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Analysis of Grid-Connected PV-Wind-Battery based Multi-Input Transformer Coupled Bidirectional DC-DC Converter

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Abstract: *This paper proposed a control technique for improving power quality in Grid-connected Hybrid PV-wind-battery based framework with a multi-input bidirectional dc-dc converter. The proposed system measures the load demand, deals with the power flow of various sources, injects surplus power into the grid and the battery is charged from grid as per requirement. A boost converter is employed to control voltage from wind, while bidirectional buck-boost converter is utilized to control output voltage from PV in conjunction with battery charging control. The battery charging and analyzer are proposed to manage power requirement of the system. The proposed work optimized power ratio and quality of the system efficiently.*

Keywords: *Solar Photovoltaic, Wind Energy, Hybrid System, Transformer Coupled Boost Dual-Half-Bridge Bidirectional Converter, Bidirectional Buck-Boost Converter, Full Bridge Bidirectional Converter*

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I. Introduction

The electrical system that includes compound loads and distributed energy resources that can be operated in parallel within the border utility grid is called micro grid. Various countries generate electricity in large centralized facilities, these plants have exceptional economies of scale, and usually transmit electricity to extended distances so are relatively costly and can adversely disturb the environment. Solar photovoltaic (PV) and wind have developed as popular energy sources due to their eco-accommodating nature and are both clean and cost effective sources that seemingly do not require any fuel (unlike fuel cell stack, biogas etc.).

However, these sources are irregular in nature. To supply steady and constant power battery with the controller is connected. Consequently, it is a best way to supply demand and constant power utilizing these sources. For accomplishing the understanding of different inexhaustible sources, the normal methodology includes utilizing committed single-input converters one for each source, which are associated with a typical dc-transport. In any case, these converters are not effectively used, due to the irregular nature of the renewable energy sources. In addition, there are different power transformation stages which decrease the effectiveness of the system.

Today, wind vitality is principally used to produce power. Wind is known as a sustainable vitality source on.

Hybrid power system (HPS) are self-sufficient power creating frameworks that have more than one renewable sources, worked alongside related supporting gear (counting stockpiling) to supply capacity to the network or on location. Through this joining of different energy sources in a single supply framework, the innovation of hybridization gives a perfect opportunity to utilize locally available sustainable power hotspots for supply control in remote areas. Hybrid system in the main covers complete systems still as island grids of little and medium power ranges. Altogether cases, it contains two or a lot of power generation sources so as to balance every other's strengths and weaknesses.

A hybrid system may contain AC (or DC) diesel generators, an AC (or DC) structure, loads, renewable power sources, energy storing blocks , control converters, rotating converters, coupled diesel frameworks, load management options or a supervisory control system. Examples of hybrid systems include:

- Wind turbines with battery storing and diesel support generators;
- Solid oxide cell combined with a turbine or micro turbine;
- Sterling engine combined with a solar dish;
- Engines (and diverse prime movers) joined with energy storing gadgets, similar to flywheels.

II. Related Work

With the purpose behind improving the capability of the drive train and to constrain the dependence on the oil fills somewhere around two sources of the driving forces (including ICE) are being used by the vehicles. These are known as the Hybrid Electric Vehicles (HEVs). The topological graph of the diverse half and half drive trains and the comparison between them has been presented. The part and the essential of the power devices and dc converter in the HEV development was researched and explained. The correlation between the diverse not separated Bidirectional DC-DC converters on the preface of their execution has been done. Speed decision and the diverse drive get ready issues depending up on the balance drive necessities and operational execution has been done. The thoughts of the fragile trading systems for the possibility change and the device extend decline.

III. Proposed Work

The proposed converter involves a transformer coupled boost double half-connect bidirectional converter interlaced with bidirectional buck support converter and a particular stage full-connect inverter. The proposed converter has reduced number of power change stages with less part figure and high capability raised out from the present structure associated plans. The topology is essential and needs only six power switches. The boost dual half-connect converter has two dc-interfaces on the two sides of the high repeat transformer. Controlling the voltage of one of the dc-joins ensures controlling the voltage of the other. This makes the control strategy fundamental. In addition, converters can be facilitated with any of the two dc-joins. A bidirectional buck-support dc-dc converter is facilitated with the fundamental side dc-interface and single-stage full-associate bidirectional converter is related with the dc-interface of the optional side.

