ISLANDING DETECTION BY PHASOR MEASUREMENT UNIT IN DISTRIBUTION NETWORK

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Abstract: *Renewable energy sources like Wind, Sun, and Hydro are seen as the reliable alternative to the traditional energy sources like oil, natural gas, coal. Recent development in distributed generation implementation into secondary distribution system near consumer ends has created some new difficulties for utility engineers islanding detection is one among them. This paper is dedicated to the islanding detection by phasor measurement unit. Phasor measurement unit is the device that measure voltage magnitude, phase angle, and frequency from a three phase voltage measurement unit. In this paper frequency is used as a measurement parameter for islanding detection. The islanding detection method define in the paper used the frequency difference between the two location and compare them for the threshold time. The frequency difference between PV station and utility grid is the main index to distinguish islanding from other tripping event. MATLAB/Simulink model is used to validate the result of the sample system in different conditions like another generation trip, large load trip, and islanding condition. Simulation Results validate that the frequency difference result for the islanding event are different from the other tripping event and normal condition operation.*

Key words: *Phasor measurement unit, islanding detection, photovoltaic station, micro grid.*

1. Introduction

Generation of power by small electric power sources is defined as Distributed generation (DG) also called distribution end generation or discrete generation. In today's power world most generating stations are built this way due to number of benefits like right of way, losses, safety, decongestion, and environmental pollution. Transmission losses are decrease by much amount due to the generation near to the load center. It also reduces the requirement of large power transmission line which decrease the number of issue in setup of the transmission line like large capital cost, maintenance cost, and right of way. According to the IEEE 929-2000 "Islanding is the condition in which a portion of the utility that contains both load and distributed resources remain energized while isolated from the remainder of the utility system". Islanding may occur as a result of fault which is detected by the utility and not detected by the distributed generator, an equipment failure, due to utility's switching of DG and loads and due to human error. Utilities feels that islanding should be detected by the distributed resources because utility cannot control voltage, frequency and it may interfere in the process of restoration of normal service, hazard for utility line workers and restoration in the islanding condition may cause re-tripping the line or damage the distributed resources equipment due to the out of phase reclosing [2].

According to IEEE 1547 the islanding should be detected and DG will be disconnected within 2 sec [3]. There are many methods to detect islanding in the power system. These methods are differentiated in three main category as per there technique of data collection like Active method, Passive method, Communication method. Passive methods are based on monitoring of grid variable. Most common methods are over/ under voltage, over/ under frequency, rate of change of frequency and voltage (ROCOF, and ROCOV), phase monitoring and harmonics monitoring. These methods are grid friendly, easy and cheap to implement but there non detection zone is larger among other method [4]. Active methods inject a small disturbance (V, F, ϕ) to the utility grid and based on response whether islanding occur or not. Different active methods are positive feedback inside the DG control, impedance detection (by a current spike injected, phase angle signal altered, a high frequency signal, and active and reactive power oscillation). These methods have of advantage of low non detection zone, some easy to implement but large penetration level of DG can create power quality problem, nuisance trip, some difficult to implement, suitable for finite number of generators [5]. Communication based method are power line used as carrier for communication and loss of signal results in islanding, signal produced by disconnect, and supervisory control and data acquisition system(SCADA) based method use placement of voltage at the PCC [2].

In communication based SCADA system may have problem in satisfying national code as pulling rate of data is around 5 to 6 sec. PMU is used in this paper whose pulling rate can reach up to 100 times per sec. PMU used to collect voltage angle and frequency for measurement. When the PV station is in interconnection with the power system in the normal condition means steady state condition the frequency at all the nodes are same to the rated value theoretically. While PV station is disconnected from the utility grid the magnitude and phase of the voltage remain same in the inverter based system in micro grid but the frequency is different in that condition at the two nodes. To differentiate the islanding event from the other tripping event like generation trip, load trip in the grid and to improve reliability a reasonable threshold value is set for the method. When the frequency difference exceeds for the reasonable threshold time than the event is detected as islanding.

