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Islanding Detection in a Distribution System with Modified DG Interface Controller

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ABSTRACT

Islanding detection of Distributed Generation (DG) is considered as one of the most important aspects when interconnecting DGs to the distribution system. It was the crucial problem in distributed generation. This detection phenomenon having a great importance. These detection methods are divided into active and passive islanding detection. These two methods are based on changing in parameters such as frequency, voltage and current harmonics. But these methods have some challenges such as reduction in power quality and large Non Detection Zone (NDZ). In this paper, the proposed method is change of Total Harmonic Distortion (THD) will be studied for islanding detection diagnosis. The studied system was considered by following the standard IEEE-1547 and UL-1741. The system was simulated using MATLAB/ SIMULINK.

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1. INTRODUCTION

Distributed Generation (DG) provides many potential benefits, such as peak shaving, fuel switching, improved power quality and reliability, increased efficiency, and improved environmental performance. For DG systems producing a DC voltage, an inverter is used to interface the DG system with the grid. The switching of the inverter is determined based on a certain implemented control strategy [1]. The DG could be designed to supply active power or both active and reactive power. Aside from controlling the DG output power, the DG interface control performs an additional function, which is anti-islanding protection [2].

Islanding is an operating condition of the system that contains both loads as well as local generation is isolated from the rest of the utility grid. One of the protection requirements for DG, mentioned by the IEEE Std. 929 and IEEE Std. 1547, is islanding detection [1-2]. Unintentional islanding of DGs may result in power-quality problems, interference with grid protection devices, equipment damage, and even personnel safety hazards.

Islanding detection techniques are divided into local and remote techniques. The local techniques further classified into passive, active and hybrid techniques. Remote islanding detection techniques are based on communication between the grid and the DG like Supervisory Control And Data Acquisition (SCADA), Power Line Carrier Communication (PLCC). Even though they are more reliable but they are expensive to implement compare to local islanding detection techniques. Local islanding detection techniques are based on the measurement of parameters such as voltage, current, frequency. They are classified as passive, based on the monitoring of these parameters but it suffers with having large Non Detection Zone (NDZ). Hence it is not useful for high DG penetration. The active islanding detection techniques are based on intentionally introduce perturbations in the parameters voltage, frequency or output power and continues monitoring of these parameters to conform the islanding detection condition. Hybrid methods employ both the active and passive detection techniques.

2. DISTRIBUTED GENERATION

The distributed generation correlates the energy generation at distribution system which is near to the load centers less than 10 MW. These distributed generation technologies are into categorized as renewable and non-renewable.

Renewable technologies includes

1. Solar, photovoltaic or thermal
2. Wind
3. Geothermal
4. Ocean

Nonrenewable technologies includes

1. Internal combustion engine
2. Combined cycle
3. Combustion turbine
4. Micro-turbines
5. Fuel cell

The main function of the inverter for DG system can be stated as follows:

1. The main function of inverter is controlling the DG as a major source of active power.
2. Protection of DG and protection of network from islanding

The inverter can also produce power quality problems such as voltage distortion and harmonics.

3. PHOTOVOLTAIC (PV) SYSTEM

A solar cell is the most fundamental component of a photovoltaic (PV) system. The PV array is constructed by many series or parallel connected solar cells to obtain required current, voltage and high power. Each Solar cell is similar to a diode with a p-n junction formed by semiconductor material. When the junction absorbs light, it can produce currents by the photovoltaic effect. It can be seen that a maximum power point exists on each output power characteristic curve. The Figure 1 and Figure 2 shows the (I-V) and (P-V) characteristics of the PV array at different solar intensities. The equivalent circuit of a solar cell is the current source in parallel with a diode of a forward bias. The output terminals of the circuit are connected to the load.

