

A Novel DC-DC Converter Based Integration of Renewable Energy Sources for Residential Micro Grid Applications

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ABSTRACT: A novel converter topology interfacing hybrid distributed energy sources and dc bus is proposed in this paper for integration of renewable energy sources with residential micro grid. This converter has low number of active device compared to the converters usually applied to similar application. Multi-Winding transformer is employed for achieving Low input and output current ripple, high voltage ratio. This paper deals with structure, principle and operation of open loop controller and MATLAB simulation is carried out results verification. Finally practicality of the integration with proposed topology is verified by hardware implementation of hybrid solar PV and Wind Source through AVR-16 microcontroller, also the outputs are compared with the simulation results for confirmation of the design.

KEYWORDS: DC-DC Converter, Multi winding transformer, AVR16 Microcontroller, micro grid, MATLAB SIMULINK.

I. INTRODUCTION

Future renewable energy system will need to interface several energy sources such as photovoltaic array, wind energy conversion system and fuel cells with load along with battery backup. A power electronic converter is used as an interfacing device. Basic dc-dc converters such as buck and boost converters and its derivatives do not have bidirectional power flow capability. This limitation is due to the presence of diodes in their structure which prevents reverse current flow. In general, a unidirectional dc-dc converter can be turned into a bidirectional converter by replacing the diodes with a controllable switch in its structure.

Most of the existing bidirectional dc-dc converters fall into the generic circuit structure illustrated in Figure-1, which is characterized by a current fed or voltage fed on one side. Bidirectional dc-dc converters allow transfer of power between two dc sources, in either direction based on the placement of the auxiliary energy storage, the bidirectional dc-dc converter can be categorized into buck and boost type. The buck type is to have energy storage placed on the high voltage side, and the boost type is to have it placed on the low voltage side. To realize the double sided power flow in bidirectional dc-dc converters, the switch cell should carry the current on both directions. It is usually implemented with a unidirectional semiconductor power switch such as power MOSFET (Metal oxide semiconductor field effect transistor) or IGBT (Insulated Gate Bipolar Transistor) in parallel with a diode; because the double sided current flow power switch is not available. The control technology in bidirectional converter utilizes mostly pulse width modulation (PWM) control technology. Because the hard switching PWM technology leads to the reduced efficiency of converter [2].

The efficiency, reliability and dynamic performance of the system relies on the operation of the bidirectional converter under different modes of operation, so that individual parts of the system can operate properly. A buck-boost type high performance bidirectional converter is used to charge and discharge the battery. This bidirectional converter is having

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the following properties which enhance its performance, like power flow with large voltage diversity, high step up and step down ratio, soft switching and zero voltage switching, reduced switching losses due to fewer switches, less conduction losses, synchronous rectification, no transformers, no magnetizing current saturation, less weight and volume.

In the past decades, traditional power converter topologies have been evolving in various directions, for example, from single phase to multiphase interleaving and from two levels to multilevel. Nowadays, most dc-dc power converters deal with single input and single output. Recently, attention has been paid to the multi-port converters [3]. Multi-port dc-dc converters are particularly suitable for sustainable energy generation system where diverse sources and storage elements are to be integrated and it can be used in high power application. Compared with the conventional solutions that employ multiple converters, the three port converter features single stage conversion between any two of the three ports, higher system efficiency, fewer components, faster response, compact packaging, and unified power management among the ports with centralized control. Therefore, multi-port converters are increasingly finding applications in various systems like alternative generation. Multi-port converter has several ports to which the sources or loads can be connected shown in Figure-1.

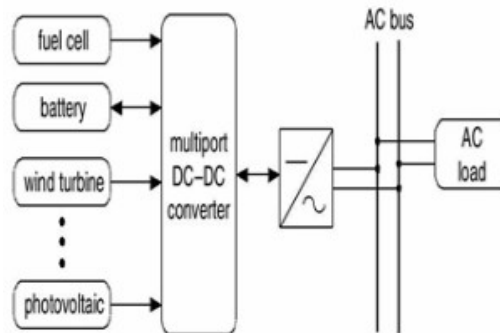


Fig 1. Block diagram of the multi-port structure

One of the most popular concepts for bidirectional dc-dc converters is the dual active bridge topology which utilizes either two full bridges or two half bridges at the primary and secondary sides of a high frequency transformer with phase shift control resulting in flexible power flow control and zero voltage switching (ZVS).

