PERFORMANCE OF HYBRID SOLAR-WIND ENERGY GENERATING SYSTEM - PROTOTYPE MODEL

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Abstract:

In this modern world, the usage of electrical energy for daily basis increased rapidly. This has created more burden on the demand for conventional energy. This also effects on environment pollution created by the bi-products of electrical energy generation. Renewable energy is an alternative solution in future to meet the energy depend. Hybrid energy systems produce the power to meet the requirements of individual power utility. Hybrid systems made up of the combination of solar and wind energy systems improve the stability among all renewable sources. Wind and solar energies are more abundant and complimentary to each other. In this paper, a prototype model of hybrid energy system is developed using the combination of solar and wind energy system and the performance of the hybrid system is analysed. Energy from solar and wind are given to SEPIC converter for boosting the voltage level. The control strategy from spartan6 FPGA will be given to all the converters in the system. The DC link voltage is maintained to a higher fixed value for stability purpose. Voltage source inverter transforms the variable energy to a fixed AC power which is given to AC induction motor. In the absence of solar and wind, the backup energy from battery is utilized to meet the connected load demand to this hybrid system. The individual and combination of solar-wind-battery is analysed with DC and AC loads. A quality and stabilized power of frequency almost equal to 50 Hz is supplied to the load. Harmonic content is also reduced to 0.02% when solar energy system is considered. Practically, harmonics are compared for each combination. The conversion of renewable energy to electrical energy system performed satisfactory.

Key words*: Solar-wind, Hybrid energy, FPGA, DC-DC converter, VSI, Battery storage, Harmonics, Induction motor.*

1. INTRODUCTION

Solar can only create electricity in the day time owing to sunlight. Wind increases in the evening and peaks at night. Solar-Wind Hybrids can even out power generation because to the alternative supply of wind and solar. Hybrids increase grid reliability by meeting peak power needs. The National Wind-Solar Hybrid Policy has helped promote hybrid wind and solar projects in India. The strategy aims to optimise and increase the use of transmission system and land, which will decrease renewable power discrepancies and improve grid stability. Hybrid plant layout with an integration of solar-wind technology is key for fulfilling the need of modern power supply. Second, resource characteristics will determine sizing. In order to enjoy the advantages of a hybrid system in terms of ideal and efficient utilisation of transmission infrastructure as well as improved grid stability through the reduction of variability in power generation from renewable sources, the size of the solar PVs capacity that is introduced as the Solar-Hybrid constituent could be relatively smaller in locations where wind power quantity is quite good. This is because in these locations wind power density is quite good. In contrast hand, in the event of locations with a wind power density that is on the lower or moderate end of the spectrum, the proportion of the site's capacity that is comprised of solar photovoltaics may be on the higher end.

2. PROPOSED SYSTEM LAYOUT

Hybrid system consists of solar Panel and Vertical Axis wind turbine units are connected to a DC link through boost converter. A battery unit also connected thorough DC-DC bidirectional boost converter. From the DC link Three Phase voltage source inverter connected to the Induction motor as a load. DC load is also connected in the form of Resistor.

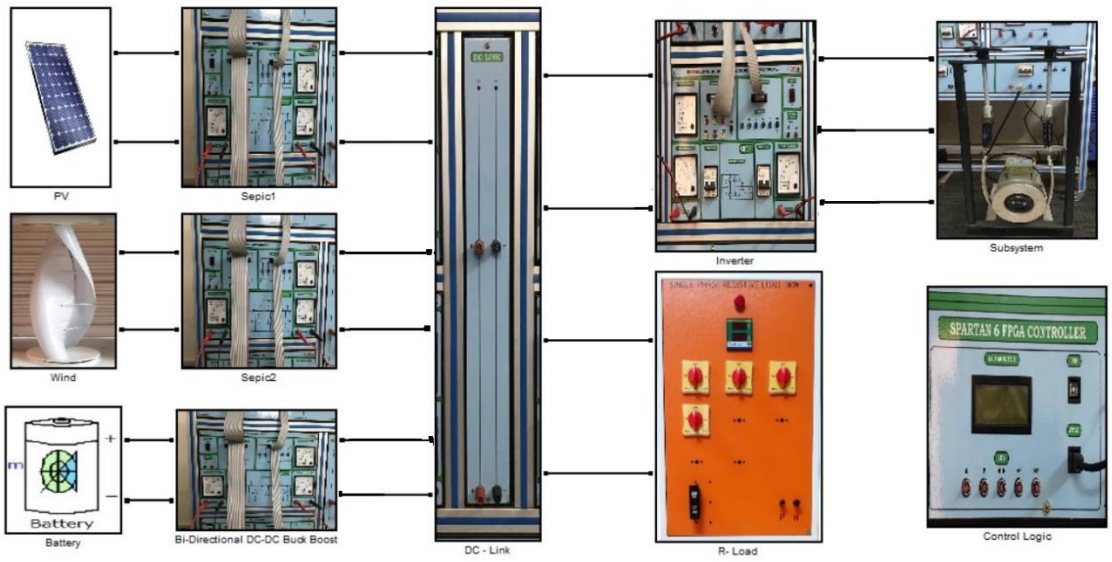

Fig 1. Proposed Hybrid system model

In this module consist of two 1KW SEPIC converters1 for solar setup and 1KW SEPIC converter2 for wind setup. Also contains DC link or DC bus, three phase interleaved bi-directional dc-dc buck boost converter for charging and discharging the batteries. Grid side

three phase voltage source inverter and Batteries. The details about each component explained in this section.

