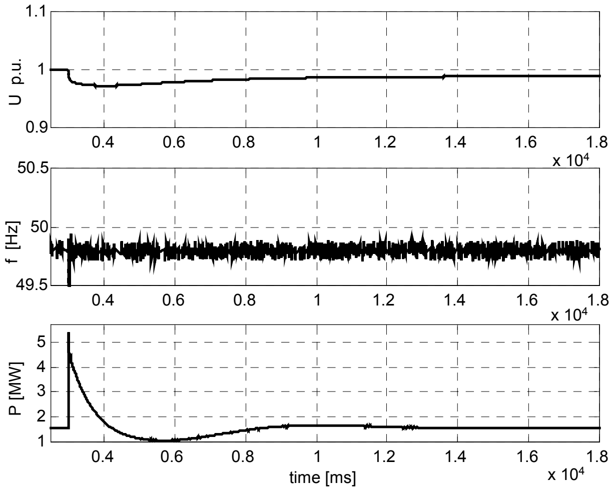

Figure 6. Effect of connecting the additional loads ZRLC

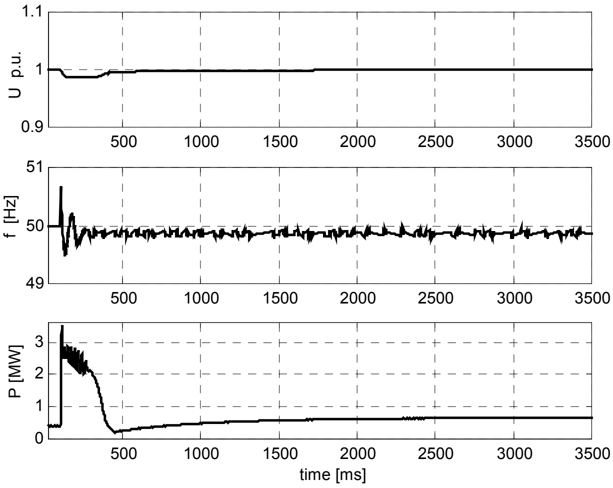

Figure 7. The result for increasing network load by starting the induction motor

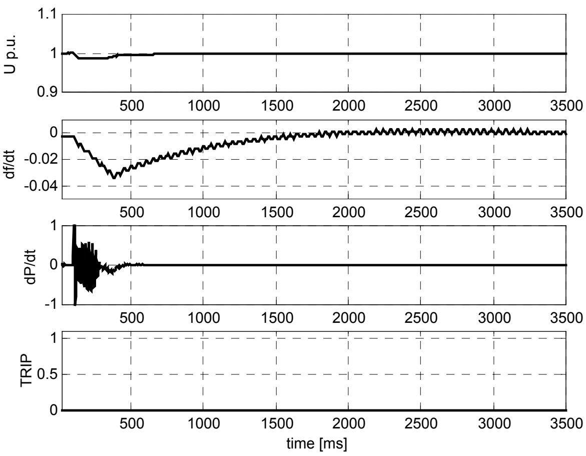

Figure 8. The response of algorithm during ZRLC load connection

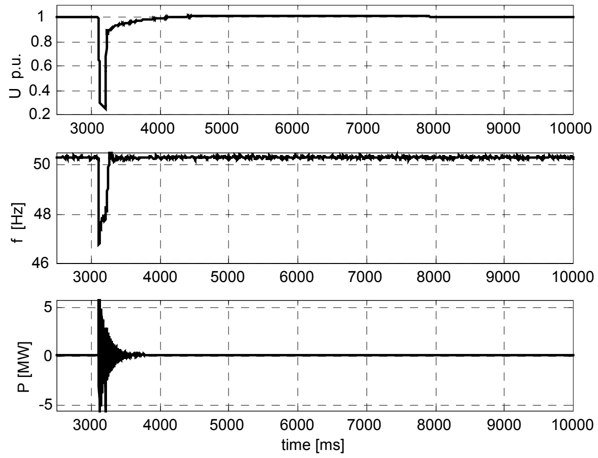

Figure 9. Parameter changes during remote 3 phase-to-ground fault

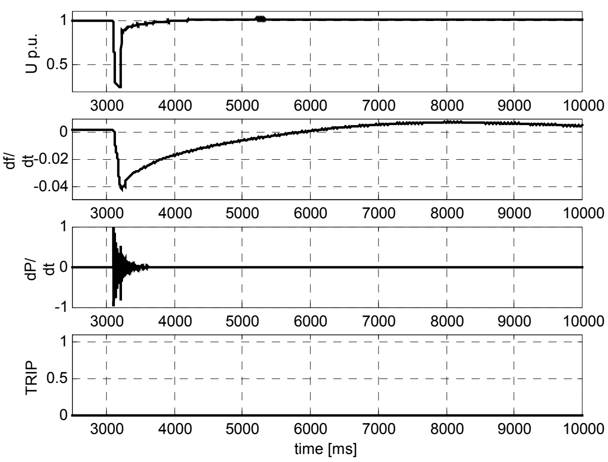

Figure 10. Parameter changes during remote 3 phase-to-ground fault

Operation during transient (remote 3 phase ground fault in GRID) fault conditions was simulated too
(Figures 9, 10).

VI. CONCLUSIONS

In the paper, the novel islanding detection method was presented. The algorithm monitors changes of the proposed three parameters and detects the islanding operations by fuzzy logic rules. The loss of grid decision is based on multi-criteria algorithm for distributed resources that are interconnected with distribution network. The proposed method using the radial distribution network with rotating type distributed generations, and different kind of loads was verified and evaluated. The test results show that the proposed criteria and algorithm is capable to detect correctly and with good selectivity the islanding and non-islanding conditions. Authors are conducting the further research on islanding detection. They intend to adopt the self adjusting of the fuzzy setting and the weight factors and tripping threshold in order to improve FLR operation.

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