Fuel cell automobiles are considered to be an option for future clean energy automobiles. The primary source will be fuel cells with the power during acceleration and deceleration supplied from batteries. Fuel cells have slow dynamic response and hence energy storage is essential in such an application. Batteries can be charged from fuel cells and during regenerative braking operation.

The advantages of using multi-port structure is that the primary source only needs to be sized according to the average power consumed by the load for a specific application, not necessarily to the peak power. Such operation would avoid over sizing of the primary source and is economically beneficial. Moreover, with the auxiliary storage, not only the system dynamics can be improved, but also the storage acts as a backup energy source in the event of a main source failure. Rooftop solar panels are being widely used to power residential and commercial buildings. Energy storage will be used to store excess power and also as a backup unit to supply vital equipment. Due to cost reasons energy storage is applicable more in off grid applications.

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II. PROPOSED CONVERTER SCHEME

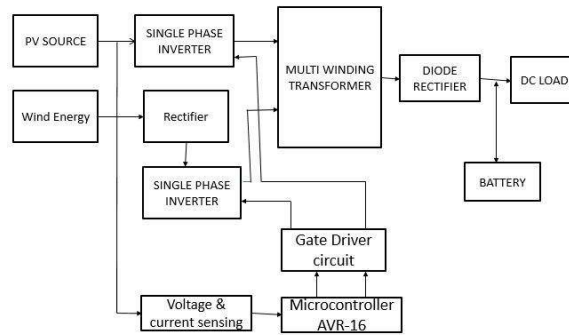


Fig 2. Block diagram of proposed system

DESCRIPTION

The integration of solar power and wind energy generates 24 volts each. Output voltage of solar power is fed to the inverter. It converts the dc to ac voltage. Similarly the wind turbine produce ac voltage and then it is converted to dc voltage. Now it is inverted to ac voltage. The output voltages of solar and wind system is fed to the Multi-Winding transformer. Multi winding transformer ratio is 1:3:3 and ratings is 1KVA. The voltage is boosted to their certain value respectively. Now ac voltage is rectified to dc voltage using rectifier circuit and is given to the load. Battery is charged at the time of dc voltage is obtained

Battery Charge controller

The circuit is intended for 12V chargers with a maximum capacity of about 7a. The essential ingredients are a voltage regulator, IC1, a current limiters, IC2 and a “big” output transistor, T2. The voltage and the current limiter, and the current limiter, and performs the actual regulation. Two potentiometers are available to get the maximum battery voltage and the maximum charge current. If the set values are exceeded, the charging current is interrupted, and a LED lights to tell you that something is miss. Similarly, a bussor sounds when the battery is accidentally connected the wrong way around.

The high power diodes, D5; is inserted into the positive line to make sure that no damage can be caused by connecting the charger outputs the wrong way around to the inputs of the circuit. Interestingly, the diode also allows the existing bridge rectifier in the charger to be skipped, and the inputs of the upgrade circuit to be connected directly to the SOLAR POWER PANEL. The diode is followed by two large reservoir capacitors, C7 AND C8, which smooth the direct voltage.

