Development of a Passive Islanding Detection Method based Fuzzy Controller for a Grid Connected Distributed Generator.

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***Abstract*— Over recent years the demand for power has increased and hence there has been a growing interest in Renewable Energy Generating units such as wind, water, photovoltaic, fuel cell units. Connection of DG to the power system network effectively reduces the losses and decrease of transmission network capacity with the consumers being provided with higher reliability. Islanding happens when a part of the distribution system turns out to be electrically disconnected from the rest of the power system, yet keeps on being energized by DG associated with the subsystem. It is important when using DG in an interconnected system that the power distributed system is capable of detecting an unintentional islanding condition.**

The IEEE 1547 Standard for Interconnecting Distributed Resources with Electric Power Systems directs that for avoiding islands in power systems the protection equipments and measures must be in order. Even if islanding occurs the duration of the situation must be decreased as much as possible. In order to achieve this, various methodologies have been proposed. Intelligent detection methods such as Fuzzy Logic and Wavelet Transformation have been effectively used to create such detection algorithms.

Keywords- Islanding detection, Fuzzy ,ROCOP, ROCOF .

I. INTRODUCTION

With the introduction of DG's there has been a significant improvement in electricity service at a higher level of reliability and power quality in comparison to the typical power so availed from the grid. It is more resilient since it serves low power demands continuously. While the central power system remain crucial to the load utility, their flexibility is limited. Large power generation facilities require immense transmission and distribution network to transmit power. DG provides a relative low capital cost in response to incremental changes in power while avoiding transmission and distribution losses by placing the power source within the already existing network and sending power back to grid when needed.

The recent interest for installation of DG into the consumer end has put forward unique engineering challenges to DG interconnection. Thus the traditional protection systems need to be reconfigured and redesigned for islanding in DG systems. The island formed is an unregulated power system and is considered as undesirable as it poses a danger to the utility equipments and deterioration in the power quality. Islanding operation can be permitted owing to the consumer power reliability by means of providing power to the facility where DG is located. But however such arrangements require considerable engineering efforts to enable such island operation which includes a portion of primary systems.

II. PASSIVE ISLANDING DETECTION TECHNIQUES

It is based on the monitoring of system parameters such as voltages, current and frequency and do not introduce perturbations unlike active islanding detection methods. During islanding these parameters vary and a certain threshold is set for normal operation conditions. Exceeding this threshold the relay trips and islanding is detected. The precision of setting the threshold is maintained so that differentiation from other disturbances and islanding is made. The detection methods are fast and do not introduce disturbances in the system but however have a large NDZ.

A. Classification of Passive Islanding detection techniques.

The passive islanding detection techniques are classified as-

a) Rate of change of output power (ROCOP)

The rate of change of output power, at the DG side, is greater than the rate of change of output power before the DG is islanded. This method is effective for load and generation mismatch. [8]

b) Rate of change of frequency (ROCOF)

During islanding the rate of change of frequency is very high. The rate of change of frequency is given by[5]-

$$\frac{df}{dt} = \frac{\Delta P}{2HG} * f$$

where

ΔP= power mismatch at DG side.
H = moment of inertia.
G= rated generation capacity.

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The ROCOF relay performs operation by continuous monitoring of the frequency signal. However the relay fails to operate during equal load condition.

c) Rate of change of frequency over power

The in a small generation system is larger than that of the power system with larger capacity. This concept is utilized for islanding detection. [8]

d) Voltage unbalance

Voltage unbalance is one of the methods of islanding as disturbances in voltage waveforms are observed. However this method is not completely reliable owing to the fact that distribution loads are single phase and disturbances are very small.

e) Harmonic distortion

If the power system has inverter based DG, harmonics are introduced in the system parameters. Monitoring the THD of the voltage waveform after and before islanding can be done to identify the changes. When DG is islanded, monitoring of third harmonic of voltages of DG provides an insight for islanding detection.

III. SYSTEM FOR THE CONTROLLER APPLICATION.

The system used for islanding detection comprises of a 9MW wind farm.The wind farm consists of a total of six wind turbines each 1.5MW connected to a 120kV grid through a 30km, 25kV feeder. A 6MW load is connected to the 575V generation bus of the DG. The circuit breaker 1 is responsible for Major Island formation. Islanding is initiated at 0.5 seconds by opening CB1 and CB2 and CB3 remaining closed.