2. Phasor Measurement Unit

Synchronized Phasor measurement unit was invented in 1980s and since then it was used by the research scholar for the new discovery around the world. Main advantage of the PMU is that it provides accurate data which help system analysts to analyse correct situation of the system. PMU can applicable to both real time data analysis and off line data analysis. Two possible architectures were used for real time system analysis for the phasor measurement; input is sampled at variable sample frequency equal to the multiple of the actual frequency of the power system and a constant frequency depending upon the nominal frequency of the power system [7].

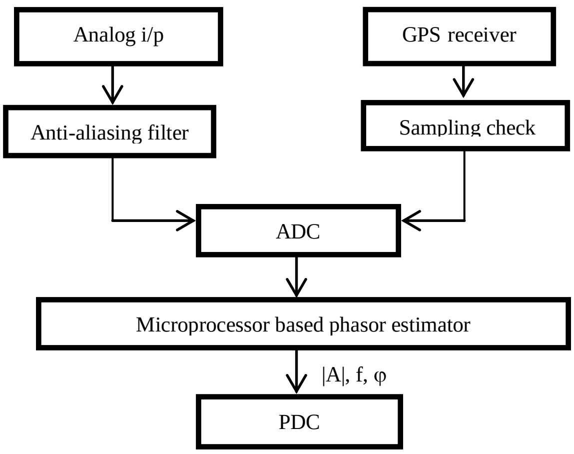

Fig. 1 Block diagram of PMU

Fig 1 shows the basic functional block diagram of the PMU. As per IEEE standard PMU is defined as "A device that produces synchronized phasor frequency and rate of change of frequency (ROCOF) estimated from voltage and/ or current signals and a time synchronizing signal". Main advantages of using PMU are time stamping of data based on GPS from different location of power system enables to know the real time phase difference, High stamping rate increase the resolution of data and increase the monitoring level of the power system, Direct angle measurement of power system.

Most of the algorithms compute phasors from measured signals using a fixed time window of data samples and computing the phasor estimate using discrete Fourier Transform. The Estimated phasor measurement over a fixed time duration from all the PMUs are sent to Phasor data concentrator (PDC) which time align all the PMUs data and send it to visualization, historian and other real time applications [7]. Any standard PMU provides six numbers of phasors of Voltages & Current, Frequency, and Rate of Change of Frequency (ROCOF).

3. Phasor representation of Sinusoidal signal

Consider a pure sinusoidal quantity given by

$$x\,(t) = X_m \cos(\omega t + \phi) \qquad (3.1)$$

Where ω being the frequency of the signal in radians per second, and ϕ being the phase angle in radians. X_m is the peak amplitude of the signal. Equation 3.1 can also be written as

$$X(t) = \mathrm{Re}\,\{X_m e^{j(wt + \phi)}\} = \mathrm{Re}\,[\,\{e^{j\omega t}\}\, X_m e^{j\phi}]$$

It is customary to suppress the term $e^{j\omega t}$ in the expression above, with the understanding that the frequency is ω. The sinusoidal equation 3.1 is represented by a complex number X known as phasor representation:

$$x(t) \leftrightarrow X = (X_m/\sqrt{2})\, e^{j\phi} = X_m/\sqrt{2}\,(\cos\phi + j\sin\phi) \qquad (3.2)$$

