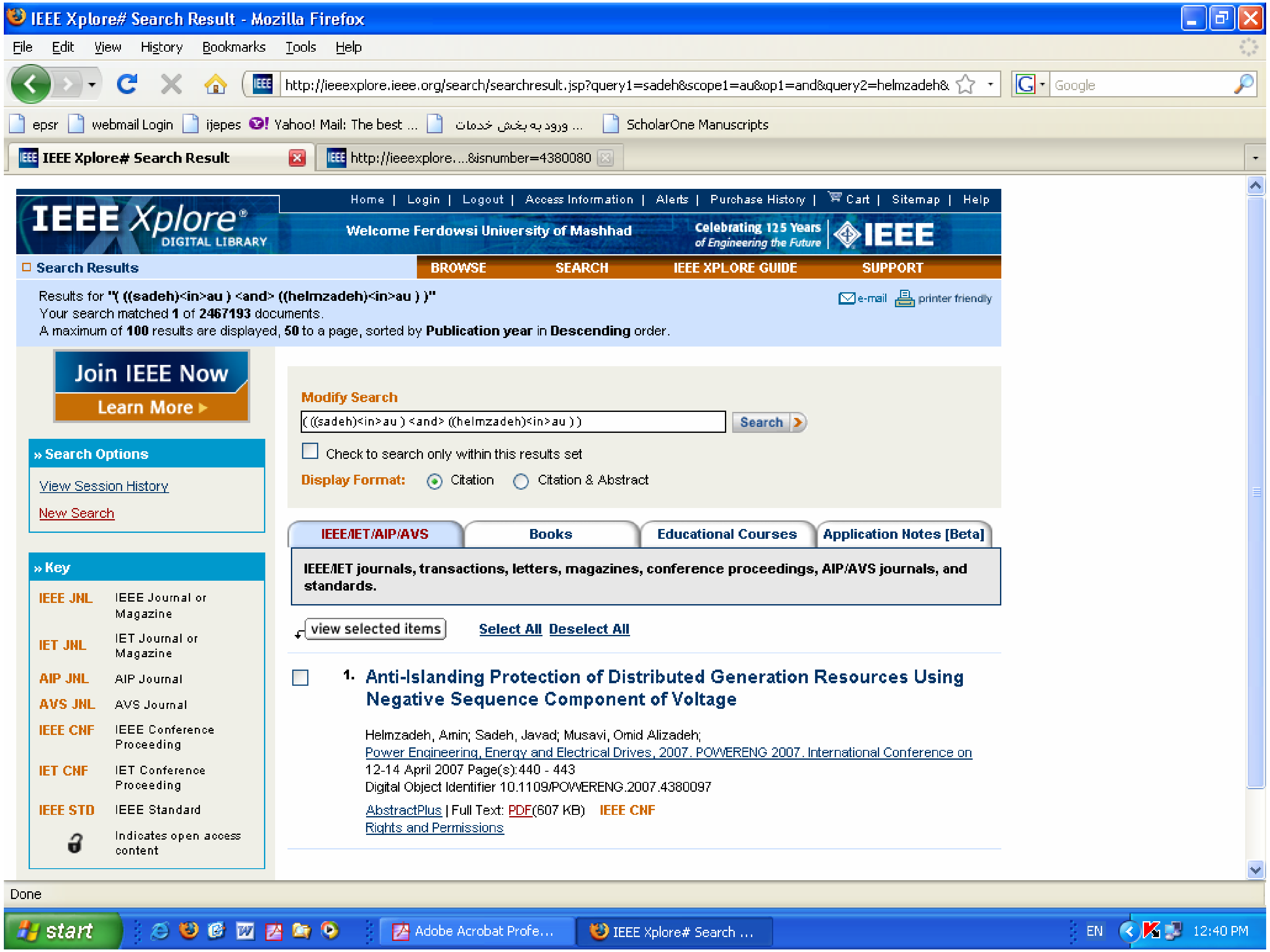

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1. **Anti-Islanding Protection of Distributed Generation Resources Using Negative Sequence Component of Voltage**

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Anti-Islanding Protection of Distributed Generation Resources Using Negative Sequence Component of Voltage

