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An effective load management for grid connected hybrid energy sources

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Abstract—This paper introduces to control a standalone hybrid renewable system, involving PV cell and wind turbines as the primary energy sources along with fuel cell and battery energy source as an emotionally supportive system. While trying to work on the solidness and security of the hybrid renewable system sustainable framework, a battery bank, is incorporated as supporting units, due to the discontinuous and fluctuation in primary energy sources commitment. In this paper we model an independent sustainable source micro grid with various sources, which are wind energy with PMSG, PV panel, Fuel cell and battery storage system. Analysis of each source is done under variation conditions and variation of source parameters, such as wind speed of wind turbine, illumination, temperature of PV cell and state of charge of the battery. If main power sources of PV panel and wind turbines is not available, the battery storage device act as backup supply for load. This storage source (battery) can be charged when abundance power is produced from the PV panel and wind generation system. Investigation on each sources with dynamic changes of boundaries are studied with siumulation results analysis is studied by utilizing MATLAB/ SIMULINK software.

Keywords— PV (Photo Voltaic) Cell, PMSG (Permanent Magnet Synchronous Generator), Fuel Cell, Battery, wind frame.

I. Introduction

The energy creation has been moving to renewable source generation all through a few worldwide areas for efficient power energy generation to decrease an unnatural weather change. The most well-known sustainable power generation [1-3] is made by using PV cells (solar cells), which generate electrical power by sunlight based illumination. These PV cells are connected in parallel to the power system at the grid. Which works in synchronization to the grid voltage. This interconnection of renewable sources offer great help to the load, where the load consume power from the grid, when there is deficiency in the power produced from PV cells. This energy sharing is extremely normal and most usually utilized for different grid connected system by using different proposed control algorithms. The drawback of PV cells, Power utilization is not possible in throughout day. To avoid this problems we can integrate another most popular renewable energy source of wind energy [4-5], with proper coordination. Another significant issue raises if there is no grid power (Power created from non-renewable sources like nuclear energy, Hydro power plants) gave to the load and when there is a lack of solar, wind power. Because of the inadequate power produced by the PV based panels (solar panel) or some other sustainable sources like wind frame, the voltage across the load drops harming the load alongside the sources associated with it. Along these lines, to relieve this issue of low voltage [6-7] (during lower sun illumination and lower wind speeds) fuel cell and battery storage device. The battery module is expected to give support to the load during this condition. The battery storage module stores energy from the solar panels and wind frame during excess power availability, which is subsequently consumed during lower power generation condition. To help the load during various natural conditions an energy management scheme is developed to control the working states of the sources associated with the load. The considered test system with sunlight based panels, wind frame, fuel cell unit and battery storage system associated with single load can be seen below with various converters are interconnected in the middle of the sources and load.

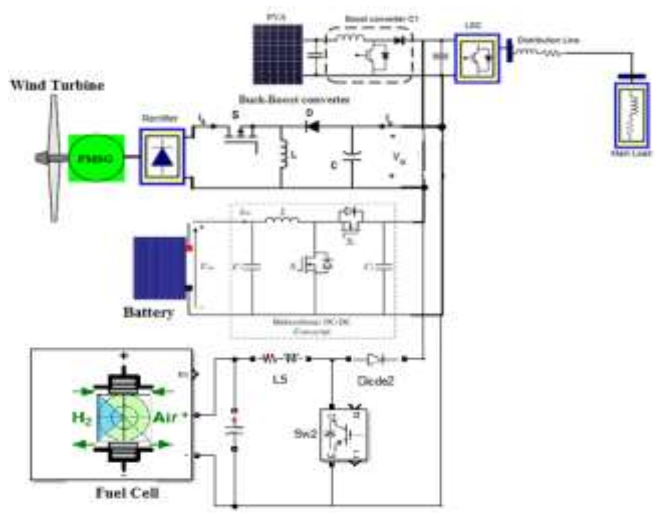


Figure 1. Proposed System with PV Cell, Wind farm, Fuel cell and battery module.

Figure 1 shows the proposed system. The PV panel is connected to boost converter [8-10] controlled by MPPT algorithm for maximum power transfer, the buck-boost converter is connected to wind farm to ensure DC output voltage stability, Fuel cell with PI controller increases voltage transfer capability. Bidirectional dc-dc converter is connected to the battery storage device at grid in order to have exchange of power charging and discharging the battery. All the outputs are connected to a single inverter [10-15] which converts DC voltage to AC voltage feeding the load.