A sinusoidal signal phasor representation are illustrated in fig. 2

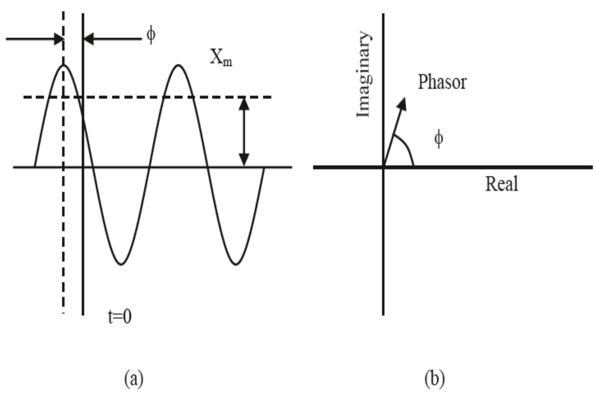

Fig 2 sinusoidal signal phasor representation

a sinusoidal signal

b Phasor representation of signal

It was known that phasor representation is only possible for the pure sinusoidal but the input signal of the PMU is corrupted with other signal of different frequency. So it is necessary to extract the single frequency component from the input signal then represent it by phasor. To extract a single frequency signal from the input signal 'Fourier transform' of the signal is calculated. Here we are using the sampled data so "discrete Fourier transform" is performed. As we calculate the phase from the Fourier transform the frequency will be calculated by the equation 2.3 [6].

$$f = 1/2\pi * d\phi/dt \qquad (3.3)$$

Where ϕ is the measured phase.

4. Algorithm used for islanding detection

The proposed algorithm used the global power system quantity (frequency) measured from the phasor measurement unit connected at different bus. In the interconnection of the power system frequency is of prime importance. The algorithm does not include any local quantity like current, active power and reactive power for the measurement which varies feeder to feeder. In normal condition the power system frequency at different nodes are same for power system stability so the frequency difference between different nodes is zero. In the islanding condition the PV station is disconnected from the grid and it will operate at different frequency than grid so the islanding can be detected at that point. This algorithm must discriminate the islanding event from the other malfunctioning event to solve that purpose a frequency and time threshold is consider in the algorithm [9]. The algorithm of islanding detection is defined in fig 3.

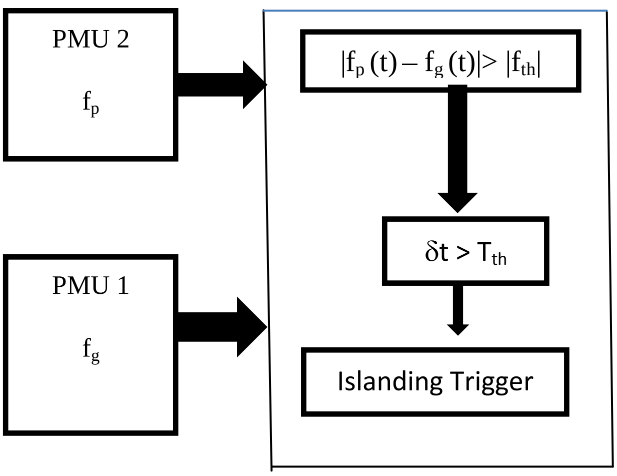

Fig. 3 Algorithm for the islanding detection method based on PMU

Where $f_p(t)$ is the instantaneous frequency measured at PCC of the PV station and $f_{g,}(t)$ is the instantaneous frequency and phase of the grid. f_{th} is the threshold frequency for frequency difference. T_{th} is the threshold value for the time delay $\delta(t)$. Frequency difference between two PMUs remains greater than the threshold value than the islanding triggered. In this paper the frequency threshold is .5Hz the time threshold is 1.8 sec and value of sampling period (T) is taken 100μs, which means 200 samples per cycle.

5. Model detail

The sampled system studied is given in the fig: 4. Simulation model is designed based on the sampled system shown in fig: 5. The PV station is a grid tied inverter which employs voltage source control and constant power.