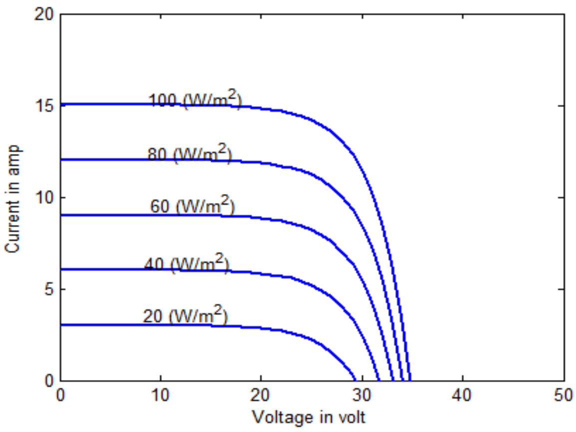


Figure 1. I-V characteristics of the PV array at different solar intensities

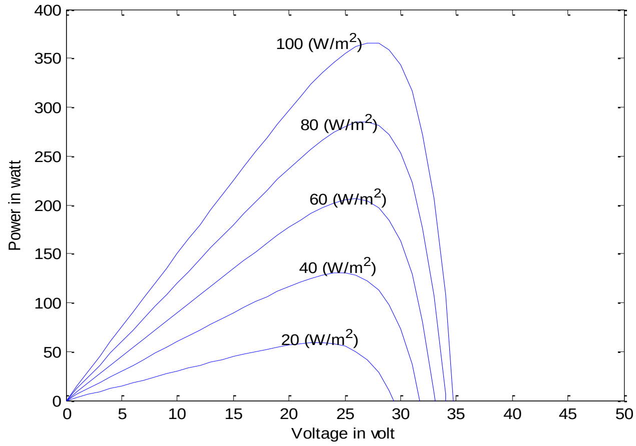


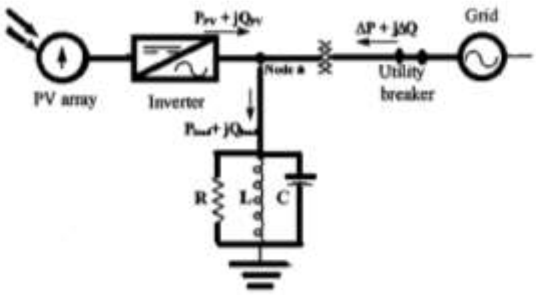
Figure 2. P-V characteristics of the PV array at different solar intensities

4. PROPOSED SYSTEM ISLANDING DETECTION

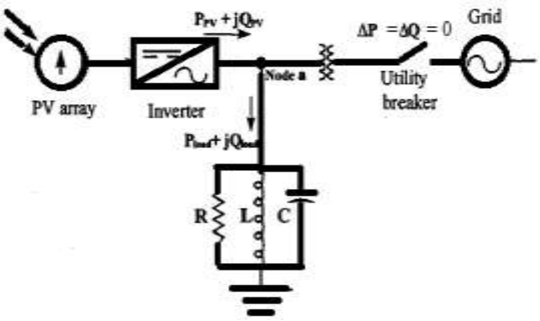
The proposed system is shown in Figure 3. It is consists of RLC load, DG source and inverter, power transformer, utility breaker. It also indicates the Point of Common Coupling (PCC) at node “a”, which is the contact point of DG source to the utility grid. The power delivered by the grid to load is the difference between the powers generated by the DG source to the power consumed by the load.

$$\Delta P + j\Delta Q = \left(\left(P_{pv} + jQ_{pv}\right) - \left(P_{load} + jQ_{load}\right)\right) \tag{1}$$

Where P_{load} and Q_{load} represent the active and reactive powers of the *RLC* loads at the grid-connected condition, respectively, P_{pv} and Q_{pv} represent the output active and reactive powers of the inverter in the DG side and ΔP and ΔQ represent the active and reactive powers delivered by the grid.



(a)



(b)

Figure 3. (a) Grid connected system (b) Isolated mode of the system

Under the ideal condition, when the utility breaker opens, the DG and the RLC load will resonate at nominal voltage and frequency and forms an island. If the PV system drifts slightly out of phase with the utility voltage source during islanding, large surge currents can flow upon reconnection. The active and reactive power of the three phase RLC load is given by;

$$P_{load} = 3\frac{V_{PCC}^2}{R} \quad (2)$$

$$Q_{load} = 3\left(\frac{V_{PCC}^2}{2\pi fL} - V_{PCC}^2 2\pi fC\right) \quad (3)$$

where V_{PCC} represents the voltage of PCC; f is the PCC frequency.
With the parameters of three phase RLC load the resonant frequency and quality factor is expressed as

$$f = \frac{1}{2\pi\sqrt{LC}} \quad (4)$$

$$Q_f = R\sqrt{\frac{C}{L}} \quad (5)$$

Mathematically, the RLC load can be represented as

$$R = \frac{V^2}{P} \quad (6)$$

$$L = \frac{V^2}{2\pi f Q_f P} \quad (7)$$

$$C = \frac{Q_f P}{2\pi f V^2} \quad (8)$$

Where;
R =Effective load resistance in Ohm;
C =Effective load capacitance in Farad;
L =Effective load inductance in Henry;
P =Real power in W;
Q_f =Quality factor;
f =Grid frequency in Hz.