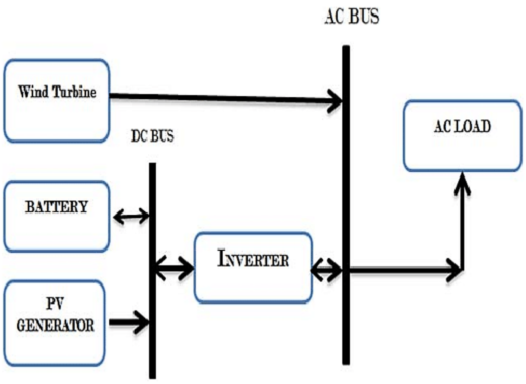
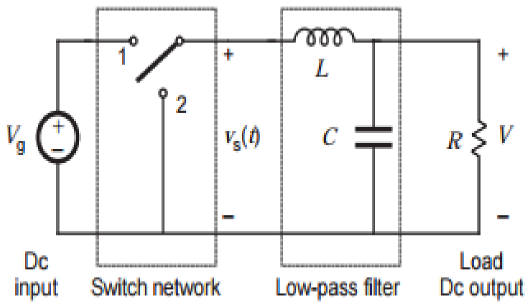


Figure 1 PV/Wind hybrid system.

A. DC–DC Converter

Dc-dc control converters are utilized in an variety of uses, including power supplies for PCs, office gear, shuttle control frameworks, PCs, broadcast communications hardware, and in addition dc engine drives. The contribution to a dc-dc converter is an unregulated dc voltage Vg. The converter creates a directed yield voltage V, having an extent (and feasibly extreme) that varies from Vg. For instance, in a PC disconnected power supply, the 120 V or 240 V air conditioning utility voltages is redressed, delivering a dc voltage of around 170 V or 340 V, individually. A dc-dc converter at that point decreases the voltage to the directed 5 V or 3.3 V required by the processor ICs.



(a)

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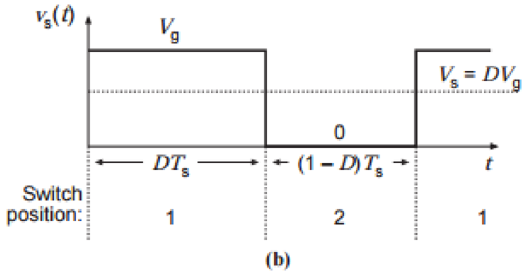

Figure.2 the buck converter consists of a switch network that reduces the dc component of voltage, and a low-pass filter that removes the high-frequency switching harmonics: (a) schematic, (b) switch voltage waveform

High effectiveness is continuously required, since cooling of wasteful power converters is troublesome and costly. The perfect dc-dc converter displays 100% productivity; practically speaking, efficiencies of 70% to 95% are ordinarily developed. This is accomplished utilizing exchanged mode, or chopper, circuits whose components disperse immaterial power. Pulse width modulation (PWM) permits control and direction of the aggregate yield voltage. This methodology is additionally utilized in applications including rotating current, including high-proficiency dc-ac power converters (inverters and power fixings), ac-ac power converters, and some ac dc control converters (low-consonant rectifiers).

A major dc-dc converter circuit known as the buck converter is laid out in Fig.2. A Single Pole, Double Throw (SPDT) change is related with the dc input voltage V_g as showed up. The switch yield voltage $_{Vs}$(t) is identical to Vg when the switch is in position 1, and is proportional to zero when the switch is in position 2. The switch position is changes irregularly, with the true objective that V_s(t) is a rectangular waveform having period Ts and commitment cycle D. The commitment cycle is equal to the part of time that the switch is related in position 1, and in this manner $0 \leq D \leq 1$. The trading repeat f_s is comparable to $1/T_s$. Before long, the SPDT switch is recognized using semiconductor devices, for instance, diodes, control MOSFETs, IGBTs, BJTs, or thyristors. Ordinary trading frequencies lie in the range of 1 kHz to 1 MHz, depending on the speed of the semiconductor devices.