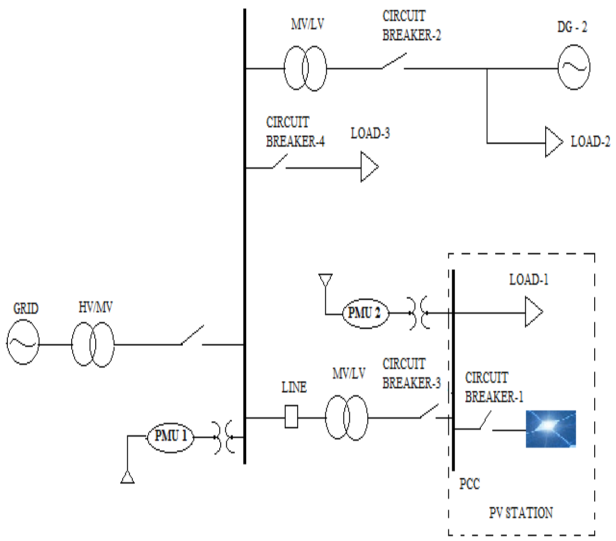

Fig 4 single line diagram for Simulink model

The grid is modeled as the Three-Phase Voltage Source: base voltage (Vrms ph-ph): 35kv, short-circuit level: 500MVA, X/R ratio: 10, frequency: 50Hz; DG-1 as the PV station: nominal power: 100MVA, nominal voltage: 4910, frequency: 50Hz. DG-2 is a 3-phase simplified synchronous machine and parameters are shown as follow: nominal power: P(MVA)n= 50 , nominal voltage: V(kv)n = 13.8 frequency: fn =50hz ; the transmission line is modeled as a single PI section; Combining with practical cases, PMU1 is implemented in the PV station or traditional synchronous system while PMU2 is implemented in a substation of the grid [1].