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***Abstract*-Distributed generation (DG) provides many potential benefits, such as peak shaving, improved power quality and reliability, increased efficiency, and improved environmental performance. Along with the development of distributed generation, especially renewable energy resources which have been increasingly considered because of environmental concerns and oil crisis, research projects dependent on these resources are being followed with more attention and sensitivity. Among these researches anti-islanding protection of distributed generation units whose duty is preventing of the operation of these resources during network disconnection is one of the most important projects related to distributed resources. In this paper a new method for anti-islanding protection of synchronous generator using negative sequence component of voltage and its damping pattern is presented. The proposed method is simulated and tested in various operation conditions. The test results showed that the method correctly detects the islanding operation and does not mal-operate in the other situations.**

Key-words: Distributed generation, Islanding operation, Anti-islanding protection, Negative sequence of voltage.

I. Introduction

By definition, any type of generation with relatively low power (a few kilo watts to 10 MW) which is close to the consumer or at its location can be considered as distributed generation [1]. With the introduction of restructuring to the electrical industry, small scale plant owners can compete with each other by using natural resources including wind, water and solar resources and creating advantages like speed of construction and operation, reducing transmission cost, helping local economy and increasing power quality. Therefore a common approach is participation of distributed generation resources in supplying power to the grid. Besides advantages that the use of DG in the distribution system offers, it also has its own problems. Complicating the process of grid protection is perhaps the greatest disadvantage of using DG resources in the distribution system. A common situation which might make the protection of distributed system difficult is the islanding operation of DG resources.

An island is a region that consists of one or more DG which feed the loads independent of the grid due to the function of the switches [2-3]. Available DG resources can form islands with the operation of fuses or reclosers. Because of different formation of switches in the distribution system, islanding is a complicated and unpredictable phenomenon. In other words, considering that the level of unbalance between generation and consumption of active and reactive power in an island can have different values, frequency and voltage variations of the island is ambiguous. Detection of islanding operation is of extreme importance because in addition to the possibility of sever damage to network instruments and consumers, network personnel and even ordinary people are exposed to severe injuries and even death. Nowadays the accepted method is to drop every DG units out of the network as soon as the feeder is cut to prevent possible damages to network instruments and personnel [4-5]. In this paper a new method for islanding detection of DG units is presented. In this method the negative sequence component of voltage and its damping pattern has been used.

The paper is organized as follows. Section II explores various alternative islanding detection methods. Section III describes the proposed algorithm for island detection of DG units including simulation results insisting on the reliability of the method.

II. Islanding Detection Methods: A Review

Various techniques have been advised to detect islanding operation of DG units. These methods are classified in two groups depending on their function. The first group is communication based procedures and the second are local procedures. The main advantage of communication based procedure is their independence on the DG unit type. In these methods signals are sent to detect the island. Depending on the signaling method communication based procedures are divided into two groups. One approach is to send trips via electro magnetic waves or phone lines to communicate with the DG unit and the other one is to use transmission lines for signaling. By considering the fact that a transmitter is needed for every switch and communication lines must cover every situated DG unit, the trip transmission method is very expensive. The use of transmission lines for signaling has many advantages. The reliability of this procedure is extremely high since it only uses one transmitter. This method has two drawbacks. First is the expense of the signal generator so if the number of DGs is not high, this method might not be economical. Second is the possibility of interference of the transmitter signal with other communication applications of the transmission line [6-7]. Local procedures for detection of islanding operation use available voltage and current signals in generator's place. These methods are classified into two groups of passive and active. In passive methods judgment is made only according to the value of voltage and current signals at the generator's location while in the active methods some disturbance signals are injected to the system and the situation of the island is detected according to the measured response of the system. Usage of local procedures is completely dependent on the type of DG.

One of the most important infrastructures in detection of island operation by local procedures is the existence of a region in which island detection in an acceptable time is not possible. The region is called non-detection zone. The extent of non-detection zone in frequency or voltage based methods is a function of unbalance between generation and consumption of active or reactive power. In other words for the relay to operate in a reasonable time the unbalance between generation and consumption of power in the island must be higher than a critical limit. For reducing the extent of the non detection zone or increasing the sensitivity of the method, the rate of variation in power parameters can be used as a comparison criterion of the anti-islanding procedure [8-9].