The switch network changes the dc portion of the voltage. By Fourier examination, the dc portion of a waveform is given by its average value. The typical estimation of Vs(t) is given by

$$V_s = \frac{1}{T_s}\int_0^{T_s} v_s(t)dt = DV_g \tag{1}$$

The basic is equivalent to the region under the waveform, or the figure Vg duplicated when DTs. It very well may be seen that the switch arrange reduces the dc segment of the voltage by a factor equivalent to the requirement cycle D. Since $0 \leq D \leq 1$, the dc segment of Vs is not exactly or equivalent to Vg.The purpose of the DC/DC converter in this work is to maintain a constant output voltage regardless of varying input voltage. It is also possible to control the output voltage in instruction to path a position, but this makes the DC/DC converter more complex and expensive. The converter should be dynamic enough to respond to the changes in required power and make the required power available on the bus. Buck, boost and buck-boost DC/DC converters are the commonly known types. DC/DC converters can also be mono-or bi-directional. Bi-directional DC/DC converters can transfer power to and from source thus allowing the regenerated energy to be saved.

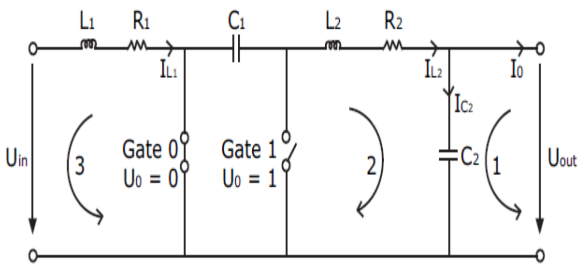

Figure.3: Circuit diagram of DC/DC converter

In this investigation, two sorts of DC/DC converter for power device application are considered. To start with, the unidirectional DC/DC converter changes the DC energy unit total capacity to yield voltage-current necessities of the outside power devices that associate with a FC system. Here we think about a boost converter (appeared in Figure 3) that can be utilized in PEM energy unit applications. The voltage and current at the DC/DC converter input are the FC total voltage Vst and the net FC current Inet, individually. In determined state, the converter usefulness can be depicted by

$$V_{st} I_{net} = v_{bus} I_{dc} \quad (2)$$

$$(1-d) I_{net} = I_{dc} \quad (3)$$

The bus voltage vbus and the output current Idc are associated with the duty cycle d of the solid state switch in the circuit. The inductance of input inductor Lin, the capacitance of output capacitor Cout and the resistance of the load Rload are shown in Figure 3.

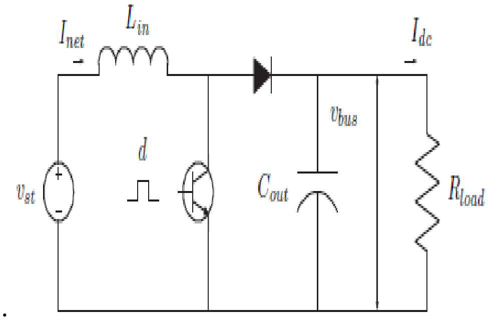

Figure 4: DC/DC boost converter

In the area of fuel cell power applications, bidirectional DC/DC converter is considered, specifically in a load-following fuel cell system that the FC power meets most of power demand while small-sized battery covers some transients and start-up/shutdown . Bidirectional converter has an ability to match high voltage fuel cells with low voltage battery when fuel cell is directly connected to the DC bus in a hybrid configuration. Figure 4. depicts one of the bidirectional converter topology for low voltage battery and high voltage DC bus.

B. DC/DC converter model

In this investigation, the DC/DC boost converter is chosen for 50 kW control and dependent on 400 V output voltage with input voltage is 250 V and along these lines input current is 200 A. In a perfect world the info control is prepared in a converter with 100 % effectiveness. Real proficiency is somewhat under 100 % because of the troubles in the inductor, capacitor, transformer, and switch and controller circuit.