TABLE 1: Simulation model details of load and DG

MODEL DETAIL

MODEL	DG-1 [MW]	DG-2 [MVA]	LOAD1 [MW]	LOAD2 [MW]	LOAD3 [MW]	LINE (km)
Value	100	50	100	35	25	10

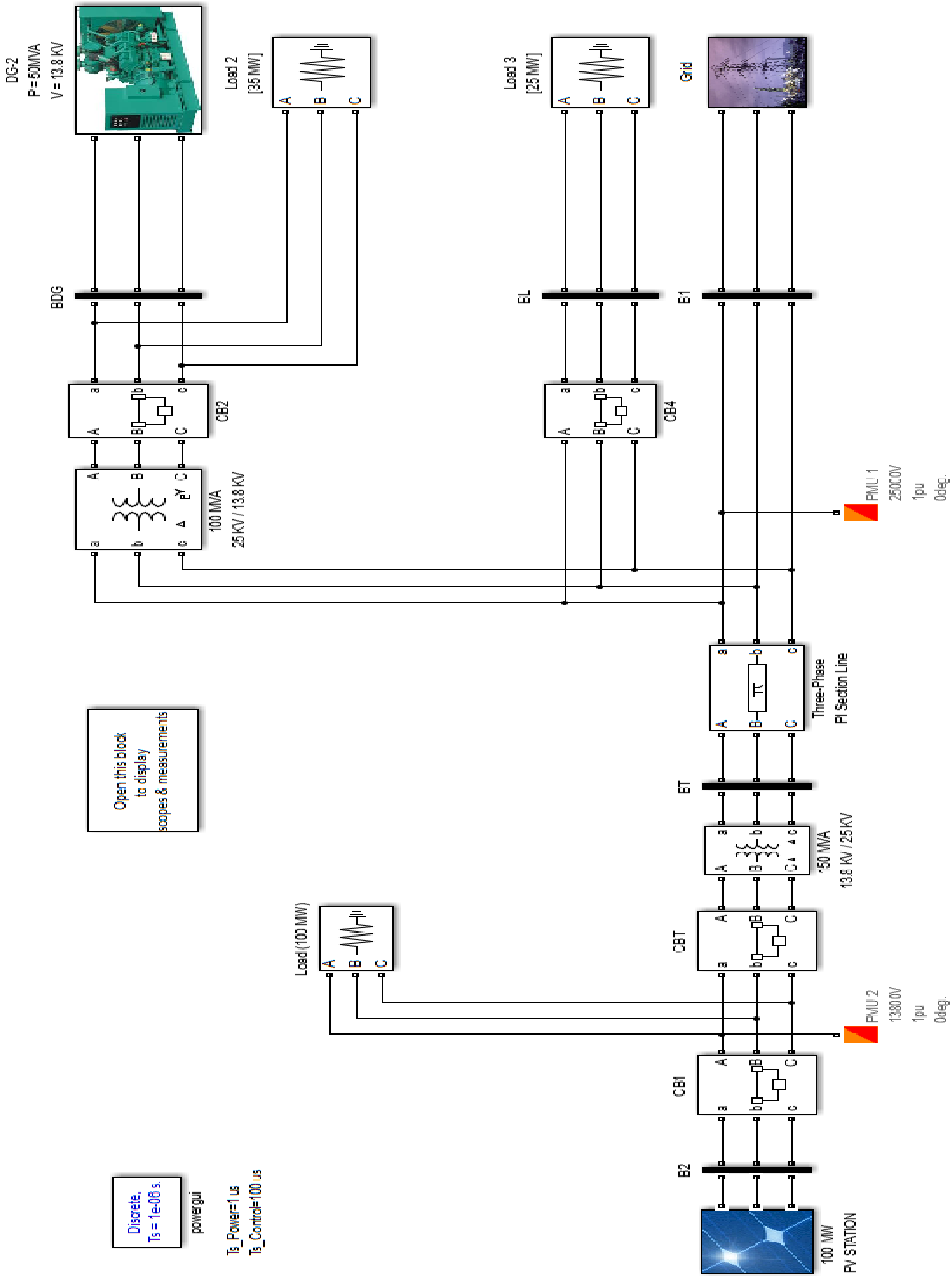

Fig. 5 Simulink model

6. Result and discussion

The performance of frequency difference between PMU1 and PMU2 are discussed in following condition: normal operation, generation trip, load trip and islanding event. For observing frequency difference between PMU 1 and PMU 2 in the following operating time window is 5 to 7.5 second is considered.

- During normal operation: In fig 5, we can observe that the frequency difference is nearly zero in the time window.

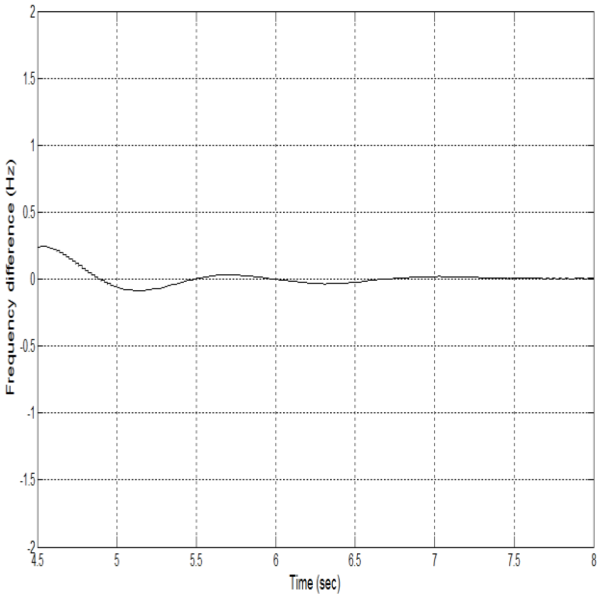

Fig 6 frequency difference during normal operation

- During normal operation: In the event of generation trip DG2 is called to trip. In fig 6, we can observe that the frequency difference is not changed from the normal operation point irrespective of time of switching.

