Universal Integrated Smart Power Supply

Jagadeesh Patil, M.S.Aspalli

Abstract - This paper presents an integrated power system, in order to supply the energy demand of a low power residence, using photovoltaic modules and wind turbines. The main functions of the proposed system are the management of the load and the energy stored, in order to increase the autonomy and the integration of all equipment necessary for the system operation, reducing the complexity and cost. The system contains well defined concepts for continuous energy supply providing a good balance between various energy sources and their capabilities and load requirements. This system fulfills the small power ratings cover local demands, e.g. one house or a small village in remote location. Multiple inputs for renewable energy are proposed in combination with high-efficiency power electronic circuits. The proposed system uses both the on grid and off grid technologies and effectively managed among them.

Keywords –DC-DC converter, H bridge Inverter, MOSFETs, SCR.

I. INTRODUCTION

The use of renewable sources as solar and wind is an interesting option. As the primary sources depend on the climatic conditions, the hybrid operation can provide better autonomy for isolated systems. However, the design of hybrid system is complex due to the random profile of energy generation and consumption. A well-dimensioned system requires a design algorithm that includes the information about the primary source variation, load profile and the efficiency of the equipment used. Other characteristic of this kind of installation is the large number of equipment necessary for the operation, increasing cost and complexity.

In order to simplify the installation and operation of hybrid systems, as well to improve the autonomy, an integrated system is proposed in this work. All power conversion stages are integrated in the same equipment and the topologies used in each power conversion are optimized to obtain high-efficiency and low cost. A high performance lighting system is also integrated in the same equipment. With the integration of all power conversion, it is possible to implement a management control unit. Some loads can be defined as priority and are enabled while there is available energy in the batteries. Other loads with lower priority can be automatically turned-off when the level of energy stored is low. The proposed system works for both on grid and off grid mode.

Rural areas those away from the grid or not connected to the electrical network of the developing world can benefit from this transition. The increased availability of reliable and efficient energy services stimulates new development alternatives. A number of renewable energy initiatives are under way in developing countries, and India can contribute to rural development through the integrated operation of locally available Renewable energy sources.

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However due to the behavioral characteristics use of single source may not be able to supply energy safely, reliably and economically. An integrated renewable energy system composed of some renewable sources, and targets a small area such as a village or remote area for power supply.

The developed hardware is tested. According to the requirement, a software program is written and is fed to the microcontroller (atmega16) for the necessary action. The various graphs/waveforms are analyzed and studied on Digital Storage Oscilloscope.

II. BLOCK DIAGRAM AND ITS EXPLANATION

A. System overview

The block diagram of the proposed system is presented in Fig. 1. There are five inputs for the power sources. The first input is for the photovoltaic (PV) module, which is connected to the battery charger circuit. The control of the battery charger allowing to obtain the power from the modules at any instant. The other input is used for the wind turbine. The wind turbine output is ac then it is rectified and given to the charger circuit. Some modern small power wind turbines normally presents the battery charger built internally, therefore, the wind turbine terminals are connected directly to the DC bus. The batteries are connected to an internal low voltage bus. A high-efficiency step-up converter increases the battery voltage to an adequate level for the next conversion stage. An inverter supplies the AC loads from the high-voltage DC bus. The inverter operates with a high frequency three-level PWM modulation and a sinusoidal output is obtained with a low-pass filter. Some loads, such as AC motors, can be connected directly to the inverter output. The high-voltage DC bus is also connected to a high frequency inverter used to implement the lighting system.

All power circuits are managed by a control unit in order to obtain a better utilization of the stored energy, increasing the autonomy of the system. There is a load control switch in series with each output, allowing to connect the loads if there is energy available. The most important loads are defined as high priority and the control unit can turn-off the secondary loads when the energy level is low. All loads are turned-off when the stored energy reaches the minimal level, in order to protect the batteries.

In order to increase the autonomy of the system, a control unit proposed for the management of the energy available in the batteries. Based on some parameters and information of the system such as battery voltage, charge or discharge current and battery temperature, an algorithm can estimate the energy stored and the autonomy of the system. Some loads can be defined as high priority and the secondary loads can be automatically turned-off, while the energy level stored is low. Thus, some important applications as lighting system can operate for a larger period, optimizing the use of the energy available. The control unit also can present some information of the system as energy level, operation status and alert signals. The control of the loads also can be disabled manually if necessary. The mains protection circuit is composed of PFC filters and ELCB's for protection of the whole system.

The integration of all power converters necessary for to supply the energy demand of a low power residence, using photovoltaic modules and wind turbine, is proposed in this paper. This integration simplifies the installation of the equipment and allows to implement a control unit for the management of the energy available.