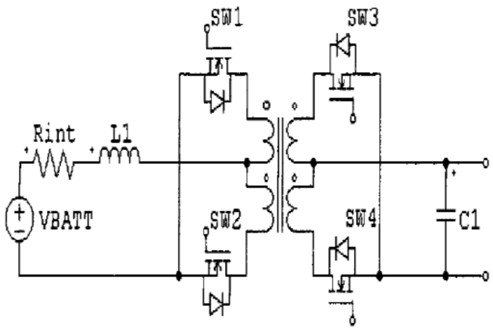

Figure 5: Bidirectional DC/DC converter

A usual boost converter for PEM energy component application has around 95 % effectiveness when the voltage support proportion is incompletely two.

Expanding Lin lessens the great of the info current. Although considerable Lin buffers the structure from high frequency AC current, the related increment in opposition may diminish the converter productivity. The extent of Cout is typically controlled by the great detail of yield voltage. Different reviews, for example, the voltage and current limit of the capacitor should to likewise be accounted particularly because of high voltage and current qualities related with FC applications. For the ensuing unique investigation, the estimations of inductor and capacitor are chosen to be as L_{in} = 1 mH and C_{out} = 1200 μF.

$$L_{in} \frac{dI_{net}}{dt} = v_{st} - (1-d) v_{bus} \quad (4)$$

$$C_{out}\frac{dv_{bus}}{dt}=\left(1-d\right)I_{net}-\frac{v_{bus}}{R_{load}} \tag{5}$$

The inputs to the converter, based on realistic FC operation, are the duty cycle d, the input voltage vst, and the output current, $I_{dc}=V_{bus}/R_{load}$. Linearization and Laplace transformation from these inputs to the output voltage vbus provide the following transfer functions.

$$v_{bus}=G_d\left(s\right)d+G_v\left(s\right)v_{st}-Z_{out}\left(s\right)I_{out} \tag{6}$$

$$G_d\left(s\right)=\frac{\dfrac{v_{bus,n}}{\left(1-d_n\right)R_{load,n}C_{out}}\left[\dfrac{\left(1-d_n\right)^2R_{load,n}}{L_{in}}-s\right]}{s^2+\dfrac{1}{R_{load,n}C_{out}}s+\dfrac{\left(1-d_n\right)^2}{L_{in}C_{out}}} \tag{7}$$

$$G_v\left(s\right)=\frac{\dfrac{1-d_n}{L_{in}C_{out}}}{s^2+\dfrac{1}{R_{load,n}C_{out}}s+\dfrac{\left(1-d_n\right)^2}{L_{in}C_{out}}} \tag{8}$$

$$Z_{out}\left(s\right)=\frac{\dfrac{1}{C_{out}}s}{s^2+\dfrac{1}{R_{load,n}C_{out}}s+\dfrac{\left(1-d_n\right)^2}{L_{in}C_{out}}} \tag{9}$$

Where d_n is the nominal duty cycle and R_{load},n is the supposed load opposition. The exchange work Z_{out} is called converter impedance and speaks to the impact of little load (current) changes to V_{bus}.

C. Battery

Batteries are electrochemical storage components where energy which is chemically bounded is converted to electrical energy just like the fuel cells; in batteries the process is flexible. Chemical energy is converted to electrical energy and vice-versa. According to [1], a battery can be modeled as a large capacitor. The chemical procedures in electrolyte can be represented by an internal resistance. According to author, to ensure safe and reliable battery operation battery management (or power management systems) is important. For this purpose, monitoring of temperature, voltages, currents are required and an estimation of states like SoC is needed. Commonly used models are electrochemical models and equivalent circuit models. A comparison and evaluation of seven battery models have been presented. As electrochemical models are complex and deal with a large number of unknown parameters, only equivalent circuit models are considered in this contribution. Some of the equivalent circuit models are Thevenin, Rint, and DP models. The disadvantage is that the relation between internal resistance and current is not considered. In reality, internal resistance is related to non-linear processes for which electrochemical models are required. In the non-linearity of battery resistance is investigated and the dependency of impedance on factors such as SoC is studied.

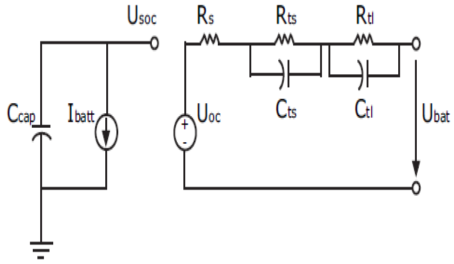

Figure 6: Battery

According to author, an alternative solution is to develop black box models using experimental data derived from constant current discharge tests. Fitting techniques can then be used to obtain input-output relations.