2.1 SEPIC CONVERTER

2.2

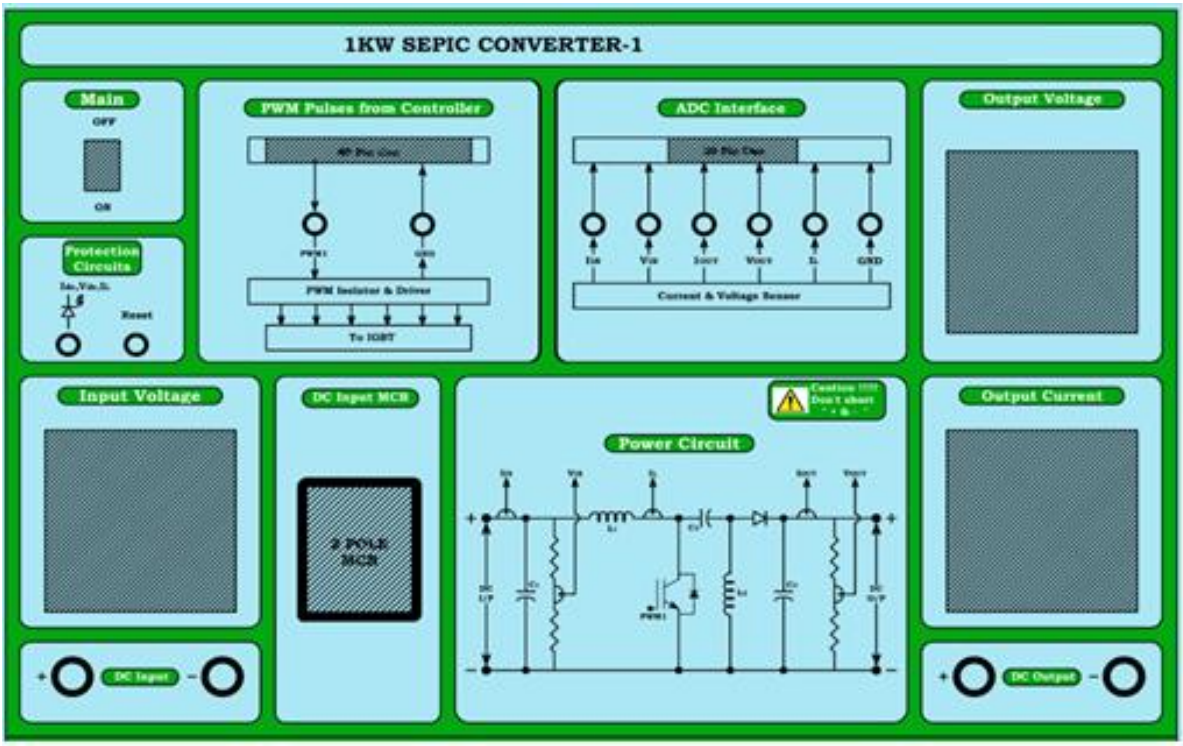

Fig2. SEPIC converter

SEPIC Converter used for both the solar and wind power systems for taking the voltage level to a high fixed value. A form of direct current to direct current (DC/DC) converter known as a single-ended primary-inductor converter (SEPIC) is a device that permits the electrical potential (voltage) being at output to be higher than, less than, or equal to that at its input. The duty cycle of the controller determines how much current is allowed to flow through the SEPIC.

2.2 DC Link

Solar power and wind power will be maintained in the DC link. In this link, remaining VSI and batteries are connected to transform the power. This voltage will always be kept to a high fixed value. Power transforms from higher potential to lower potential.

2.3 Three Phase Interleaved Bi-Directional Dc-Dc Buck Boost Converter

In this module consist of one three phase interleaved DC-DC bidirectional converter.

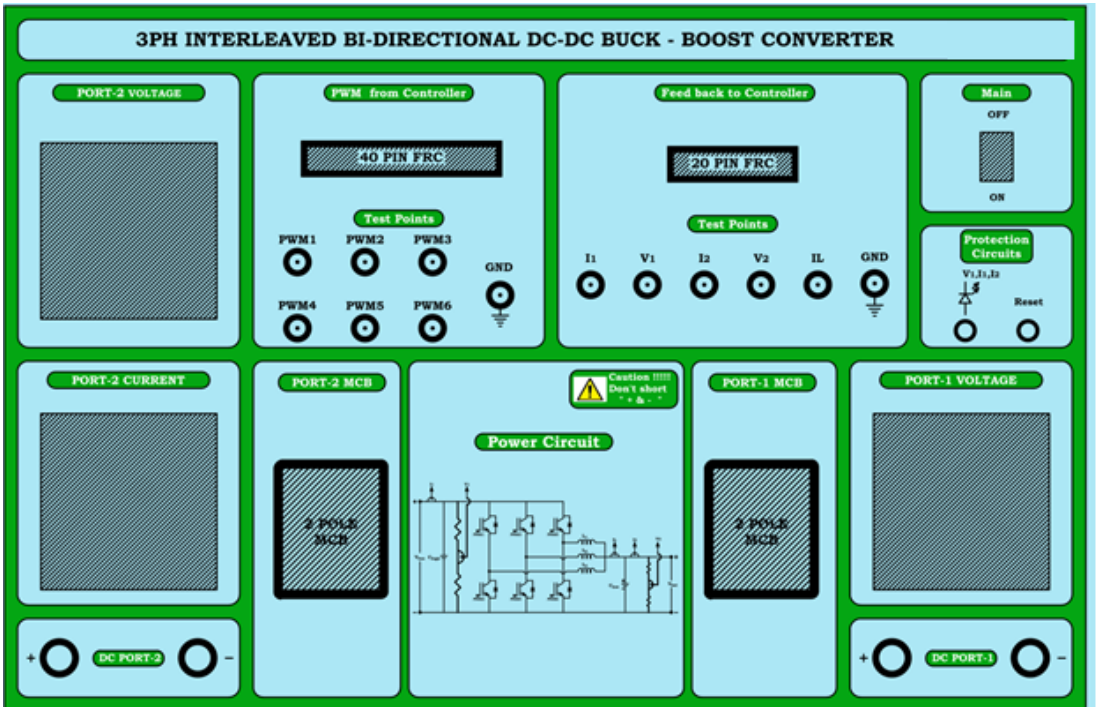

Fig. 3. Three Phase Interleaved Bi-Directional Dc-Dc Buck Boost Converter

The DC-DC bi-directional buck boost converter operates in two modes. When there is no supply from solar-wind sources, it operates in buck mode energy transmitted to the dc link from the connected battery. Control strategy to operate in boost mode will be developed by the Spartan 6 FPGA controller. In this boost mode energy will be stored in batteries. The below table shows the ratings of parameters associated to this converter.