5. NDZ OF UOV AND UOF

In practical situations, there will be power mismatch between the DG output and the RLC load. This mismatched load can be represented by $(R + \Delta R, L + \Delta L, C + \Delta C)$. Before the grid is disconnected, the power mismatch will be compensated by the grid.

When grid is disconnected, the voltage and frequency will be forced to new values of voltage and frequency. If the DG is controlled as a constant power in the system. When the power mismatch is large enough, the values of voltage and frequency may be out of nominal ranges and under/over voltage/frequency protection will trip the circuit breaker present at the DG side to prevent continued island operation. The relationship between the power mismatch thresholds and voltage/frequency thresholds can be derived.

$$\left(\frac{V}{V_{max}}\right)^2 - 1 \le \frac{\Delta P}{P} \le \left(\frac{V}{V_{min}}\right)^2 - 1 \quad (9)$$

$$Q_f\left(1 - \left(\frac{f}{f_{min}}\right)^2\right) \le \frac{\Delta Q}{P} \le Q_f\left(1 - \left(\frac{f}{f_{max}}\right)^2\right) \quad (10)$$

where $V_{max}, V_{min}, f_{max}, f_{min}$ are under/over voltage and under/over frequency thresholds, respectively. Non detection zone is shown in Figure 4. In the NDZ the islanding detection is not possible.

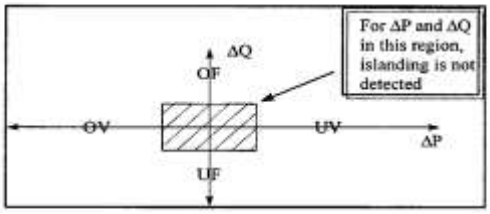


Figure 4. Non detection zone

6. SYSTEM DESCRIPTION

The proposed system modelled in Simulink is shown in Figure 5. The system parameters are taken from the reference paper [3-7].The rating of the inverter is 100 kW. The DG interface controller is the constant power control in which both voltage and current controller will takes place.

Figure 6 shows the control scheme based on *dq* synchronous reference frame. In this system, the dc-link voltage controller and reactive-power controller determine *d* and *q* components, respectively. The input power extracted from the DG unit is fed into the dc link. Therefore, the voltage controller counteracts the voltage variation by specifying an adequate value of the *d* axis inverter current to balance the power flow of the dc link.

The reactive power controller, shown in Figure 6, specifies the reference value for the *q* component of the converter current. The reactive power reference value Q_{ref} is set to zero in order to model a unity power factor DG operation. Also, Figure 6 shows two Proportional-Integral (PI) controllers for the *d* and *q* axis current controls. The outputs of these controllers obtain the reference voltages for the PWM signal generator. The main features of the current control strategy are the limitation of the converter output current during a fault condition, providing overcurrent protection, and reducing the fault current contribution of the unit. The d-q transformations of the Phase Locked Loop (PLL)

$$V_d = \frac{2}{3}\left(V_a \sin(\omega t) + V_a \sin\left(\omega t - \frac{2\pi}{3}\right) + V_a \sin\left(\omega t - \frac{4\pi}{3}\right)\right) \quad (11)$$

$$V_q = \frac{2}{3}\left(V_a \cos(\omega t) + V_a \cos\left(\omega t - \frac{2\pi}{3}\right) + V_a \cos\left(\omega t - \frac{4\pi}{3}\right)\right) \quad (12)$$