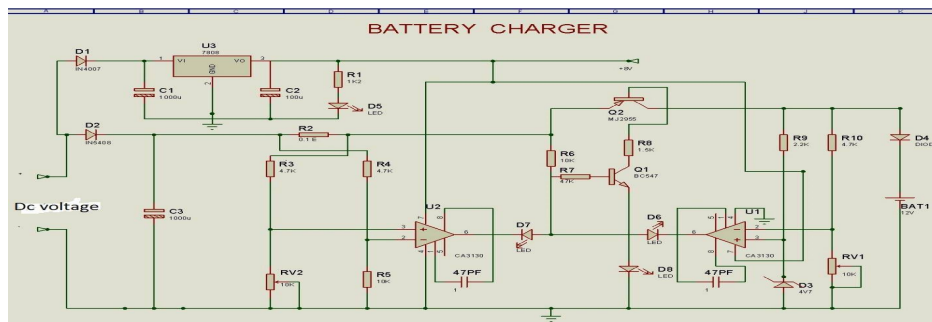


Fig.3 Charge controller circuit

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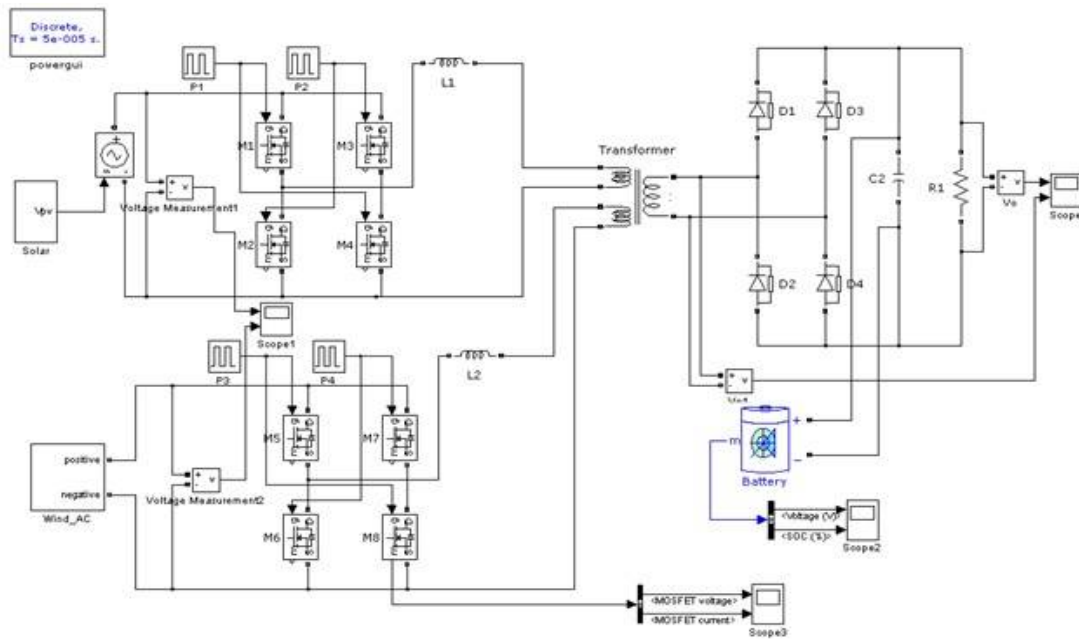


Fig.4 simulation of proposed hybrid system integration

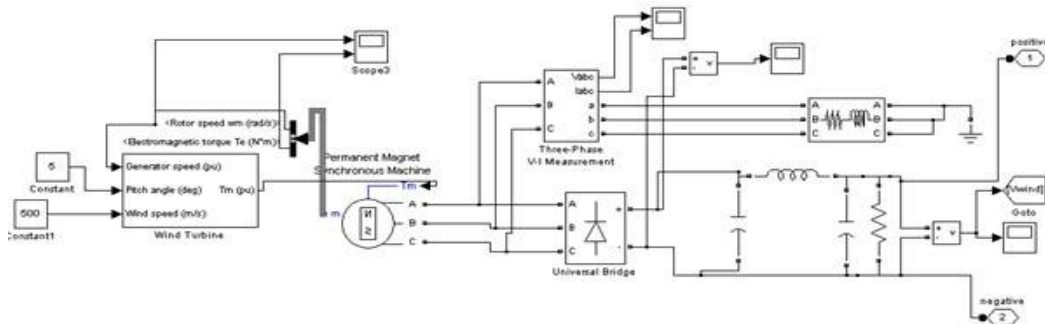


Fig.5 simulation of Wind system

In this wind simulation, it is designed to get 24 volt from the wind turbine generated system. Now the wind output is inverted and then is given to the multi winding transformer of 1kva rating. Ratio of the transformer is 1:3. Output from the transformer is boosted from dual input 24volt to 70 volt. The state of charging of battery is done