Parameter	**Ratings**
Inverter rating	1KVA
Nominal current	5A
Nominal voltage	230V per phase
Weight:	2.7kg
Protection current	12A
Maximum DC link voltage in Vbus	350V
Maximum DC link voltage in battery side	160V

Table 1. DC-DC Bi- Directional Buck Boost Converter Ratings

2.4 Three Phase Voltage Source Inverter

An inverter is a kind of power electronic equipment that can convert electricity from one form to another, such as from direct current to alternating current, while maintaining the required frequency and voltage output.

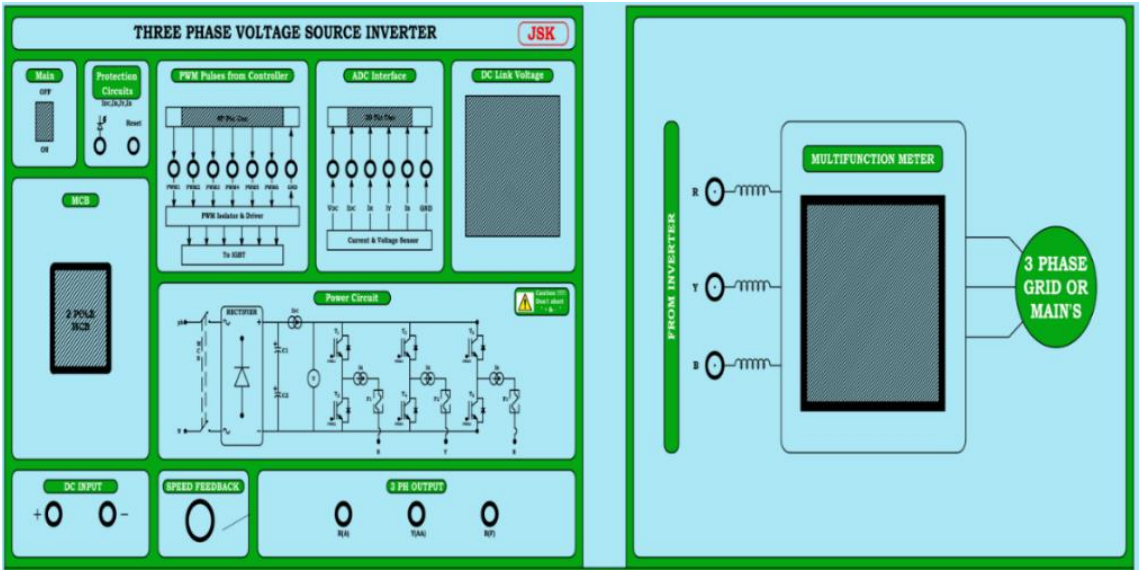

Fig. 4. Three Phase Voltage Source Inverter

The input terminals of a VSI type inverter have a DC voltage source that has a lower impedance than other types of inverters. The inverter of the CSI type utilises a DC current source that has a high impedance. We are aware that an inverter will convert DC current into AC current. In order to convert the DC power into a three-phase AC supply, an inverter with three phases is required. In the power transformation from DC-AC harmonics rectified and pure sinusoidal wave form at load we found. The frequency is also will be at 50 Hz.

The ratings of the parameters used in this hybrid system given in the below table2.

Parameter	Ratings
Inverter rating	10KVA
Nominal current	7.3A
Nominal voltage	230V per phase
Protection current	12A
Maximum DC link voltage	750V
Capacitors.	200 µF, 450V
IGBTs.	6
IGBT model no:	SKM 100GB12T4
Driver name	semicron.

Table 2. Three Phase Voltage Source Inverter ratings

The below section provides an overview of a three-phase inverter, including how it works, its uses, and a circuit diagram.