Basically relays that use rate of change in power parameters such as frequency, have a major problem called unwanted trip. In other words there are cases that these relays turn off the generator even without the formation of an island. This problem becomes critical when there are more than one DG units in the feeder. The probability that relays based on rate of change in power parameters causes unwanted turn down of other generators is very high.

So a suitable anti-islanding method, besides detecting island operation of DG units in an acceptable time, must have the least malfunction in case of other disturbances such as switching of capacitor banks or big loads.

In some local schemes proposed the THD of the current and voltage unbalance of the DG terminal output as new monitoring parameters for power islanding detection [10]. These proposed parameters are capable of correctly detecting the islanding operation not affected by variation of DG loading, like the frequency and voltage based schemes. These schemes have a good selectivity for islanding conditions and non islanding conditions.

In the following, a new algorithm for detection of islanding operation of DG units using negative sequence component of voltage and its damping pattern is introduced. Simulation results using MATLAB shows that these procedures in addition to detecting the island situation correctly, does not face the unwanted trip problem.

III. THE PROPOSED ALGORITHM

The cause of negative voltage creation in synchronous generators can be analyzed considering the voltage profile of phases during islanding. As can be seen in "Fig. 1" the phase voltage of the generator varies instantaneously. These changes occur in voltage waveform at a different time for every phase.

With respect to the unbalance between voltage phases, negative sequence component of voltage will have a non-zero value during islanding. In this method suitable anti-islanding procedure would be to compare the negative sequence component of voltage with a predefined value. However, if value of the negative sequence component of voltage is considered alone problems related to voltage relays including capacitor and parallel line switching would still exist. Our proposal for the correction of the mentioned algorithm is to use the damping pattern of the negative sequence component of the voltage when islanding happens. The value of the negative sequence component of the voltage damps steadily during islanding. Therefore using the value of the negative sequence component of the voltage and its damping pattern, a suitable criterion for detection of islanding operation may be achieved. This phenomenon can be seen in "Fig. 2".

This figure shows the simulation results for the network in "Fig. 3". In the simulation process one of the parallel lines enter the circuit at t=1 sec. Then the mentioned line is dropped out at t=3 sec and disconnecting of the other line at t=5 sec, the synchronous generator (DG_1) operates as an island.

As can be seen in "Fig. 2", in addition to the amplitude of negative sequence component of voltage at islanding instance (t=5 sec), its damping pattern differs greatly from the other disturbances. Simulation results related to other disturbances including capacitor switching or the entrance of another DG unit is analyzed in section III-B.

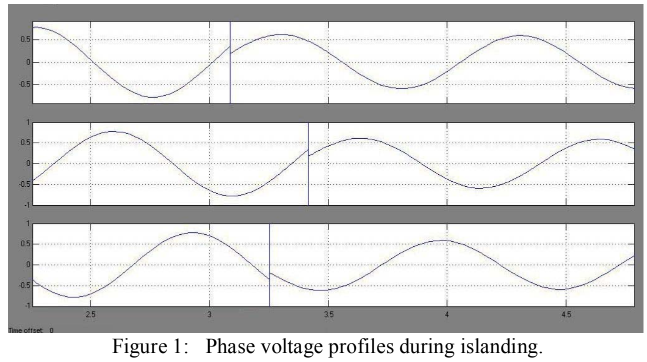

Figure 1: Phase voltage profiles during islanding.

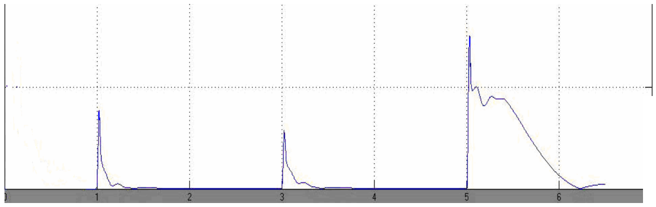

Figure 2: The negative sequence component of the voltage and its damping pattern.