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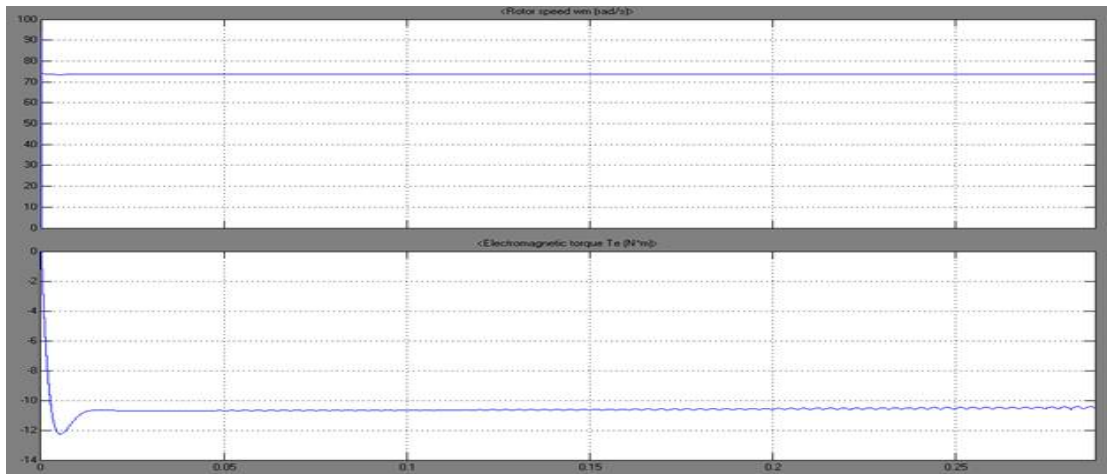


Fig.6 Wind Speed & Torque Output

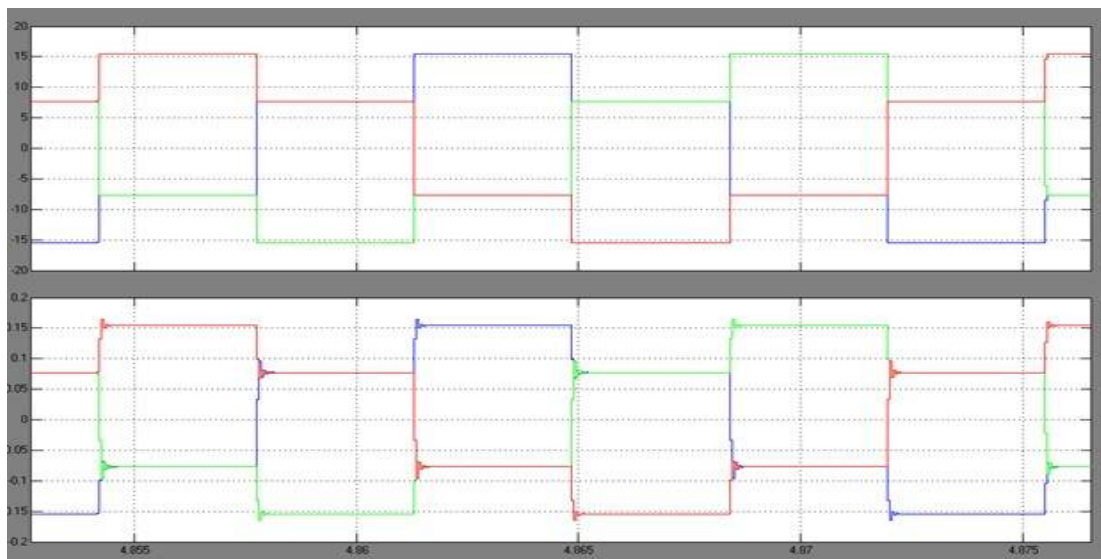


Fig.7 Output Voltage & Current for Wind

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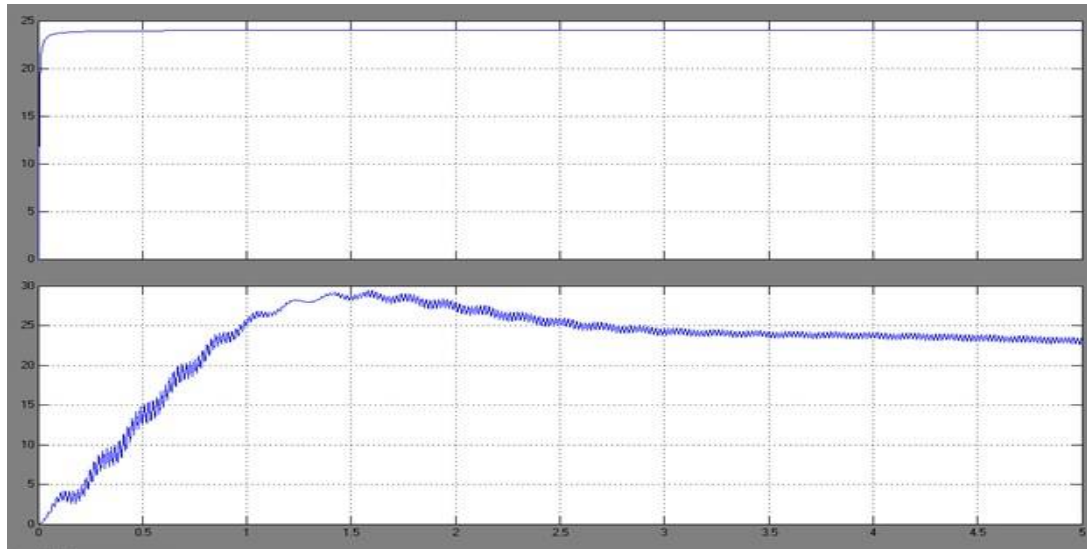