$$V_0 = \frac{1}{3}(V_a + V_b + V_c) \quad (13)$$

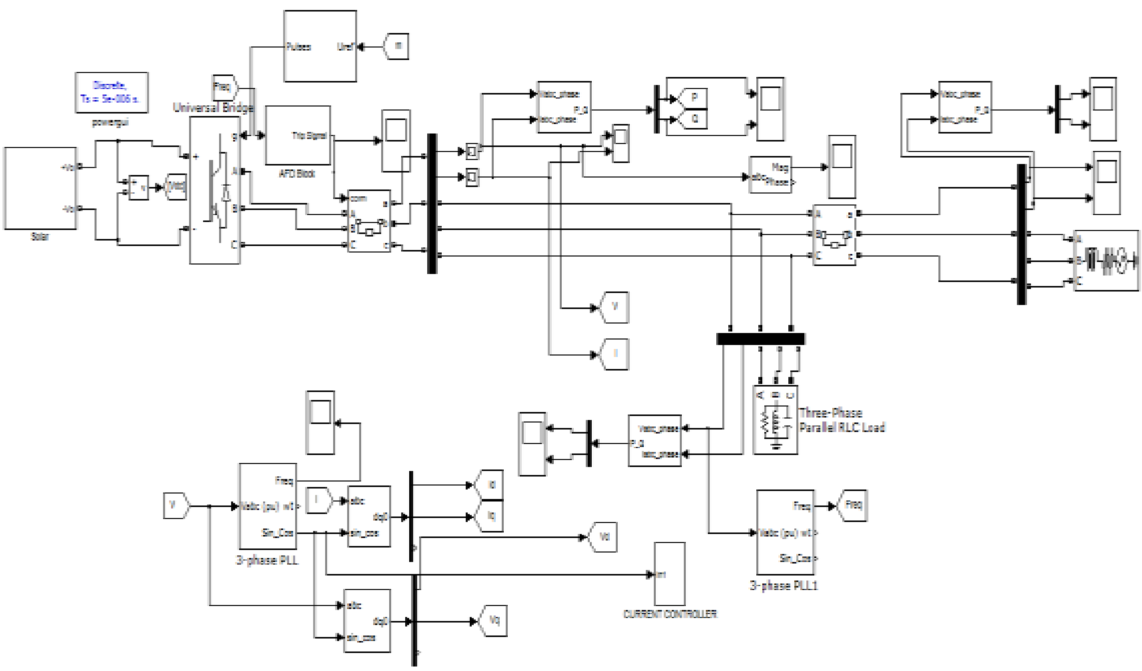


Figure 5. Simulink diagram of the system

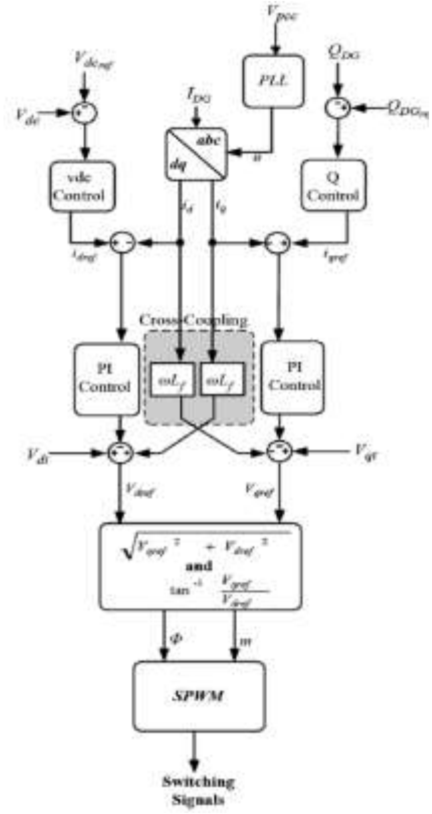


Figure 6. Block diagram of DG interface controller

7. RESULTS

When the Grid is connected to the system the output of three phase voltage and current is stable but with the opening of CB at grid side, the system becomes isolated mode. Whenever the Grid is disconnected at t=0.3 sec the the output of voltage and current was distorted and becomes zero.The output waveforms of voltage and current at PCC and grid is shown Figure 7-8.