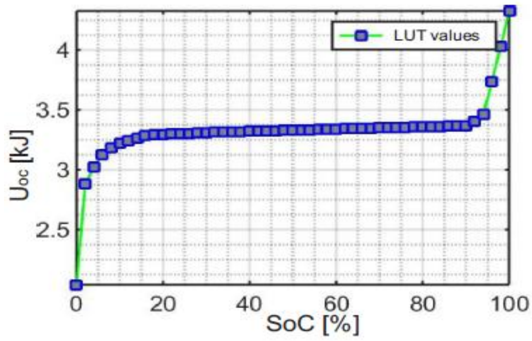

Figure 7: Relation between SoC and voltage

Developing accurate methods to estimate states like SoC is a challenge. The approach called ’Coulomb counting’ is briefly described along with quasi-static and dynamic modeling of batteries. [19]The quasi-static model is based on R_{int} model and dynamic model based on Thevenin model.

D. The Solar PV System

Solar PV generation involves the generation of electricity from solar energy. With the greater enhancement in inverter advancements, PV cell is currently chosen worldwide as Distributed Energy Resources (DERs). The significant preferences of a PV structure are:
(a) The economical idea of solar energy
(b) Positive natural effect
(c) Longer life time and silent activity.

The most normally utilized model for a PV cell is the one-diode equal circuit as appeared in fig.8. Since the shunt obstruction R_{sh} is infinite, it tends to be ignored. The five parameters demonstrate appeared in fig.8 (a) and efficient four parameters display appeared in Fig. 8(b).

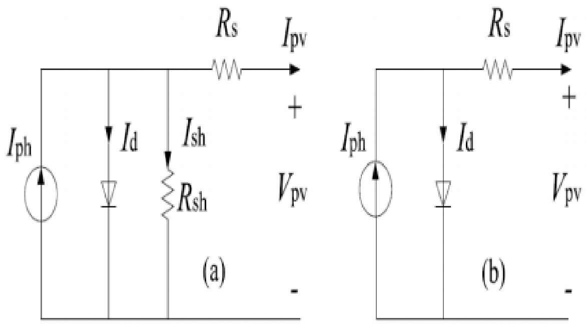

Figure.8 One-diode equivalent circuit model for PV cell (a) five parameters model; (b) simplified four parameters model.

This simplified equivalent circuit model is represented by the following expressions:

$$\begin{aligned} I_{pv} &= I_{ph} - I_d \\ I_d &= I_0\left[\exp((V_{pv} - R_s I)/V_t) - 1\right] \\ I_{ph} &= G/G_{ref}\left[I_{ph,ref} + \lambda_I (T_c - T_{c,ref})\right] \end{aligned} \quad (10)$$

Where I_{ph} is the light current, I_{pv} is the load current and I_o is the immersion current. The $V_{pv}$is the yield voltage, R_s is the arrangement obstruction, the V_t is the warm voltage, G is the illumination, Tc is the cell temperature and λI is the temperature coefficient. The primary PV parameters are V_{mp}, I_{mp}, V_{oc}, I_{sc}, P_{max}. Sun based PV stage system is a conveyed power age and supply system, comprising of PV battery exhibit, PV converter, system controller, storing and nearby loads. Its evaluated yield control is determined under the standard state of light energy 1000W/m^2 and temperature 25°C, and its open yield control is affected by numerous variables. The PV system is a decent decision to supply self-governingly, extraordinary appropriate for the remaining tasks at hand not ask for top notch control and the remote region with incredible expense of power.

IV. Results

In proposed work design hybrid power system. That is connected battery, PV and Wind. Here show basic parameter of the system in table 1.

Here figure 9 show voltage generation of wind and figure 10 show current generation of wind according the load demand and wind speed. Demand variation of the speed of rotor. It is seen that according to the wind speed variation, the generator speed varies and that its power to rotating speed of rotor is produced corresponding to the wind speed variation.