- **Circuit Diagram of Three Phase VSI**

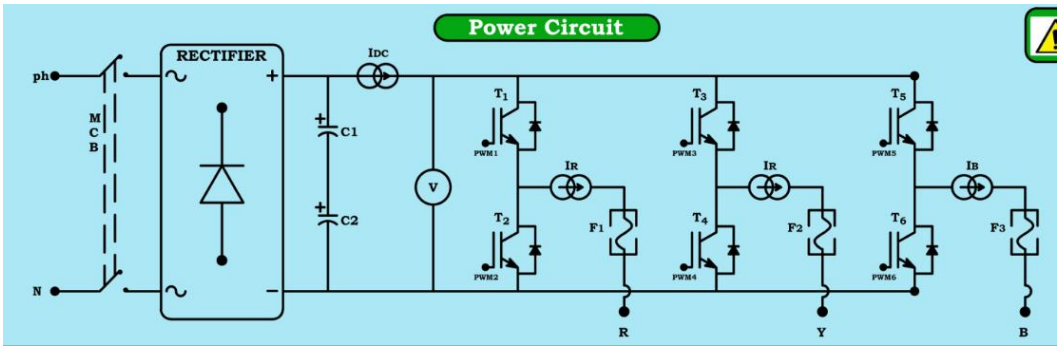

Fig. 5. Circuit Diagram of Three Phase VSI

- **Control strategy**

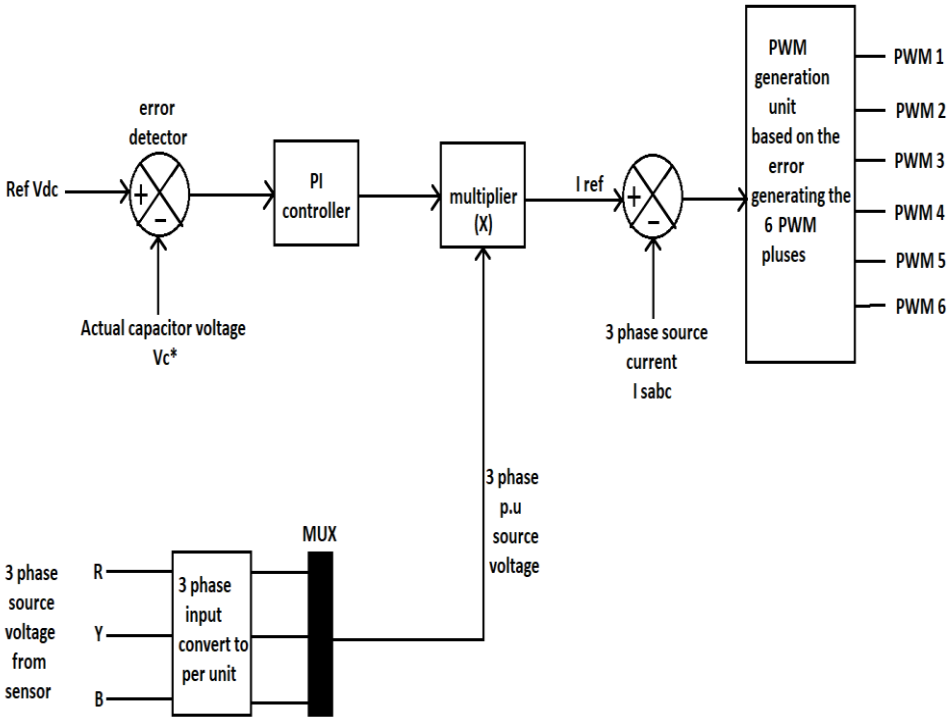

Fig. 6. Circuit Diagram of Three Phase VSI

The inverter control signal are generated from the six pulse PWM generator. Ref. Voltage and DC link voltages are compare, error is given to PI controller. PWM will generate the Gate signals according to the ref. AC current and the actual current given to it. Hysteresis current controlled technique is used to generate the PWM Pulses.

2.5 Battery Banks

Hybrid system with battery as energy storage, will give more efficient performance and it is reliable. Here in this paper, the battery bank consist of 12 no's of 12V, 7Ah batteries are connected in series. The total voltage becomes 144V.

Batteries	Ratings
Nominal voltage:	12V
Nominal capacity	@ 20hr rate (AH):7.0.
Discharge current	20hr rate (Ma):350.
Weight:	2.7kg

Table 3. Ratings of Battery

3 REAL TIME IMPLEMENTATION

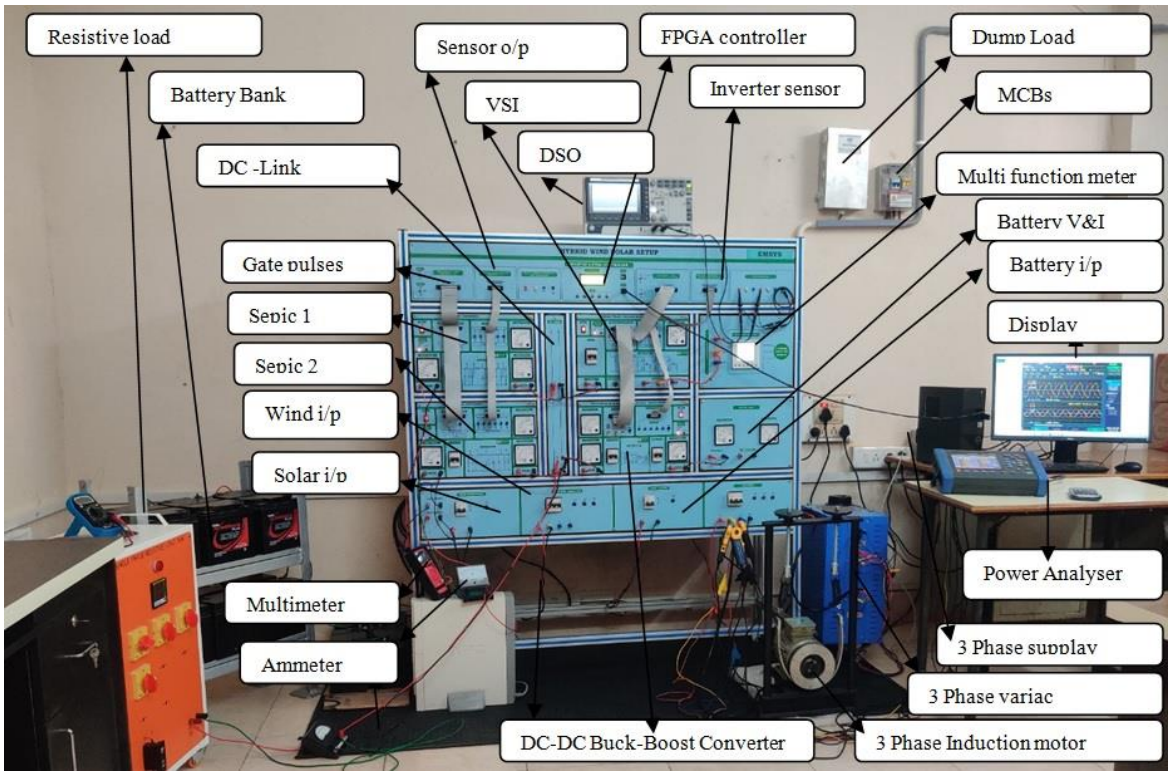

Fig. 7. Real time model of Hybrid wind solar energy system setup

Working Procedure

Hybrid wind solar energy system setup consists of two SEPIC converters, three phase voltage source inverter, bidirectional DC – DC buck boost converter, a DC link and SPARTAN 6 FPGA controller and a battery bank. This panel also has a provision of three phase grid connecting terminals, a provision to connect an AC load (induction motor) and DC resistive load. The panel board also has the supply terminals of DC input for solar power, wind power and battery power. SEPIC converters used for boosting DC voltage with the gate pulses generated from SPARTAN6 FPGA controller. This controller is embedded with P&O MPPT

technique in XLINK environment. For three phase voltage source inverter hysteresis current controlled technique is used.

An intelligent PI controller will generate the gate pulses for DC-DC buck boost converter with the help of SPARTAN 6 FPGA. From all the converters a sensory feedback signal given as input to the SPARTAN 6 controller for an intelligent priority-based load sharing. Each converter is connected to input and output measurements of voltage and ammeter. This VSI configuration converts DC-AC and with rectified the harmonics in the system. This rectification process eliminates the additional use of the filter. Each power converter is having a reset button used for malfunctioning operation and having a protective LED.