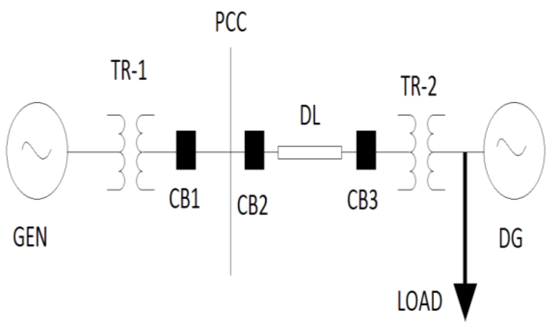

Fig.1- Power system network studied.

a) Parameters of the system components-

i. Generator : Rated kV=120, V_{base}=120kV, f= 60Hz, Rated short circuit MVA= 1000

ii. DG : Wind Farm (9 MW) comprising of six 1.5 MW turbine each, exporting power to a 120kV grid through a 30 km 25kV feeder.

iii. Transformer (TR 1): rated MVA= 47, f = 60Hz, rated kV= 120/25, V_{base}=25kV, R_1 = 0.00267 pu, L_1 = .08 pu, R_2 = 0.00267 pu,L_2 = .08 pu, R_m= 500 pu, X_m= 500 pu.

iv. Transformer (TR 2): rated MVA= 10, f= 60 Hz, rated kV= 25kV/575V, R_1 = 0.0008 pu, L_1 = 0.025pu, R_2 = 0.0008 pu, L_2 = 0.025pu, R_m= 500 pu, X_m= 500 pu.

v. Distribution line: Three phase PI section, 30 km, Rated kV=25, Rated MVA=20,Vbase =25kV, R_1=0.1153 ohms/km, R_0 = 0.413 ohms/km, L_1=1.05e-3 H/km,L_0=3.32e-3 H/km, C_1= 11.33 e-9 F/km, C_0 =5.01e-9F/km

vi. Load: 6MW resistive load.

IV. PROPOSED FUZZY LOGIC CONTROLLER

The parameters such as voltage and current are extracted from the DG location and the calculation of frequency deviation, rate of change of power, rate of change of frequency, positive sequence impedance calculation are done.

The study includes the loss of mains in which the main circuit breaker CB1 isolates the DG and load at a specified time and creates an islanding condition. For each parameter, three sets of operating ranges, low, medium and high have been used. For instance since any one criterion of the parameter is not sufficient to determine islanding, hence the set of three ranges of individual parameter can be made as a rule base for islanding detection.

The ranges of the values of each individual parameter are transformed to Membership Functions (MF) of the fuzzy controller. Mamdani rule base has been used owing to its linguistic simplicity. The MF for the parameters are-

Table 1- Membership Functions for frequency deviation.

Name	Type	Range
Low	Trapezoidal	[-3 -2.9 -0.37 -0.3]
Normal	Trapezoidal	[-0.28 -0.24 0.38 0.43]
High	Trapezoidal	[0.47 0.49 2.85 3]

Table 2- Membership Functions for rate of change of frequency.

Name	Type	Range
Low	Trapezoidal	[-34 -33 -3.6 -3]
Normal	Trapezoidal	[-2.65 -2.44 2.84 2.95]
High	Trapezoidal	[3.49 4.53 33 34]

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Table 3- Membership Functions for rate of change of output power.

Name	Type	Range
Low	Trapezoidal	[-2000 -1980 -1335 -1300]
Normal	Trapezoidal	[-1290 -1270 1290 1300]
High	Trapezoidal	[1323 1352 1980 2000]

V. FLOW CHART OF THE PROPOSED CONTROLLER

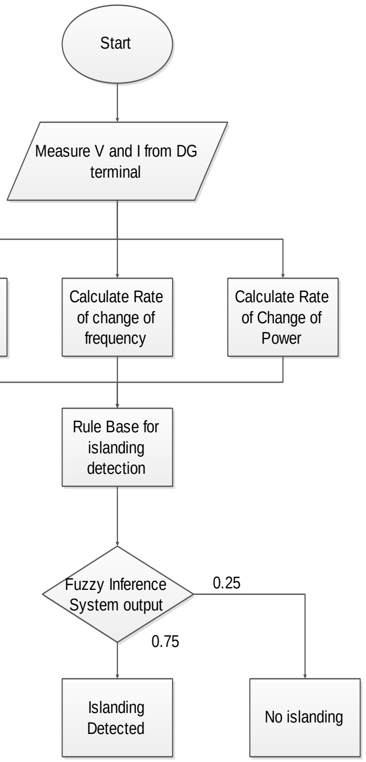

Fig.2- Flow Chart of the proposed controller

VI. SIMULATION RESULTS

The system is subjected to islanding at 0.5 seconds by the disconnection of CB1 producing the Major Islanding Condition. The parameters were measured from the DG terminal.