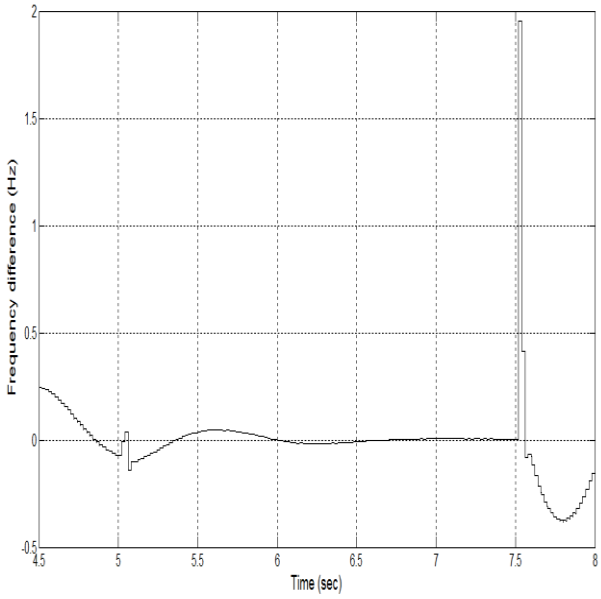

Fig 7 frequency difference during DG2 trip

- During load trip: In the event of load trip load 3 is called to trip. In fig: 7, we can observe that the frequency difference remain zero irrespective of the time of switching. At time of switching the frequency difference is few Hz but it last for few milliseconds and it is less than of T_{th} set.

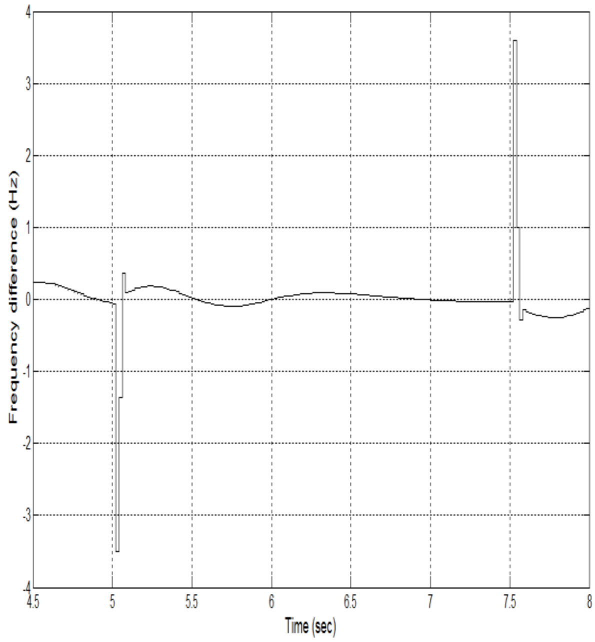

Fig 8 frequency difference during load 3 trip

- During islanding: At time of islanding PV station is disconnected from the grid by operation of CB 3. In fig 8, we can observe that the frequency difference is above the threshold value and for the time more than T_{th}. So the islanding event is recognized.

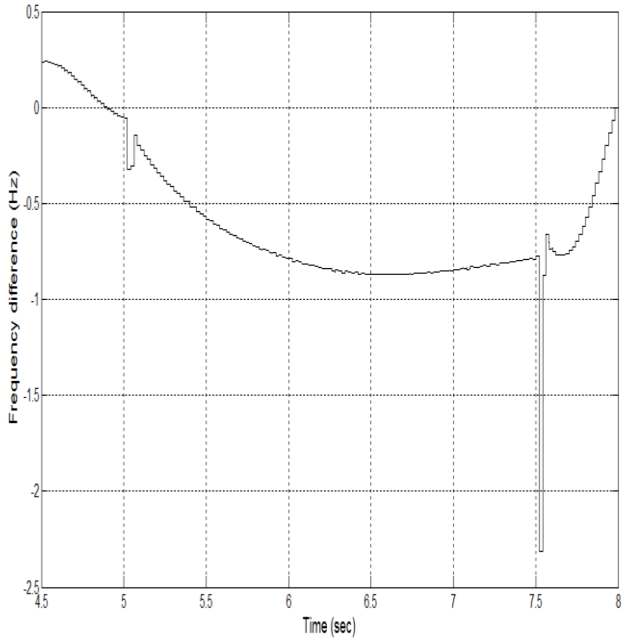

Fig 9 frequency difference during islanding

7. Conclusion

This paper is focused on the islanding detection by the PMU. In this paper we discussed the effect of islanding in power system, different types of islanding detection method and introduction to the PMU. Here we try to satisfy the IEEE std.1547 condition to detect the islanding within 2 sec. As discussed in [1] the frequency difference threshold is set larger and time threshold are taken less. The simulation result shows that the islanding will be detected within the limits and the results of islanding event and the other tripped event are completely different. So with the help of PMU islanding will be detected effectively in the micro grid.

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