A Standalone induction motor load of 250W capacity is connected across the VSI terminals. The connected power sources of solar, wind and battery have to feed this load continuously. SPARTAN 6 controller has an LCD display to sense all initial parameters of connected converters. It has a provision to set the DC link voltage to a fixed value. The MPPT will extract the power from the available source and maintains the DC link voltage to a reference fixed value by giving gate pulses to the SEPIC converters. This DC link power has to transform to the load with the help of VSI triggered by SPARTAN 6 gate pulses. The sensory feedback signals from VSI has to be given to Spartan 6 through an intelligent hysteresis control controlled technique. This controller keeps the dc link voltage to its fixed reference value by enabling all converters connected to it. In this controller, gate pulses are generated according to the available power sources connected to it.

There are few combinations of hybrid system working as below

- If solar energy is capable of feeding the load only the SEPIC converter and VSI are triggered by gate pulses.
- If solar power is not sufficient to feed the load, wind power SEPIC converter is also enabled to meet the load requirement.
- If wind and solar power sources are not capable of running the load, the remaining power will meet by enabling battery connected dc-dc buck-boost converter.
- In the absence of wind and solar power, only the connected battery source will run the load continuously.
- Excess power available from the dc link will be stored in connected battery source by the bidirectional buck-boost converter in boosting operation mode.
- This has also a provision to connect to the grid supply, in the absence of all three connected power sources, power required the load will be met from the connected grid.
- The multi-stage and multi-function grid connected hybrid wind solar energy system configuration is effective use of renewable energy in all disaster conditions.

4 RESULTS AND DISCUSSIONS

Performance analysis with different modes of operation of hybrid energy system

The performance of the Hybrid system is observed in operating five modes. By observing the load characteristics and the total harmonic distortion in the wave form. The system is to be verified in all operating modes.

4.1 Performance analysis when solar energy source is acting alone

When only solar energy is present, it has to feed the connected AC load. In the below wave foam, the three phase voltage is observed. It has low harmonics disturbance. As a variable nature of the load, the disturbance effect is nullified by this hybrid configuration. The current wave form also has a satisfactory sinusoidal nature. The supply frequency is also formed to be 50.17 Hz.

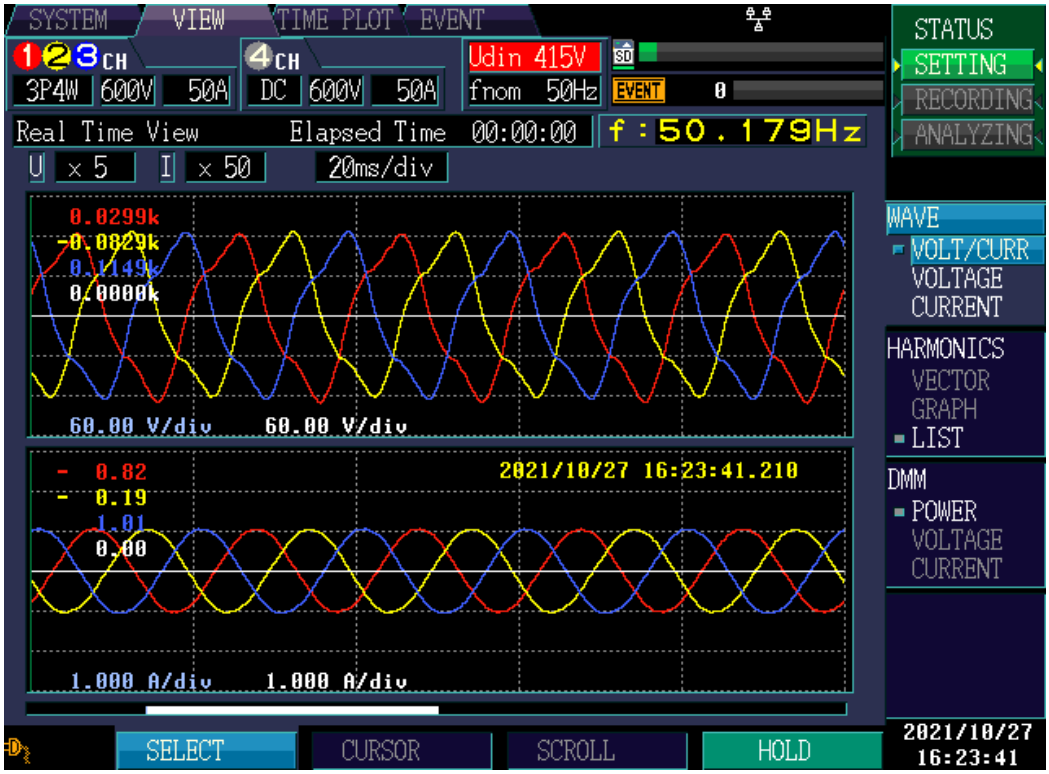

Fig.8. Load Voltage and Current wave forms for solar acting alone

The THD is found by the power analyser and it is shown in the below figure. The solar energy is converted to electrical energy without any harmonic disturbance. Alone this solar energy is capable of producing quality input power to the AC load. The voltage 1.5 order harmonic value is 0.06% and the current 1.5 order harmonic value is 0.18%. The primary harmonics only considered due to their predominance.