A. *Proposed algorithm simulation in a sample system*

The presented network in figure 3 includes 132 kV and 50 Hz transmission system with 100 MVA short circuits which are modeled with a voltage source and impedance. The transmission system is connected to distribution system trough a, 132 kV/20 kV transformer connected to distribution system. DG_1 and DG_2 units are 5 MVA synchronous generators. DG units have voltage control system (AVR) and frequency control. The distribution network begins with a 1MVAR capacitor C for power factor correction. Values are: P_{D2}=2 MW, Q_{D2}=0.5 MVAR, P_{D3}=5 MW and Q_{D3}=2 MVAR.

For analyzing situations and other disturbance in network, the following states have been considered:

State 1: disconnect one of parallel line by switch CB_1.

State 2: connect one of the parallel lines by switch CB_1.

State 3: disconnect two parallel lines by switch CB_2. In this state DG unit disconnect from the network and DG_1 operates islanding.

State 4: isolation of DG unit (DG_1) from system by disconnecting switch CB_3 and thus, its islanding.

State 5: change in DG unit load. In this simulation maximum load variation is supposed to be 15% which is considered with an additional load of 15% load 1 to DG_1.

State 6: disconnecting a big load (load 3) near DG units.

State 7: connect capacitor C with switch SW_1.

Seven aforementioned states are simulated for the following 5 systems.

System 1: P_{D1}=2 MW, Q_{D1}=1 MVAR.

System 2: P_{D1}=1 MW, Q_{D1}=0.5 MVAR.

System 3: P_{D1}=6 MW, Q_{D1}=3 MVAR.

System 4: in this system the effect of the change in the distribution line length had been analyzed. Here increase line length from 4 km to 40 km.

System 5: in this system the effect of adding DG unit 2 to system is analyzed. For this purpose using switch SW_2, DG unit 2 is connected to the distribution system trough a 5 km line. System variations are so that after each simulation its parameters are changed to its default system (system 1). Totally 35 different situation have been analyzed that each case is numbered with two digits, the first digit shows state number and the second digit shows system number, for example (1,2) shows first state(disconnect one of parallel lines) and system 2 (P_{D1}=1 MW , Q_{D1}=0.5 MVAR).

Proposed algorithm for anti-islanding protection use negative sequence of the voltage and its damping pattern after reaching the maximum value. In order to consider the damping effect, of the negative sequence's component's maximum value, the voltage is multiplied by this value 0.1 second after maximization. Now these values are used as a comparison criterion.

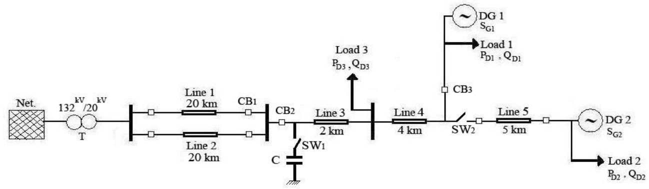

Figure 3: Single line diagram of studied network

B. *Simulation results*

These simulation results (35 modes) have been shown in "Fig. 4". Each column of this figure indicates one of the situations noted in section 3-A, respectively. Thus the third and fourth columns show two islanding situations of the synchronous generator. As it is seen, the minimum value in these two columns is considerably greater than other columns. For comparison between the minimum value of islanding and maximum value of other disturbance, apart of "Fig. 4" has been magnified in "Fig .5". Results in figure 5 show reliability of the proposed procedure. Relay setting that its function based on this algorithm can be choice between two dashed lines as shown in "Fig .5".

Asymmetric faults and loads are the only problem that this algorithm faced. In these cases because of unbalance in the phase's voltage, the negative sequence component of voltage has non-zero value. So to overcome this problem it's necessary to modify the mentioned algorithm.

As shown in "Fig. 6" the value of the negative sequence during faults and asymmetric loads not only has no damping but also its value increases after a transient period.