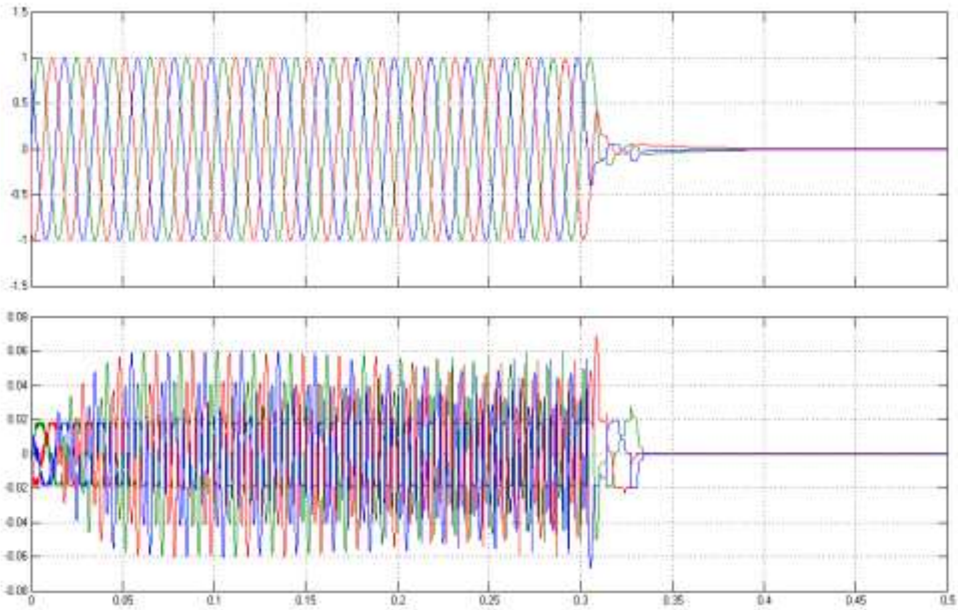


Figure 7. Voltage and current at PCC

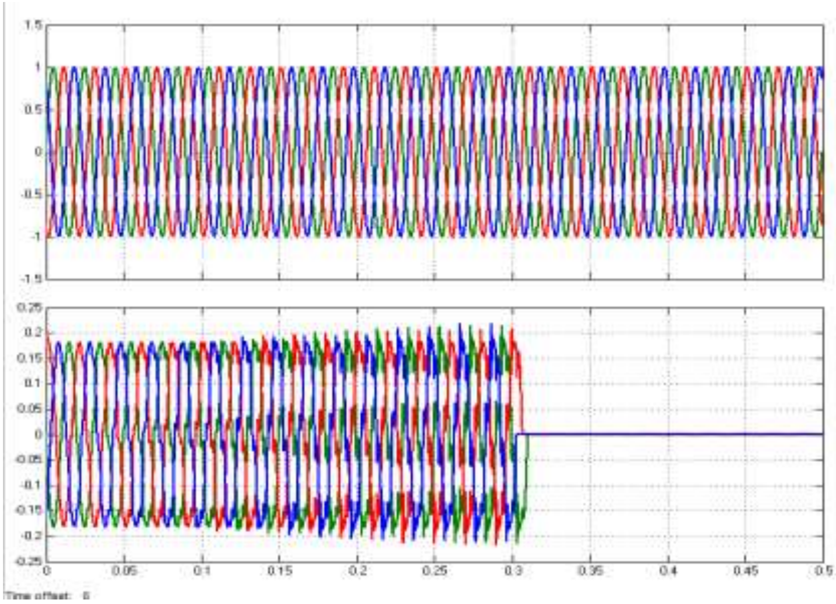


Figure 8. Voltage and current at grid

Due to the opening of CB at t=0.3 sec the frequency at PCC will change continuosly shown in Figure 9. Due to the change in frequency the trip signal is generated and given to CB at DG side.

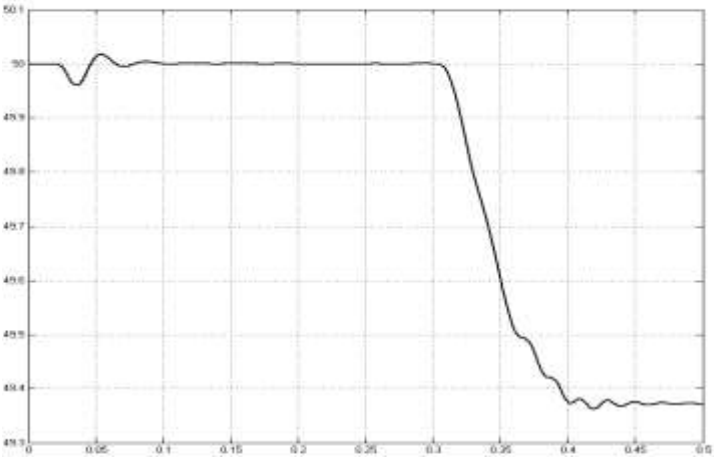


Figure 9. Frequency at PCC

As per IEEE std,the DG is disconnected with in 0.02 sec from the rest of system and the trip signal provided to the CB at DG shown in Figure 10.