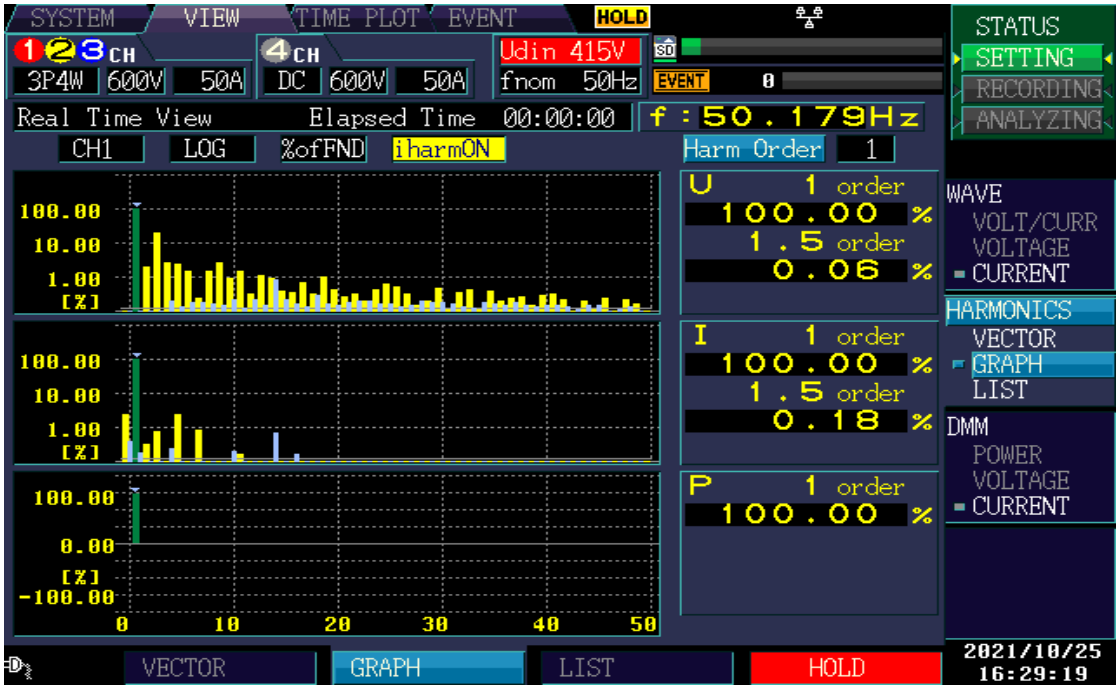

Fig.9. THD Graph for solar acting alone

4.2 Performance analysis when wind energy source is acting alone

When only wind energy is present, it has to feed the connected AC load. In the below wave foam, the three phase voltage is observed. It has low harmonics disturbance. As a variable nature of the load, the disturbance effect is nullified by this hybrid configuration. The current wave form also has a satisfactory sinusoidal nature. The supply frequency is also formed to be 50.17 Hz.

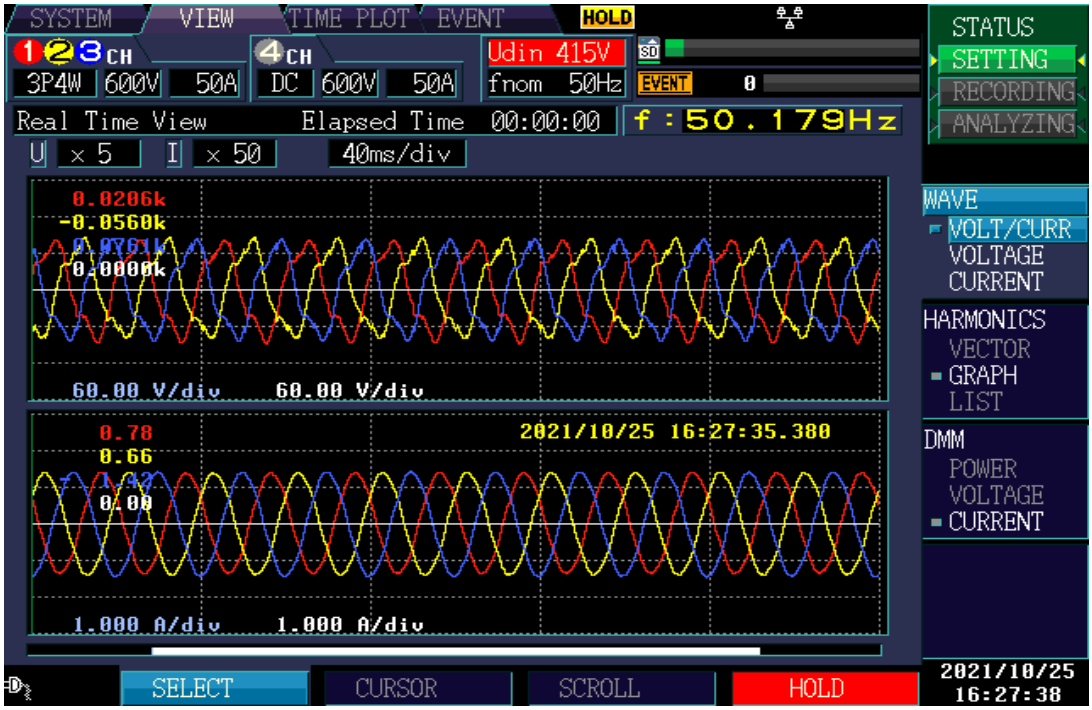

Fig.10. Load Voltage and Current wave forms for Wind acting alone

The THD is found by the power analyser and it is shown in the below figure. The solar energy is converted to electrical energy without any harmonic disturbance. Alone this solar energy is capable of producing quality input power to the AC load. The voltage 1.5 order harmonic value is 0.08% and the current 1.5 order harmonic value is 0.11%. The primary harmonics only considered due to their predominance. The primary harmonics only considered due to their predominance.

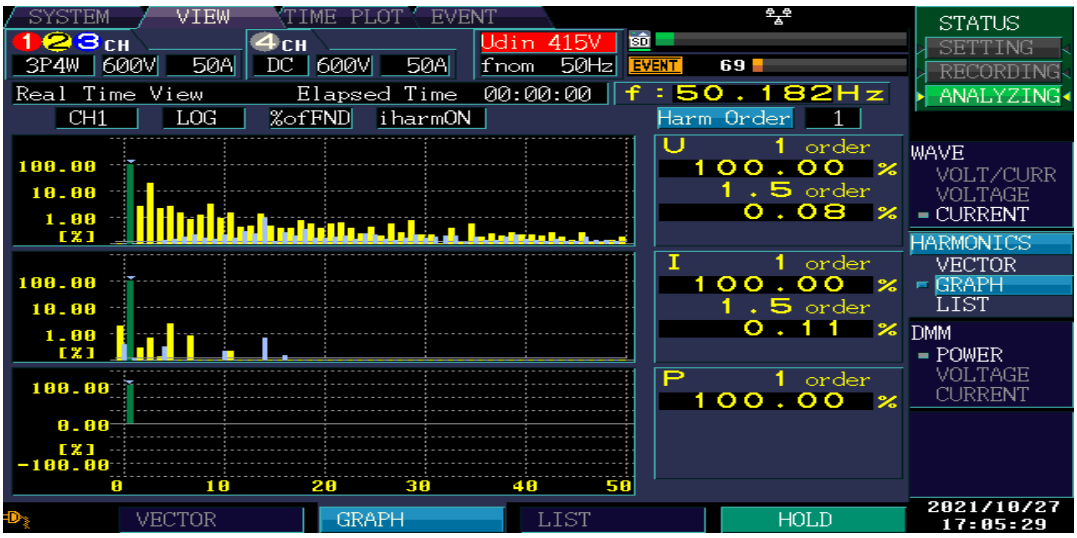

Fig.11. THD Graph for Wind acting alone

4.3 Performance analysis when battery energy source is acting alone

When only wind energy is present, it has to feed the connected AC load. In the below wave foam, the three phase voltage is observed. It has low harmonics disturbance. As a variable nature of the load, the disturbance effect is nullified by this hybrid configuration. The current wave form also has a satisfactory sinusoidal nature. The supply frequency is also formed to be 50.18 Hz.