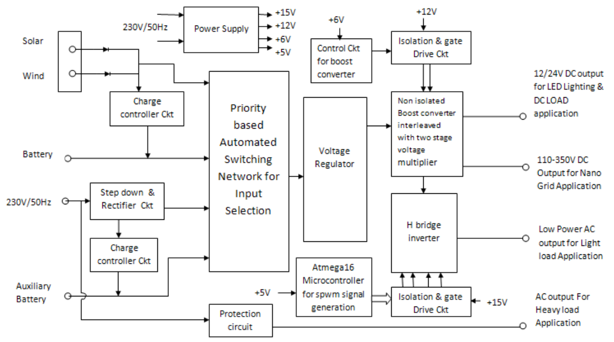

Fig1. Block diagram of the proposed system

B. Priority Based Automated Switching Circuit

The priority based Automated Switching circuit is made up of relay switching network, in order to select the input power source, the circuit is designed in such a way that the higher priority is given to the renewable energy source (solar/wind), battery, grid and auxiliary battery respectively. This circuit works fully automatic and the input selection is done according to the priority assigned (shown in below table-I).

INPUTS			OUT PUT
GRID	BATTERY	SOLAR +WIND	
✓	✓	✓	SOLAR +WIND
✓	✓	X	BATTERY
✓	X	✓	SOLAR +WIND
X	✓	✓	SOLAR +WIND
X	X	✓	SOLAR +WIND
X	✓	X	BATTERY
✓	X	X	GRID
X	X	X	Auxiliary BATTERY

Table I Priority Table for Automatic Input Selection

C. Step-Up Dc-Dc Converter

Non-isolated Dc-Dc converter topologies are used and it is possible to obtain high static gain, low voltage stress, low conduction and commutation losses, resulting in higher efficiency and more compact equipment than with the use of the classical solutions. The structure adopted to implement this converter is based on a boost interleaved converter integrated with a voltage multiplier circuit.

D. Battery Charger

Some operational characteristics are important for the battery charger circuit. The battery charger must present a current source output characteristic to allow the connection of different sources in parallel with the batteries. A current source input characteristic is also interesting for this application because the batteries normally are installed far from the power converters. The inductance of the connections may cause problems in the operation of converters with a voltage source input characteristic. The isolation is not necessary in this application and the non-isolated topologies present higher efficiency than isolated converters, due to the power transformer losses, and leakage inductance.

E. DC - AC Converters

The AC loads are supplied by a single-phase full-bridge inverter operating with three-level sinusoidal PWM modulation. The commutation leg composed by S3 and S4 operates at low frequency (50Hz) while the commutation leg composed by S1 and S2 operates at high switching frequency with the PWM modulation.

F. Control circuit

The control circuit of the proposed scheme consists of an ATmega16 Microcontroller. The microcontroller is operated at 16MHz crystal frequency. Microcontroller controls power switches in the inverter circuit. To derive a varying single phase ac voltage from the dc bus the PWM outputs are required to control the four switches of the converter. This is done by connecting the PWM outputs to MOSFET drivers. The controller also decides the instant timing of the gate signal to be given to MOSFETs, in order to avoid the overlapping in the conduction of incoming and outgoing MOSFET's. It also consists of six opt isolator for isolating the control and power circuits. In this work an opt isolator TLP250 is used to isolate the gate drive circuit and the MOSFET-based power circuit. Four MOSFETs of the power circuit are controlled by the PWM signals generated by the control circuit. And two power MOSFETs are used in boost converter.

III. EXPERIMENTAL SETUP AND ITS RESULTS

The integration of various power sources is done successfully and the developed hardware is tested with load. The proposed control system is implemented by an ATmega16 microcontroller based PWM inverter. C language is used to develop the program. The device is programmed using microC PRO for AVR Integrated Development Environment (IDE) tool. The integrated toolset for the development of embedded applications employing AVR family microcontrollers. For execution of C-code microC PRO compiler is used.

The hardware set is developed and tested in power electronics laboratory and the photograph of complete setup is shown in fig 9 and 10. The test is carried out for various input power source and load. For the different input sources and loads, all inputs, outputs and intermediate voltages are noted and are tabulated. Tektronix TDS2024B Digital Storage Oscilloscope (DSO) is used in the complete experiment to store the gate pulses and voltage waveforms.

The inputs solar and Wind sources are the non-linear sources, so for experimental analysis a laboratory module power supply is used in place of solar and wind power sources.