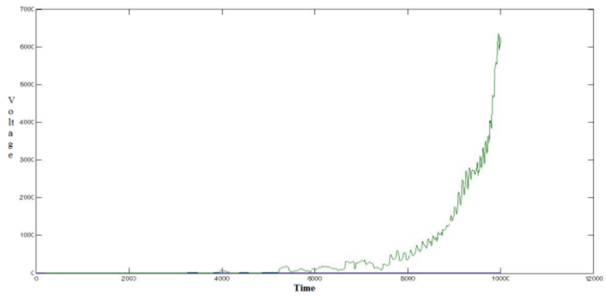

Figure: 9 Wind voltage with respect to Time

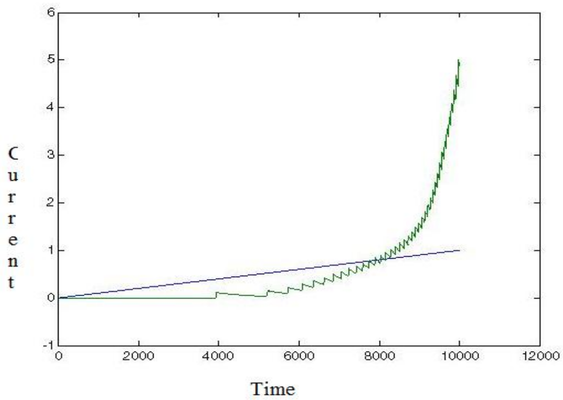

Figure: 10 Wind current with respect to Time

Same here figure 11 show PV voltage as generated through pv panel with respect to time and irradiance value all is manage by MPPT.

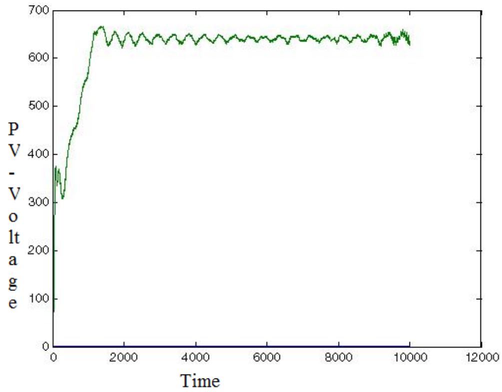

Figure: 11 PV voltage with respect to Time

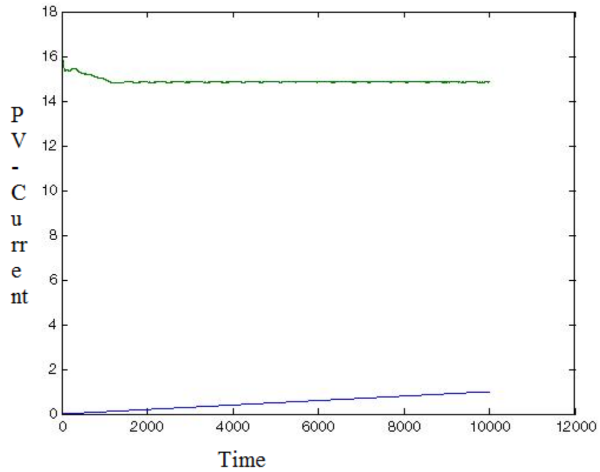

Figure: 12 PV Current with respect to Time

Figure 13 show power graph between load , PV , Battery, and wind power. In this four color wave form cyan color shows battery power, pink color shows wind power, yellow color show PV power, and red color shows load power.