Fig.8 Wind & Solar Hybrid Output Voltage

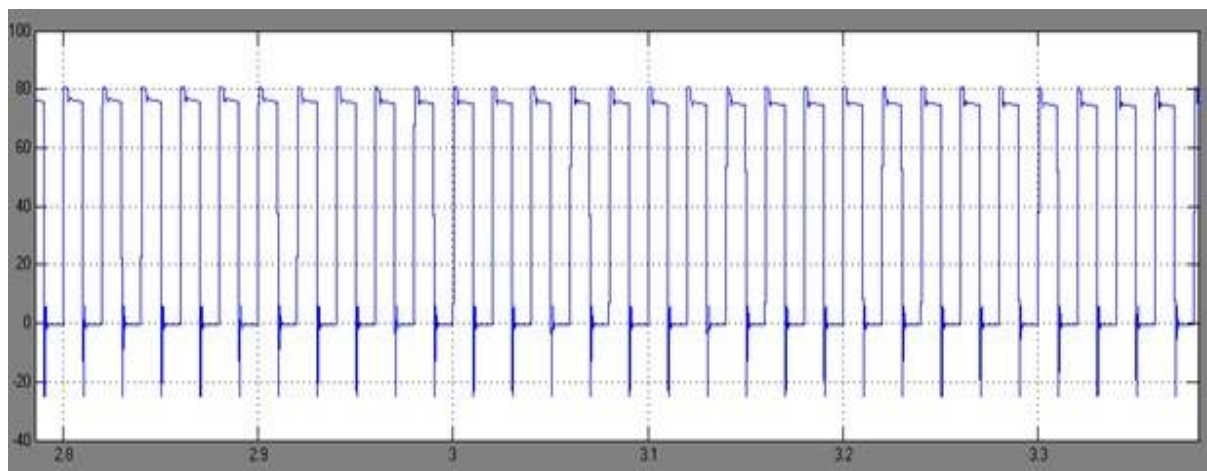


Fig.9 Transformer Voltage

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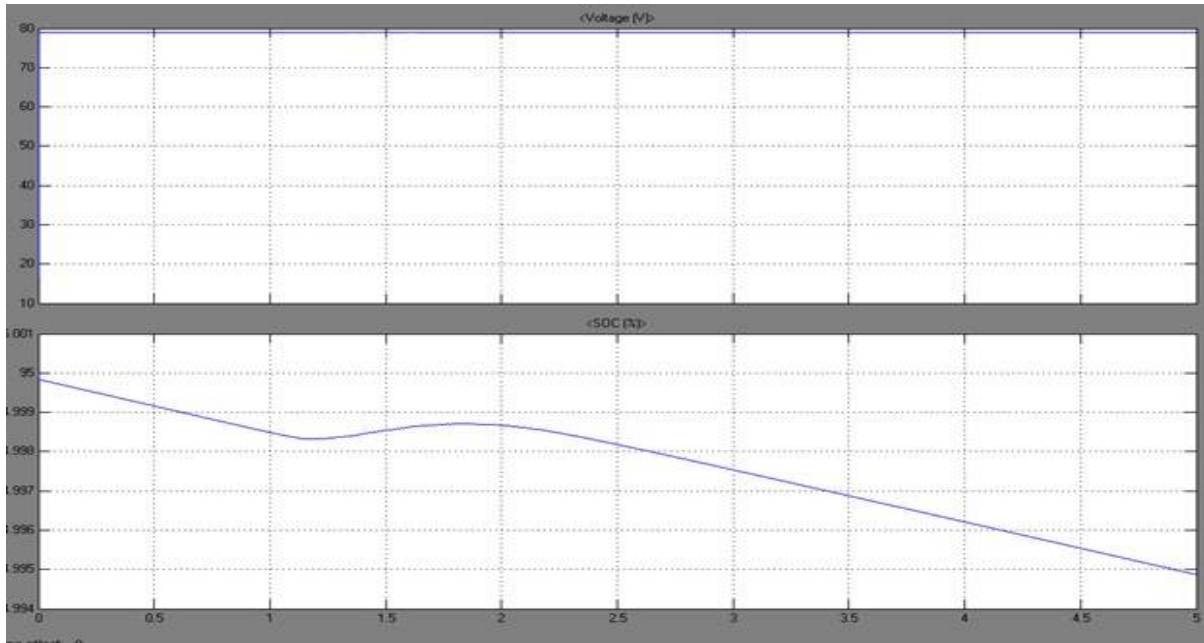