The system is connected with different loads and observed the voltage and current levels of the system, also checked the different switching priority levels of the system. By varying the voltage and current levels of the module power supply, observed the different intermediate voltage levels of the system, also observed system under over voltage and short circuit protection mode.

Table II and III shows the Experimental Results of the proposed system for CFL, Power LED and Incandescent Lamp as load and corresponding waveforms are taken from the DSO and are shown in figs 4 to 8. The gate pulses are observed and shown in figs 2 and 3.

A. Experimental Results of Boost converter

Table II Experimental Results of two phase Boost converter with single Multiplier

Sl. No.	Input Voltage in Volts	Output Voltage in Volts	Static Gain
1	3	23	7.66
2	6	42	7.0
3	9	62	6.89
4	12	87	7.25
5	14	102	7.2
6	18	127	7.05
7	20	137	6.85
8	24	170	7.08
9	26	187	7.19

The above table II shows the experimental results of two phase boost converter interleaved with single multiplier. The readings are obtained for resistive load, and they are tabulated and calculated in the above table. The practical static gain of boost converter is 7.13 is obtained for single multiplier stage, thus the obtained gain is nearly equal to the theoretical values of the boost converter i.e. 8.

B. Experimental Results of the proposed system

Table III Experimental Results of the proposed system

Sl. No.	Type of Input	Input Voltage in Volts	Output Voltage in Volts (for CFL, Power LED and incandescent Lamp as load of 10W to 100W)			
			HIGH voltage DC output (Nano Grid Application)	LOW voltage DC output (Power LED lighting Application)	LOW Load AC output voltage	HIGH Load AC output voltage
1	SOLAR (Module Power Supply)	12V	140	12	120	230
2	WIND (Module Power Supply)	12V	140	12	120	230
3	Battery	12V	181	12	140	230
4	AUX Battery	12V	181	12	140	230
5	GRID	230V	140	12	140	230

The gate pulses are observed for different loads and voltages are shown in the following figures.