In this work the working of the proposed system converters are discusses in section 2, followed by controllers of these converters along with proposed energy management scheme elaboration in section 3. In section 4, the simulation results of the proposed test system operated by novel energy management scheme with different environmental conditions is presented. Section 5, includes conclusions.

II. PROPOSED TEST SYSTEM

From the Fig- 1, the PV panels are connected to boost converter for increasing the voltage from a lower level. The boost converter is used for the PV panels due to low voltage generation of the PV panels. If the PV panels are generating higher voltage, buck-boost converter should be utilized for increase and furthermore decrement of voltage during various working states [16-20]. Subsequently the wind frame is associated with buck-boost converter which keeps up with the voltage at constant valve in any event, during high voltage variation caused because of change in wind speeds. The machine used for wind frame is PMSG (Permanent magnet synchronous generator) which is the only standalone power generation machine as it involves permanent magnet rotor. The power from PMSG is generated with no outer excitation or power utilization from different sources.

The voltage obtained from PMSG is AC which varies as for wind speeds [20-22]. The frequency, amplitude and period of the AC voltage obtained by PMSG changes consistently, as the wind speed is rarely steady. To maintain steady voltage generation from PMSG the AC voltage is changed over to DC voltage by utilizing diode connected rectifier. The DC voltage produced by the diode bridge rectifier is additionally not consistent, so a buck-boost converter is associated for balancing out the voltage at particular user defined valve. Both the boost converter and buck-boost converter include just one power electronic switch (MOSFET) separately for controlling the output voltages of the converters. The output voltage of the converters is constrained by changing the duty ratio of the switches regarding change in environmental conditions. The duty ratio control of the converter is clarified in section 3.

Battery storage device is connected across to solar panel and wind frames converters through bidirectional converter [23]. This converter is totally not quite the same as the converter presented previously. This is the only converter which works in the two ways, which can charge and discharge the battery. The charging and discharging conditions of the battery is chosen by energy management scheme. The bidirectional converter works in buck mode when the battery should be in charging mode, and worked in boost mode when the battery should be in discharging mode.

Booster converter and buck-boost converter working guideline [24] is very simple straightforward. The higher the duty ratio of the switch the more the output voltage again. With expansion in duty ratio energy stored in the boosting inductor is expanded which brings about increment of output voltage during discharge of the boosting inductor. Bidirectional converter contained two power electronic switches which should be controlled regarding the ideal working state. The two switches are named to be S1 and S2, one associated in series and one associated in parallel. The parallel switch is considered as boost switch and series switch is considered as buck switch.

During buck mode the switch S2 operates the switch S1 is turned OFF completely and with dynamic duty ratio at high switch frequency. WhenS2 is turned OFF and S1 operates the bidirectional converter operated as in boost mode under at high switching frequency [25]. The variation in modes of the converter varies on the power delivered by two renewable sources PV cell and wind farm. The operating conditions of two bidirectional converters can be seen in Fig. 2a and 2b.

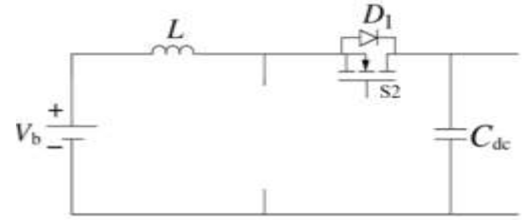


Figure 2a. Buck mode operating state.

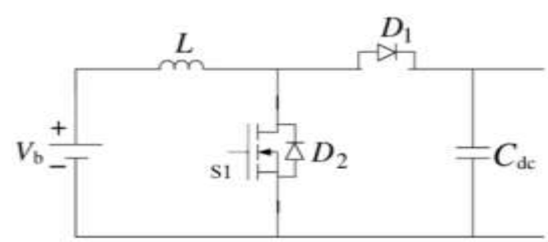


Figure 2b. Boost mode operating state

From the Figure 2a and 2b. Under the boost mode S2 is wound turned off, the switch S1 is working and the body diode D2 of switch S2 will be in forward bias condition which just discharge the battery. The Cdc capacitor is placed to reduce the ripple in the DC voltage output of the converter.

III. CONVERTERS CONTROL AND ENERGY MANAGEMENT

A. *PVA MPPT control*

The booster converter associated with PV panels is varied by MPPT strategy [7] which develops pluses for the switch of booster converter. The MPPT procedure used in the proposed test system is Incremental conductance technique for quicker reaction to the solar radiation changes. The flowchart of working MPPT is observed in the Fig- 3.