Fig.10 Battery Voltage & State of Charging

Battery stores the charge of 80 volt and the state of charging is shown in above circuit.

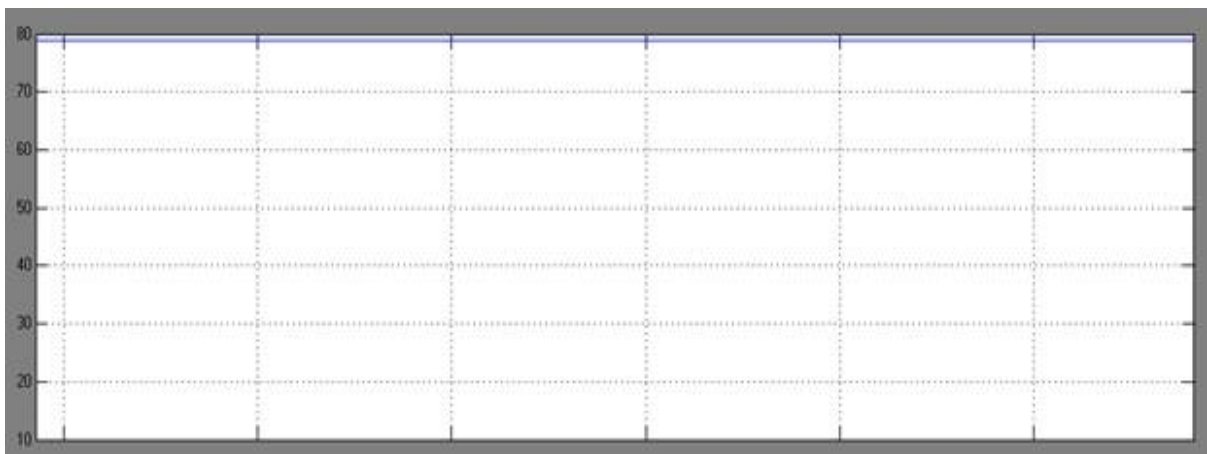


Fig.11 Three port Output Voltage

III. HARDWARE IMPLEMENTATION AND EXPERIMENTAL RESULTS

The overall circuit is show below with input as solar pv and wind generating. In the initial step, 50% duty cycle is generated for the h-bridge inverter operation

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Fig 12 Experimental hardware setup

When the switches S1 and S4 are closed (and S2 and S3 are open) a positive voltage will be applied. By opening S1 and S4 switches and closing S2 and S3 switches, this voltage is reversed, allowing reverse operation of the motor.