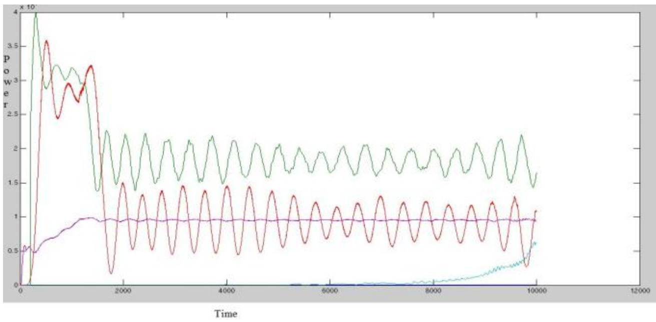

Figure:13 Different power compares with respect to Time

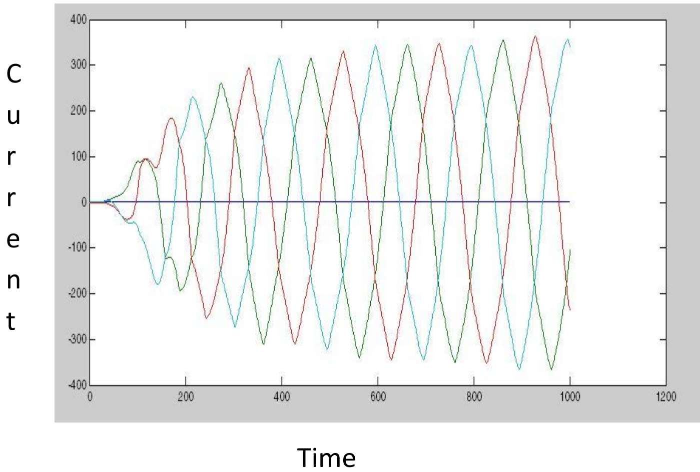

Figure 14: Output Current with respect to Time

In Figure14, the current produced by PV and wind is high; the load demand is also high. In this case the PV alone is sufficient to run the load; the excess power from the wind is used to charge the battery through. Figure 15 show voltage demand of the load as for load variation its fulfill all condition without delay.

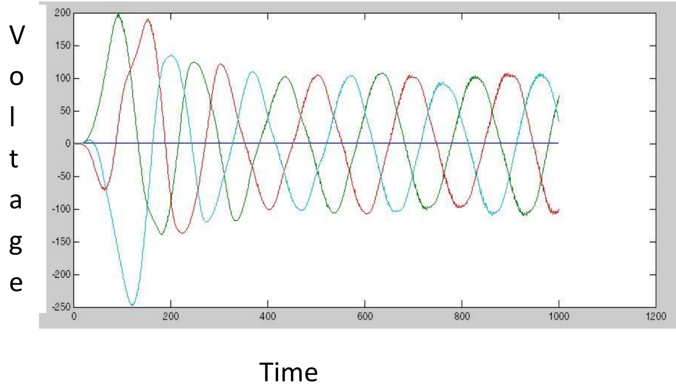

Figure 15: Output Voltage with respect to Time

Figure 16 is show harmonic distortion (THD) of the system that is less. THD of the system is 5.34% that is indication, our system generate best quality power and less harmonic.

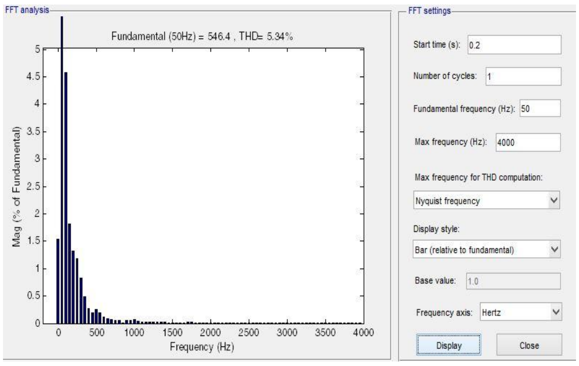

Figure16: THD Value

Table 1 Parameters value

Parameter	Value
Base Torque	8500,152.89
MH Battery	200V
MPPT Voltage	666V
LC filter	2mH
Fundamental frequency	50Hz
Carrier Frequency	10000
Proportional Gain	60kp
Integral Gain	550ki
Resistance	0.001ohms
Inductance	0H
Forward Voltage	1V

V. Conclusion

This proposed work presents the modelling of DC Grid-connected with solar and wind as their input source. These renewable sources are integrated into the main DC bus through bi directional dc-dc converter. Wind energy variation and rapidly change in solar irradiance was considered in order to explore the effect of such environment variations to the proposed grid connected system. Network are utilizes elective power structures to help these load focuses, for example, sun based power, wind control and so on. In this exploration work solar power was chosen as an elective energy source. In this simulation proposed system is manage load variation and manage quality output. The inexhaustible power which can be created from the sustainable assets can be incorporated by the aggregated model. By this assembled model the power for the individual time can be determined. Proposed work decreased harmonics and optimized power quality. THD value is 5.34%..

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