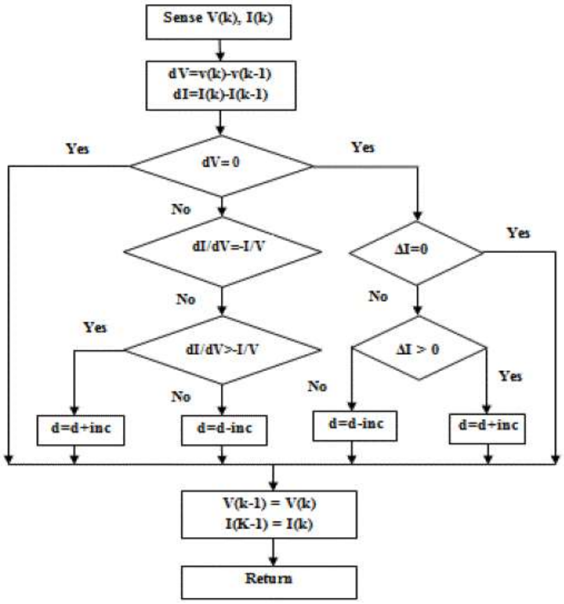


Figure 3. Incremental conductance method MPPT Voltage.

B. *Buck-Boost converter voltage oriented control*

The buck-boost converter is constrained by voltage situated control [9] with output from yield voltage of the converter. The contribution to the converter is taken from three stage diode connect rectifier which gets three stage AC contribution from PMSG machine. The variable DC voltage from the diode bridge rectifier is balanced out by the buck-boost converter at specific value given by the user.

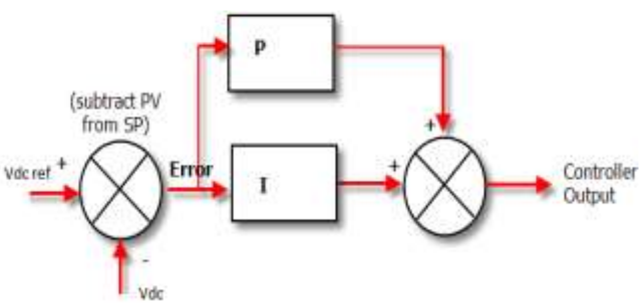


Figure 4. Voltage oriented feedback control strategy.

C. Energy Management Control

All The energy management control deals with the battery working mode with respect to power delivered by the renewable sources of PV panel and wind frame, fuel cell based on load demand. The battery is moved to from no working mode, buck mode and boost mode with comparison of renewable power with lower and upper limit threshold values. The implemented energy management scheme on the proposed test system is shown in Figure 5.

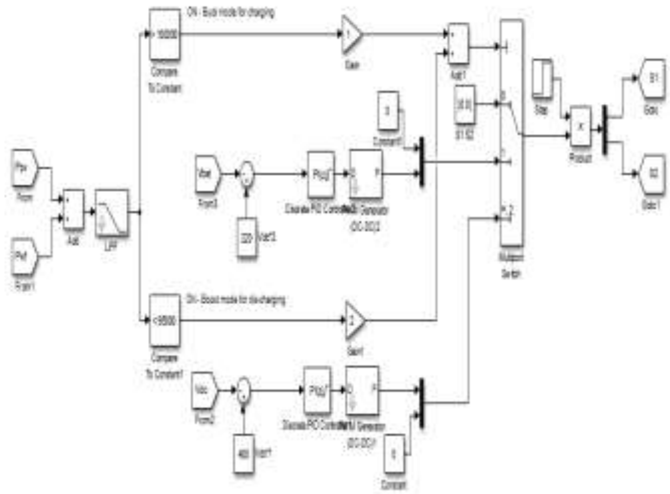


Figure 5. Energy management scheme.

The PV panel, and wind frame powers are accumulated to decide the total renewable power produced went through LPF (Low Pass Filter) to decrease disturbance in the signal. The total power value is compared to maximum limit 100kW and minimum limit 95kW. The both the limit of the controller decides the no working mode, buck mode or boost mode. At the point when the power produced by the renewable sources is somewhere in the range of 100kW and 95kW the battery will be set off to no working mode where the switches S1 and S2 are totally turned down.