Output waveform of charging the battery voltage at 13.2V is show below

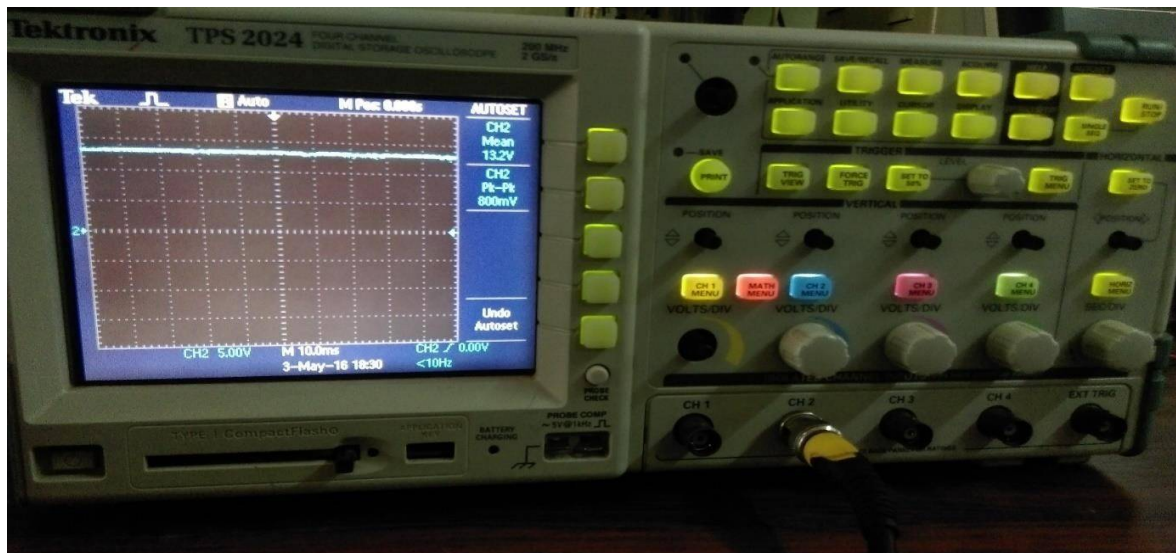


Fig. 13 Battery voltage at the time of charging

After the inverter operation, the voltage is fed to transformer. The output of transformer is shown below

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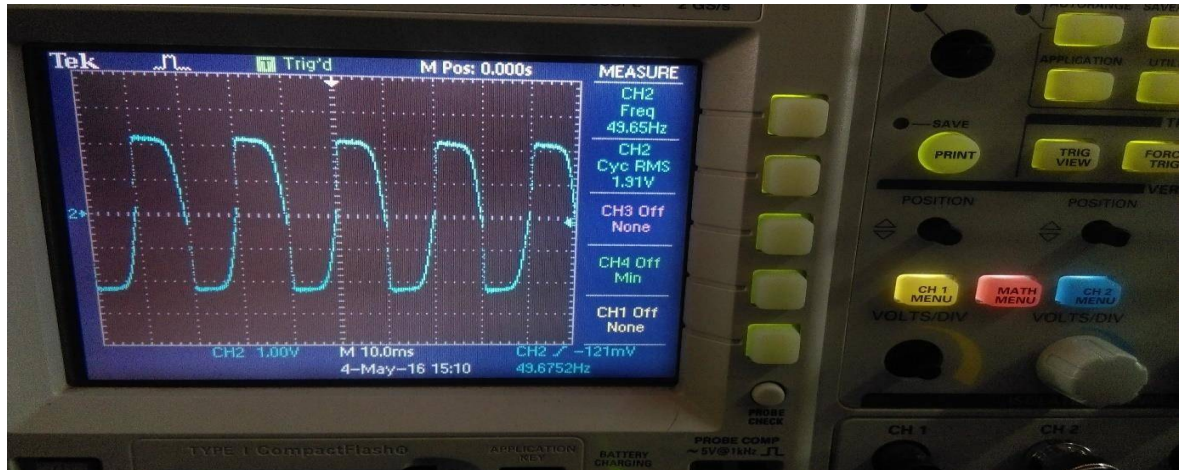


Fig. 14 Transformer output voltage

From the transformer voltage it is rectified as dc voltage and given to the dc load. The dc voltage of 12.8V for dc load is show below.