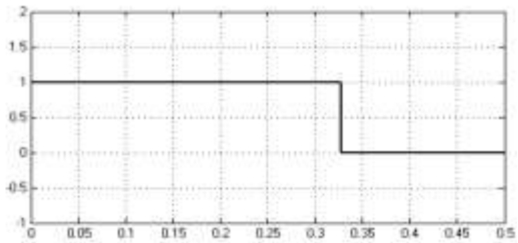


Figure 10. Detection signal for CB at DG

The THD values for voltage waveform is measured and given in Figures 11 and 12 for the before and after islanding events occurred.

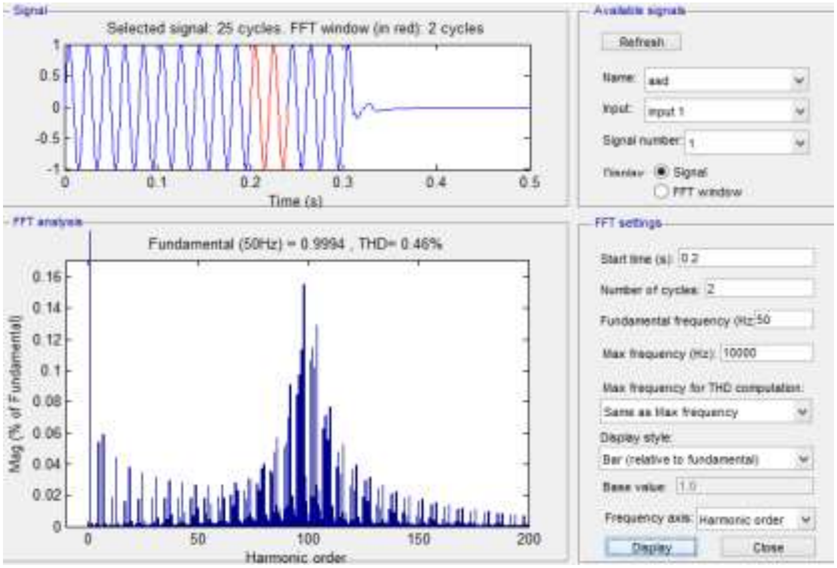


Figure 11. THD value of voltage waveform before islanding event occurs.

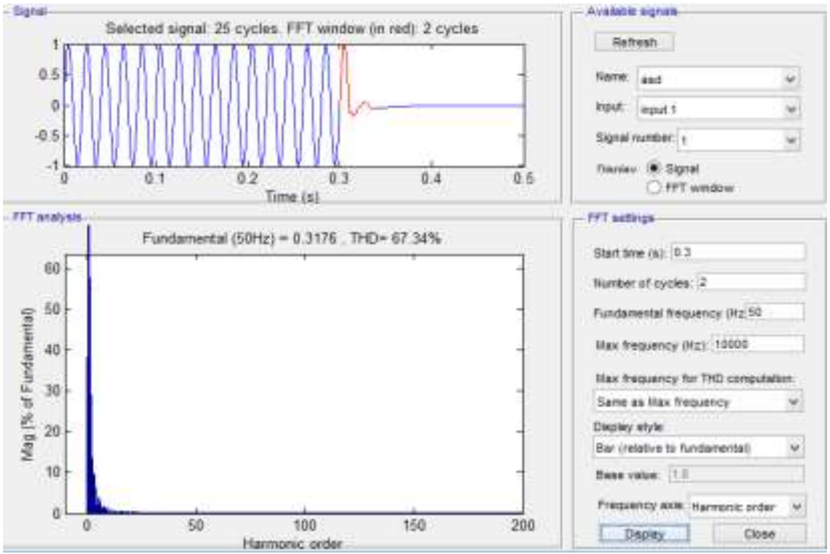


Figure 12. THD value of voltage waveform after islanding event occurs

8. CONCLUSION

With the proposed method NDZ is eliminated by taking the reference of active power as function of terminal voltage. The change in real and reactive power at PCC is observed by disconnecting the grid for RLC load. This work will be carried out for the different loads and observe the change in real and reactive power for different load when islanding is formed. Those variations will be taken as reference for the islanding detection.

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Mr. Shailesh B. Modi is M.E. (Electrical Power Engineering) from M.S. University of Baroda. Presently he is working with Electrical Research & Development Association (ERDA), Vadodara as Head of Section, Power System Section. The key responsibilities are calculations of technical losses of distribution feeders, Design of HVDS scheme, Energy Accounting, GPS survey based distribution system study, R-APDRP project for verification of AT & C losses, Power System studies like Load Flow, Short Circuit Studies, Relay Co-ordination study, Transient Stability study, Insulation Coordination study etc. He is working in ERDA since last 12 years.