In different conditions when the renewable power more than 100kW the bidirectional converter is worked in buck mode which charges the battery, and when the power dips under 95kW the converter works in boost mode which gives shortage power to the load from the battery. Both the regulators of the converter in buck mode and boost mode use voltage arranged feedback control, which are given reference voltages of 220V and 400V for buck and boost modes separately. Here 220V is the battery voltage and 400V is the voltage reference of DC link. A multiport switch is utilized to switching between one mode to other mode. The mode is given as '0' for non-working mode, '1' for buck mode, '2' for boost mode.

IV. SIMULATION RESULTS AND DISCUSSION.

The proposed system as shown in Figure 1 is developed by using Simulink software. The system consist of PV cell with booster converter controlled by MPPT, PMSG wind frame with buck boost converter, fuel cell component with boost converter and battery with bidirectional converter. The all the sources are connected to single phase load using single phase inverter. The LC filter placed before the load. The LC filter reduces harmonics generated from the inverter and develop accurate sinusoidal voltage for the load. The load is fixed with load of 100kW which is taken care of by PV panel, wind frame and fuel cell sources. Ideal power of the PV panel produced during 1000W/mt2 sun oriented illumination is 100kW and power created from wind frame is 50kW during 12mt/sec wind speed.

The performance of the proposed system under the following cases are observed

- Solar cell without wind frame, fuel cell and Battery storage system
- Solar cell with wind frame and without fuel cell and Battery stroge system
- Solar cell with wind frame, fuel cell and with Battery stroge system.

A. Solar cell without wind frame, fuel cell and Battery storage system

When PV Cell only supplying power to the load without using other sources of wind, Fuel cell and without battery support, the corresponding waveforms as observed from the Figure 6. The PV cell is supplying power of 100kw to the load under the Irradiation of 1000W/mt2, for the duration of 0 - 2.5sec. The sudden decreasing of irradiation of 200W/mt2 from 2.5 sec-7.5sec, the PV cell supplying power of only 10kw to the load is observed from the Figure 6. The load receiving power of 100kw up to 2.5 sec. From 2.5sec- 7.5sec the load received deficiency power of 10kw only because unavailability of solar irradiation. As observed from the Figure 6.The load not receiving constant power which may damage the load.

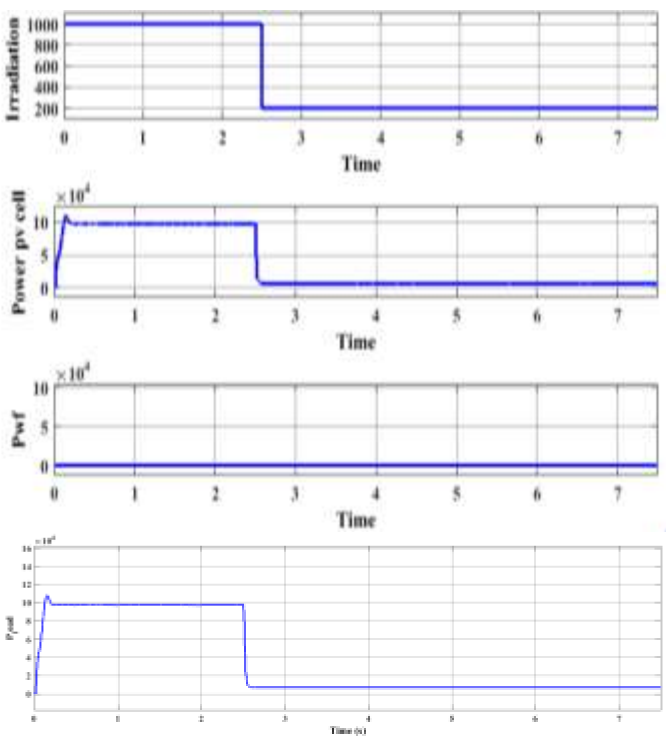


Figure 6. Output Wave forms of Irradiation, solar and Load output power.

B. Solar cell with wind frame and without fuel cell and Battery stroge system

The two sources of PV cell and wind frame are supplying the power to the load without using Fuel cell and battery storage system, as observed from the Figure 7.The PV Source and wind frame operated in co-ordinately and supplying a power of 100kw to the load up to the duration of 2.5sec. And two sources are sharing power almost equally as observed form Figure 7. The sudden decreeing of solar irradiation from 1000W/mt2 to 200W/mt2, the PV Cell supplying power of 10kw only and wind frame supplying same power (60kw), the load received total deficiency power of is 70kw only as observed from Figure 7. This also supplying in consistent power which will effecting the load.