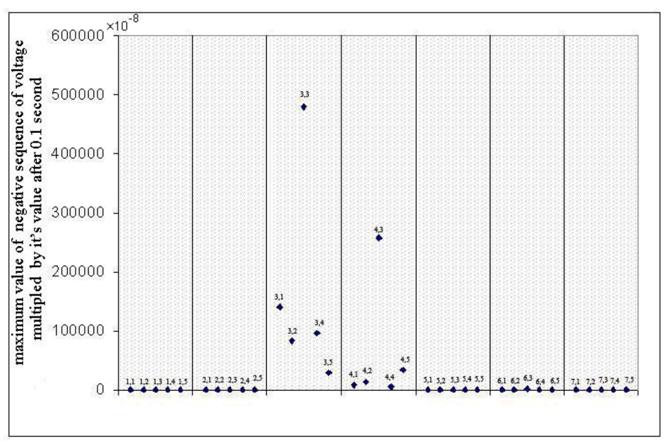

Figure 4: The maximum value of the negative sequence of the voltage multiplied by its value after 0.1 second

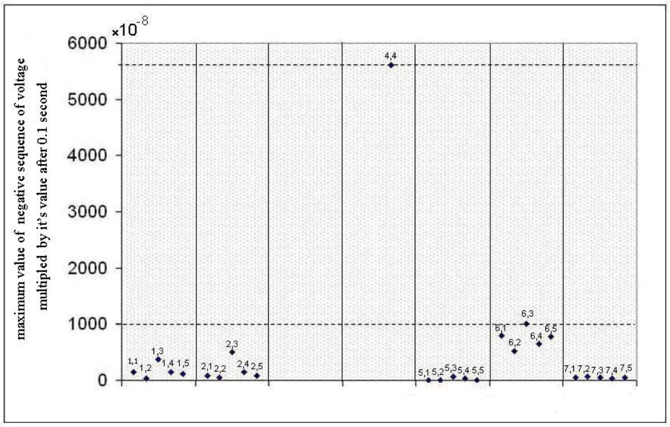

Figure 5: The maximum value of negative sequence of voltage multiplied by its value after 0.1 second

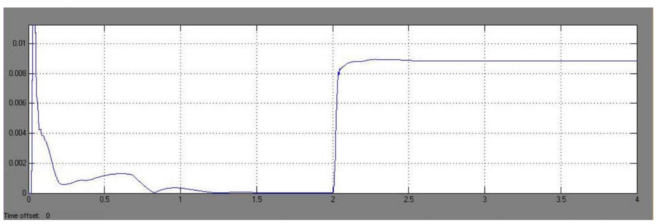

Figure 6: Negative sequence of voltage profile during asymmetric faults

In order to distinguish the islanding operation of a synchronous generator and asymmetric faults, the proposed algorithm in "Fig. 7" will be efficient.

Simulation results prove that using this method has the least unwanted trip and maximum reliability in detection of islanding operation of distributed generation.

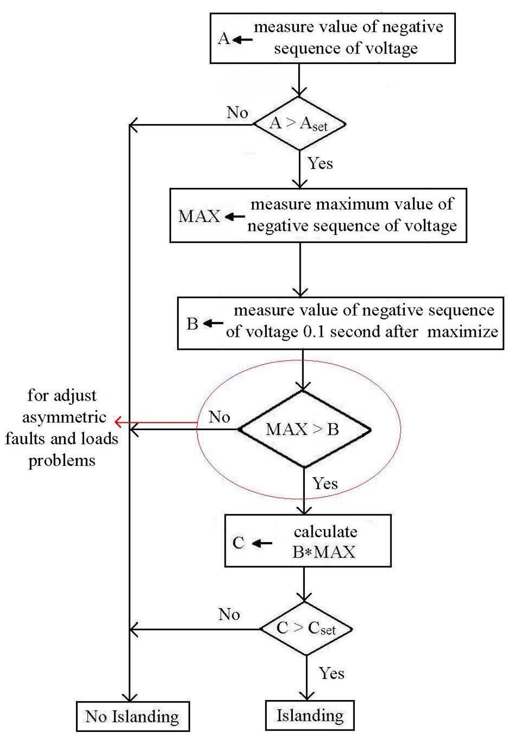

Figure 7. Proposed algorithm for negative sequence of voltage relay

IV. Conclusion

In this paper a new method for anti-islanding protection of DG units is presented. In this method the negative sequence component of voltages and its damping pattern has been used. In order to consider the damping effect, the maximum value of the negative sequence component of the voltage is multiplied by its value after a specific duration of time; simulation results insisted on the reliability of the approach.

In other words using relays specified in this algorithm not only reduces the extent of the non detection zone but also shows no malfunction in the presence of other system disturbances. A method for distinguishing islanding operation of DG unit from asymmetric faults was also explored.

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