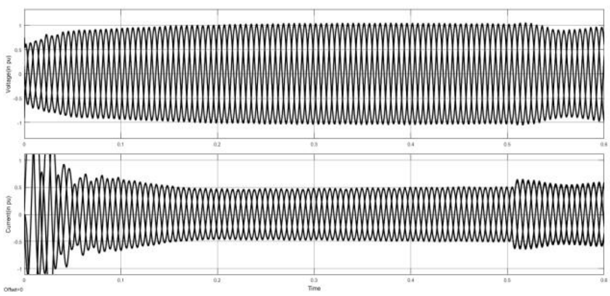

Fig.3 -Voltage and current at DG terminal with islanding at 0.5 seconds.

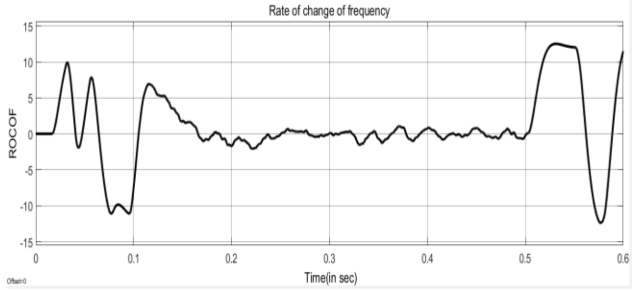

Fig.4- Rate of change of frequency during islanding at 0.5 seconds.

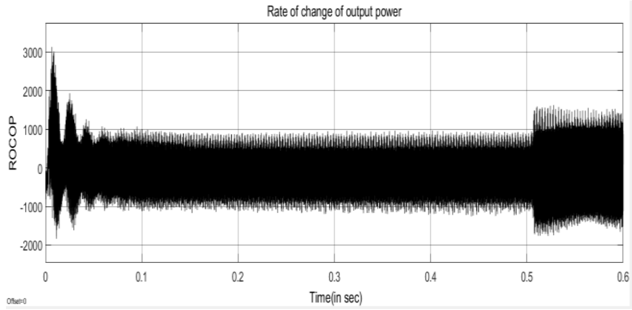

Fig.5- Rate of change of output power during islanding at 0.5 seconds.

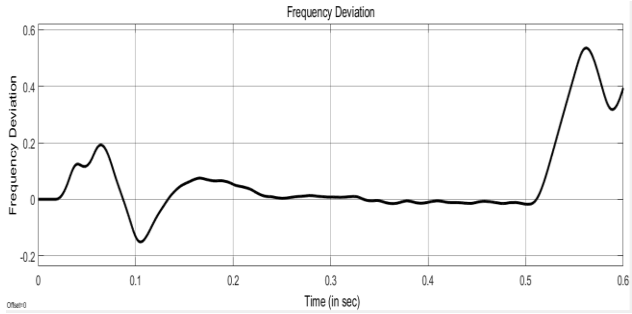

Fig.6 – Frequency deviation during islanding at 0.5 seconds.

The controller processes the input signals and the FIS output signal during islanding at 0.5 seconds is as follows-

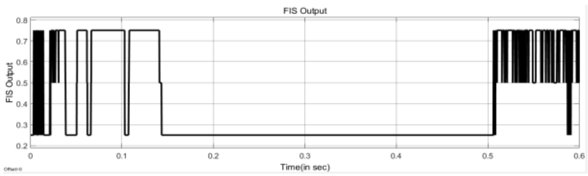

Fig.7- The FIS output during islanding at 0.5 seconds.

It is observed that the FIS output is 0.25 during normal and 0.75 during islanding. The FIS output resorts to 0.75 during the starting owning to initial transients during machine startups. The detection speed is recorded at 6.4ms.

VII. CONCLUSION

The proposed controller takes into account the three input parameters for islanding detection and analyses them in the developed rule base. The controller detects islanding during Loss of Mains or Major Island formation.

The controller can be further modified for detection of minor island formation during islanding of multiple DG interconnections. The rule base can be reconfigured for distinction between load change and islanding condition.

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