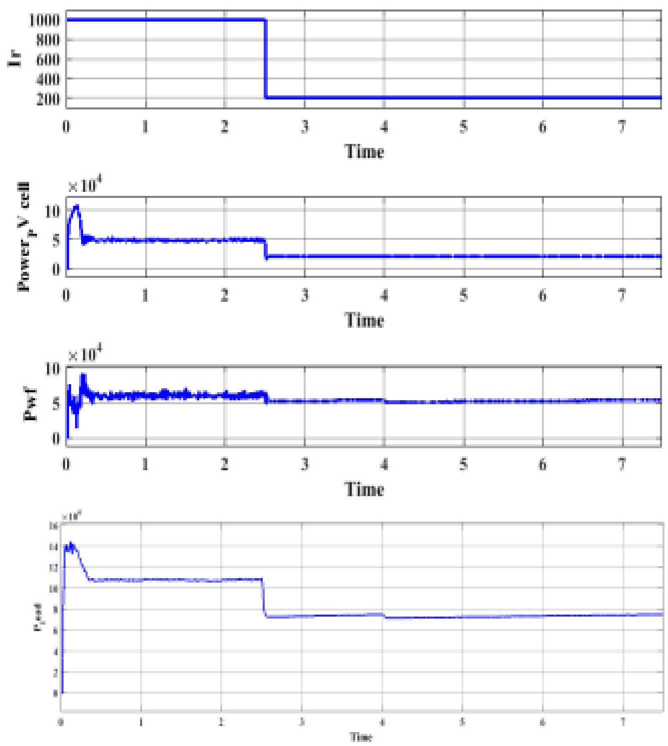


Figure 7. Output Wave forms of Irradiation, solar, wind and Load output power.

C. Solar cell with wind frame, fuel cell and with Battery stroge system

All Fig -8. Shows the output wave forms of PV cell, wind frame and Fuel cell with battery storage system. The three sources of PV cell, wind frame and Fuel cell operated under energy management system and supplying constant power the load. Even through sudden decreeing of solar irradiation from 1000W/mt2 to 200W/mt2, the load receives constant power. The batter is charging during available source power and supplying power to the load during unavailability of source power. The load always receiving constant power of 100kw.

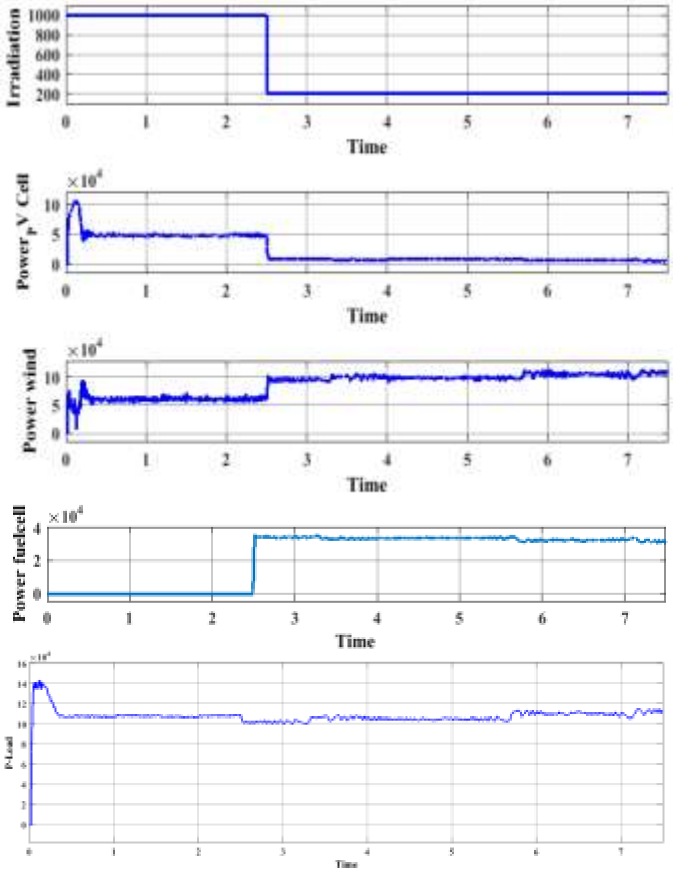


Figure 8. Output Wave forms of Irradiation, solar, wind, fuel cell and Load output power.