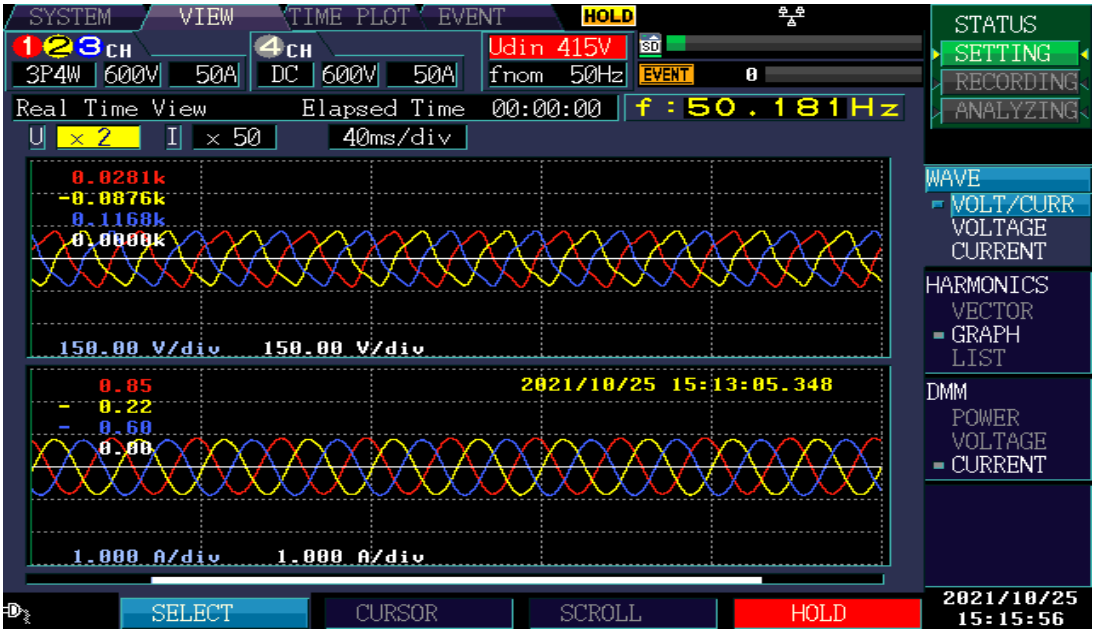

Fig.12. Load Voltage and Current wave forms for Battery acting alone

The THD is found by the power analyser and it is shown in the below figure. The solar energy is converted to electrical energy without any harmonic disturbance. Alone this solar energy is capable of producing quality input power to the AC load. The voltage 1.5 order harmonic value is 0.02% and the current 1.5 order harmonic value is 0.2%. The primary harmonics only considered due to their predominance. The primary harmonics only considered due to their predominance.

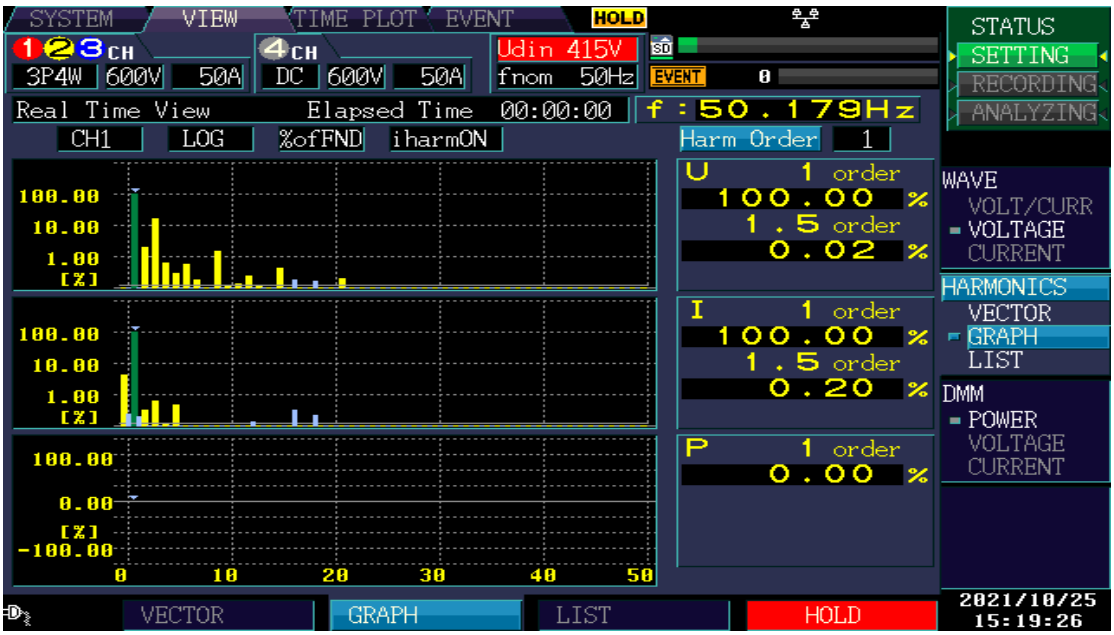

Fig.13. THD Graph for Battery acting alone

4.4 Performance analysis hybrid energy system when all energy sources are acting

When only wind energy is present, it has to feed the connected AC load. In the below wave foam, the three phase voltage is observed. It has low harmonics disturbance. As a variable nature of the load, the disturbance effect is nullified by this hybrid configuration. The current wave form also has a satisfactory sinusoidal nature. The supply frequency is also formed to be 50.179 Hz.