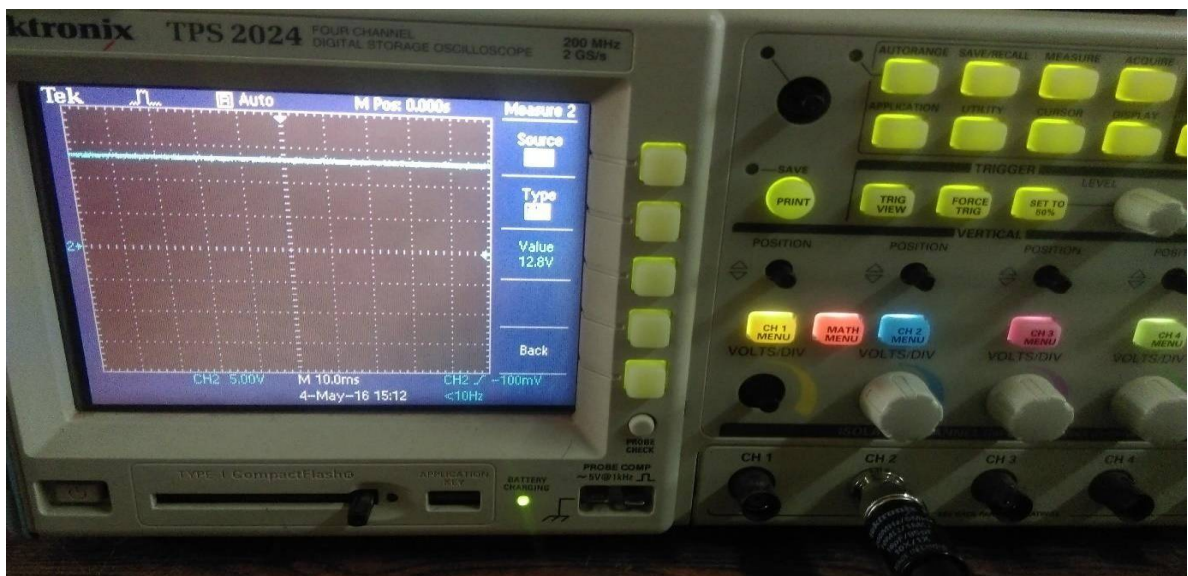


Fig. 15 Output waveform of dc load side

At the time of charging the battery voltage is 13.3V. State of charging condition is shown below.

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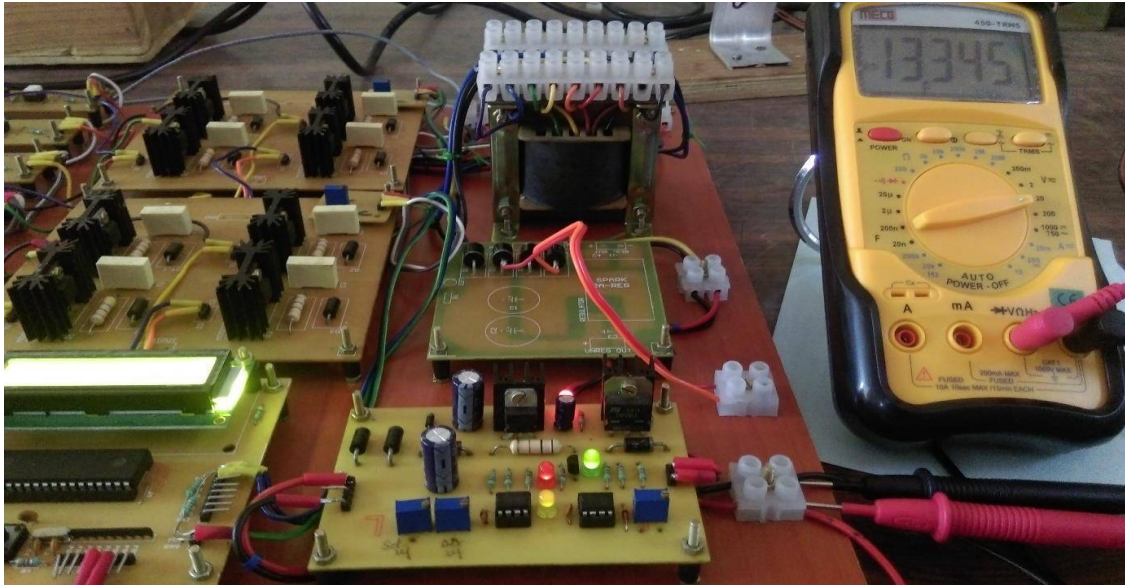


Fig. 16 State of charging condition

IV. CONCLUSION

An integrated forward dc-dc converter, to connect the energy storage system to the dc bus of a residential micro grid was done. This gives high voltage ratio, low input and output current ripple. The advantages are reduced active switches and double-ended forward converter. The output voltage is always maintained in the grid when any one source is disconnected. Even though all the sources are disconnected in grid, the grid voltage is maintained constant by battery source.

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