The DC-link voltage waveform as shown in Figure 9. The DC link voltage is kept up with at 350V consistent is any state of the test system.

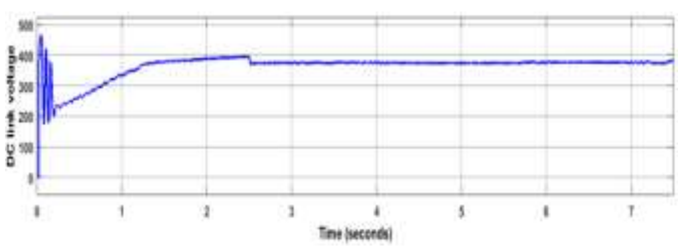
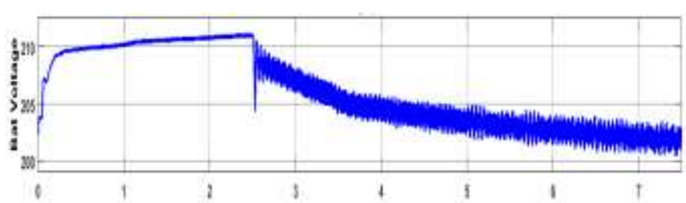


Figure 9. DC link voltage at PCC.

The time of operation is also observed separately from 0-0.25sec and 0.25sec to 0.75. and also without battery and with battery, without fuel cell and with fuel cell, without and with wind frame is studied.



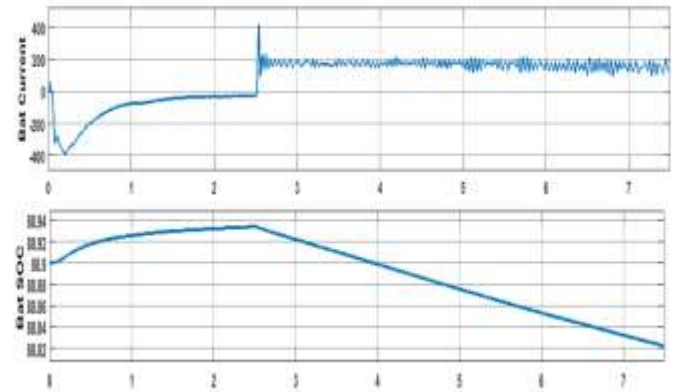


Figure 10. Battery characteristics.

Figure 10. shows the battery characteristics wave form.The above battery characteristics show the battery is in charging state until 2.5sec of SOC (State of Charge) rising and battery begins releasing from 2.5sec until 7.5sec with dropping SOC as the solar irradiation and wind speed drops.

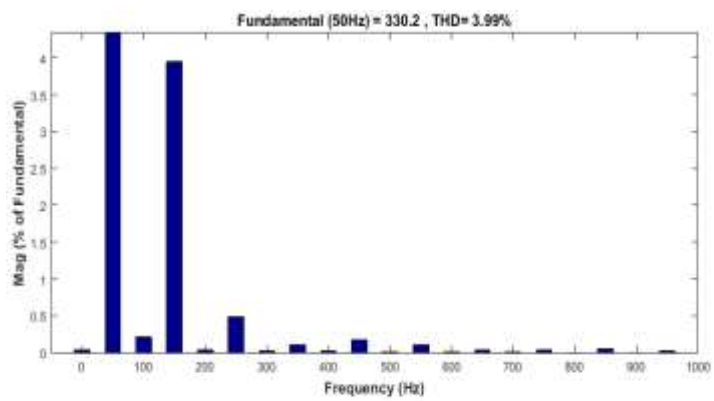


Figure 11. THD of load voltage.

Figure 11 Shows the total harmonic distraction waveform. The THD of load is maintaining at 3.99%. And amplitude of the voltage is recorded at 343.2V.

V. Conclusion

The renewable source of standalone micro grid network performed very well under with various sources conditions is observed by using simulation results. From the simulation results it is seen that the wind, fuel cell, fuel and PV system maintain the load with battery supports. The battery is storing energy when low burden condition. The battery is likewise charged when abundance power is created by the renewable sources, which is later release when there is shortfall of power needed by the load. In any condition the DC link voltage is continually kept up with at 350V and AC voltage created with top worth of 343V which is peak of 240V RMS value. The THD of the load voltage is kept up with underneath 5% which is according to the IEEE normalized esteem. In any atmospheric condition the standalone test system load power is kept up with at 100kW with steady state voltage.

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