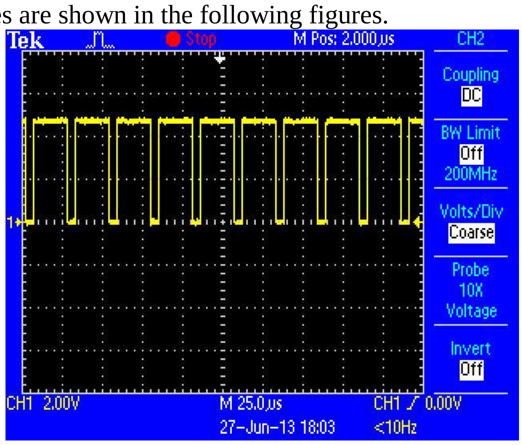

Fig 2 Gate pulses for Boost converter control

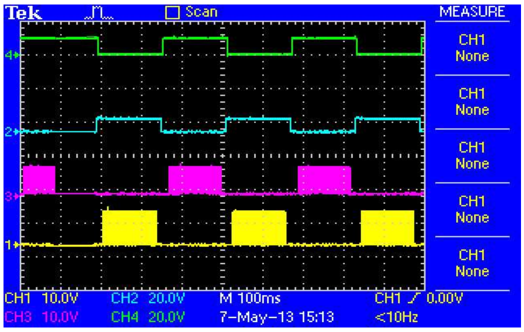

Fig 3 Gate pulses for H Bridge inverter control

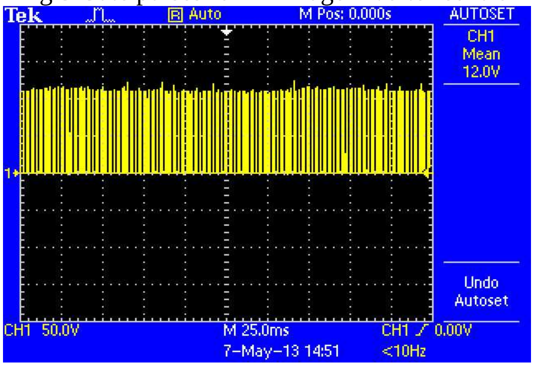

Fig 4 Boost converter output waveforms

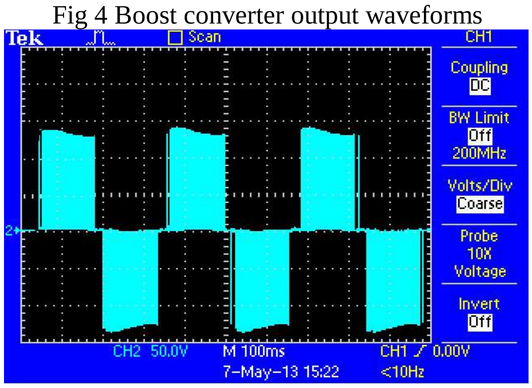

Fig 5 Inverter output waveform without filter

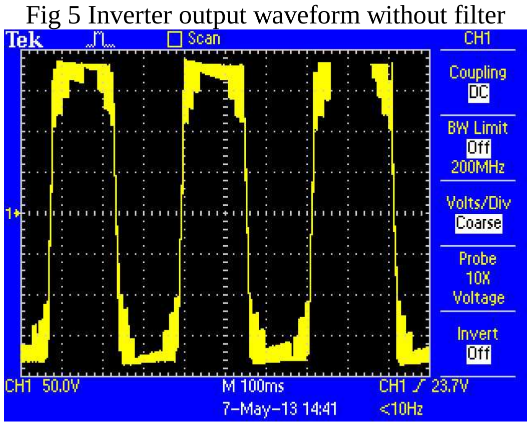

Fig 6 Inverter output waveform with filter

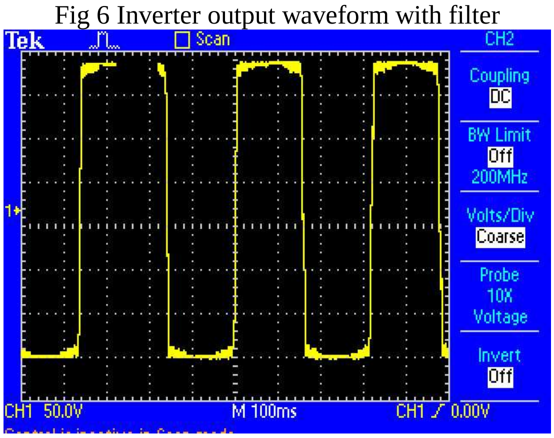

Fig 7 Inverter output voltage for CFL LOAD

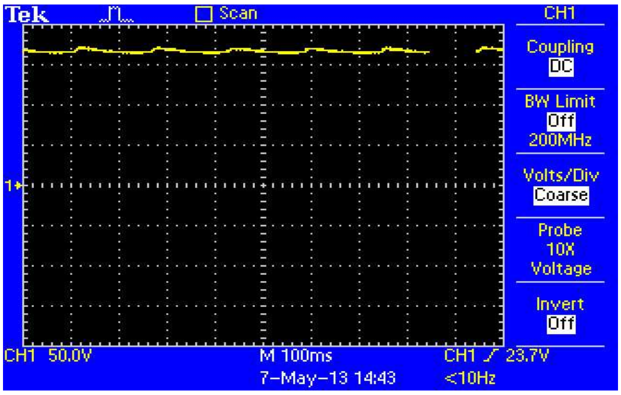

Fig 8 High DC output voltage waveform for the input of 12V

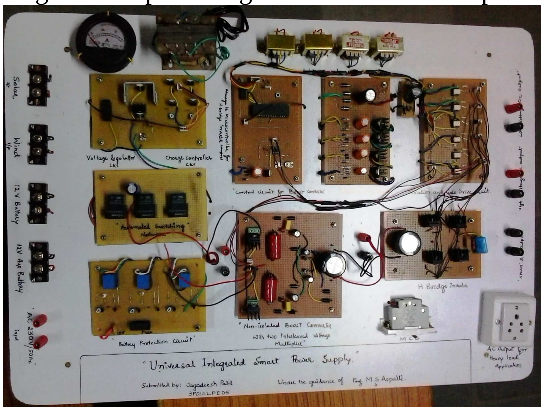

Fig 9 Photograph of the complete system

Fig 10 Photograph of complete Experimental setup

IV. CONCLUSION

A "Universal Integrated Smart Power Supply" advantageous opportunity is presented here. Combination of various supplementing energy sources shall create a unique renewable energy based system with optimized usage.

The integration of all power converters is necessary to supply the energy demand of a low power residence, using photovoltaic modules and wind turbine is proposed in this work. This integration simplifies the installation of the equipment and the system inter connects number of renewable sources and grid connection to the end user.

The developed system is tested in power electronics laboratory, compact fluorescent lamp (CFL), Power LEDs and Incandescent lamps are used as load and the maximum ratings of the designed system is about 400 watt. The experimental result shows that the developed hardware satisfactorily works for both ON grid and OFF Grid mode.

Applications of the proposed system: Rural electrification, On grid / off grid low power application, Third generation lighting (power LED), House/small office electrification, Power supply for Remote servers, Street light, Farm house electrification, and Remote area electrification etc.

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