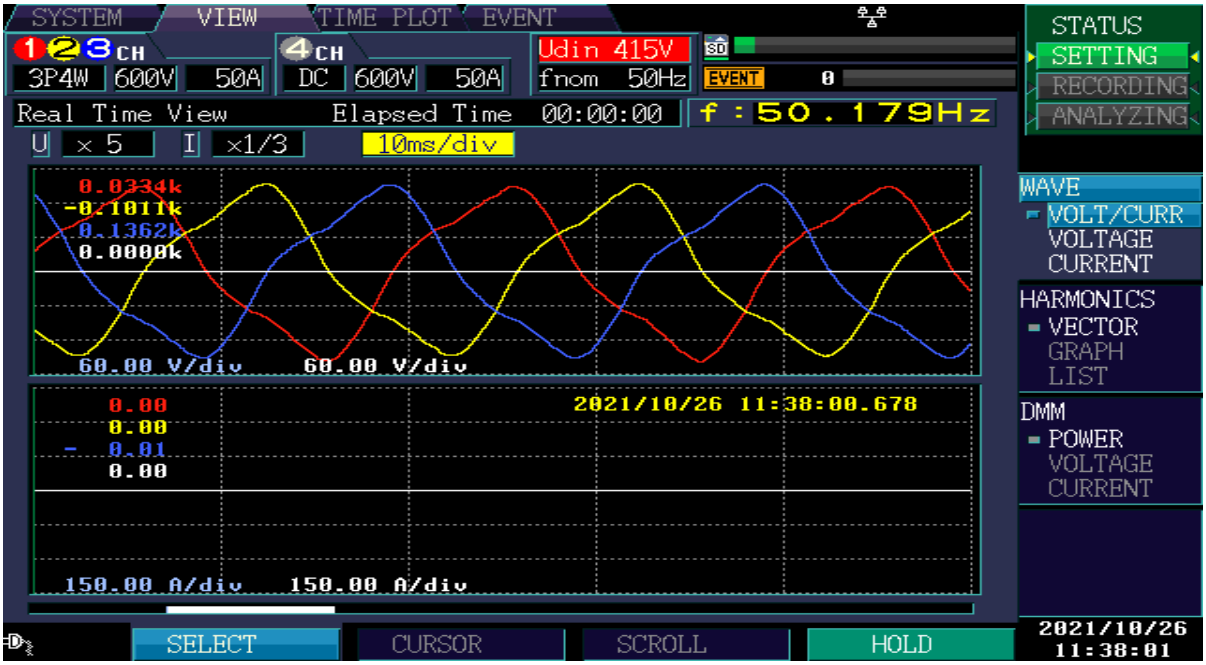

Fig.14. Load Voltage and Current wave forms for all # sources

The THD is found by the power analyser and it is shown in the below figure. The solar energy is converted to electrical energy without any harmonic disturbance. Alone this solar energy is capable of producing quality input power to the AC load. The voltage 1.5 order harmonic value is 0.04% and the current 1.5 order harmonic value is 0.13%. The primary harmonics only considered due to their predominance. The primary harmonics only considered due to their predominance.

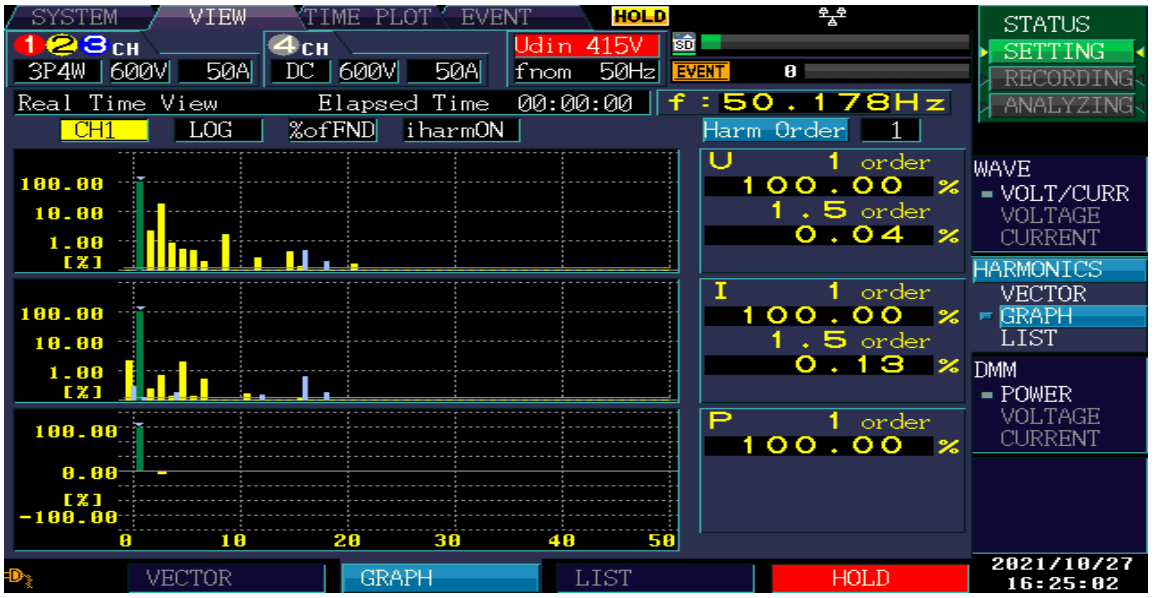

Fig.15. THD Graph for all sources

5 CONCLUSIONS AND FUTURE SCOPE

In this paper, a stand-alone hybrid Solar PV Wind energy system is developed for standalone applications. The wind and solar PV system are connected to a DC link through DC/DC Boost converter. Three phase load is connected to this system with help of Voltage source Inverter. Load sharing is done by the Spartan 6 FPGA Controller. The connected battery to this system will be efficient with the DC-DC bidirectional buck boost converter. The integration of solar and wind to become a hybrid energy system was done practically. The performance was satisfactory with Induction motor as a load. The THD and inverter frequency found satisfactory. This system will be implemented with a bidirectional energy meter for effective coast sharing and with different power converters at its voltage boosting levels.

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