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Single Stage Single Phase Reconfigurable Inverter Topology

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ABSTRACT: This paper suggest a reconfigurable single phase inverter topology for a hybrid AC/DC solar powered home. This inverter possess a single phase single stage topology and the main advantage of this converter is that it can perform DC/DC, DC/AC and grid tie operation, thus reduces loss, cost, size of the converter. This hybrid AC/DC home has appliances of both AC and DC types. This type of home helps to reduce the power loss by avoiding unnecessary double stages of power conversion and improves the harmonic profile by isolating DC type loads to DC supply side and rest of AC side. Firstly, simulation is done in Proteus Software and secondly, obtained results are validated with hardware implementation using Arduino Uno controller. Such type of solar powered home and inverter would be a basic building block of energy efficient future Smart Grid and Microgrid.

KEYWORDS: Single phase single stage inverter, solar Photo Voltaic, Hybrid AC/DC Home, harmonic mitigation

I.INTRODUCTION

Now a day, Electricity is becoming very essential for survival. The consumption of electricity is increasing due to increasing population. Because of increasing load demand, the various electricity board doesn't able to fulfill the Load Demand. So gap between generation side and utility side is increasing. To Overcome the Gap between generation side and utility side Now a day Renewable Energy Source, such as photovoltaic, Wind power, etc are very much Popular. Most of the load used by consumes are AC, which cause Harmonic loss. These harmonic losses affect the whole system. It causes decreasing efficiency as well as Power Quality of the system. Hence performance of the whole system Decreases. Most of the devices used in domestic loads are work on DC supply, but supply provided by the grid is AC. It is then rectified to DC at required value and provided to the various devices. At this junction, major losses are occurs, which cause harmonic current and this harmonic current affect voltage coming from supply resulting voltage fluctuation and voltage harmonic. Due to increasing Non-linear household equipments, harmonic loss increases; so we need to improve power quality by reducing harmonics.

In this paper, it is proposed that the inverter topology will make it efficient and will be able to perform with this situation, and also be able to reduce harmonic losses by using DC/DC, DC/AC converter. For this particular purpose two stage conversions are required to boost up the DC voltage and to invert it. However, this will increase the cost, size and loss of the system. To avoid this, single phase single stage topologies of inverter are suggested.

II.WORKING

1. MICROCONTROLLER

The Atmega32 is used to generate Sinusoidal PWM. Atmega328P used for switching operation.This board is interfaced with environment in order to implement the control logic of RSC. It has inbuilt PWM pulse generators and analog and digital input reader which will be very useful in controlling the voltage and phase of the proposed converter**.** The DC power supply in a battery in the Different power levels are generated by changing the voltage and current setting of the DC power supply to replicate different operating conditions. The Loads and relay used in this experiment. The maximum harmonic producing loads in household is identified as charging and lighting loads in literature. By replacing them with their DC counterpart and connected to a DC supply side of the Hybrid AC/DC home, a significant improvement in the harmonic profiles can be achieved in residential feeder. So in this work, DC and AC LED lamps

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are used as AC and DC loads. For charging loads, a 12 V, 9 Ah battery is used which is charged through RSC for DC supply side connection and charged from AC through an adaptor to show the difference between AC and DC charging in terms of harmonics. The relay used in this experiment is 4 relay module each with a rating of 250 V AC, 10 A or 30 V DC, 10 A. The operation time of this relay is 10 milliseconds. The operating time of a relay when a pulse from UNO board is given for testing purposes of the relay. In mode 1, to synchronize with the grid LEM (a leading company manufactures current and voltage sensors) low voltage transducer LV-25 is used to measure the voltage and it is given to the UNO analog input. Due to the interfacing with the analog input will read in and produce the synchronizing pulses using PWM pulse generator. This pulse is given to the PWM output pins of the UNO board. The voltage of the inverter is lies along the voltage of the grid. The active power transfer with the grid. Current Transducer LA 25-P is used for the sensing of current and its setting is 1/1000, and 1 kΩ resistor is connected to read in the DSO.

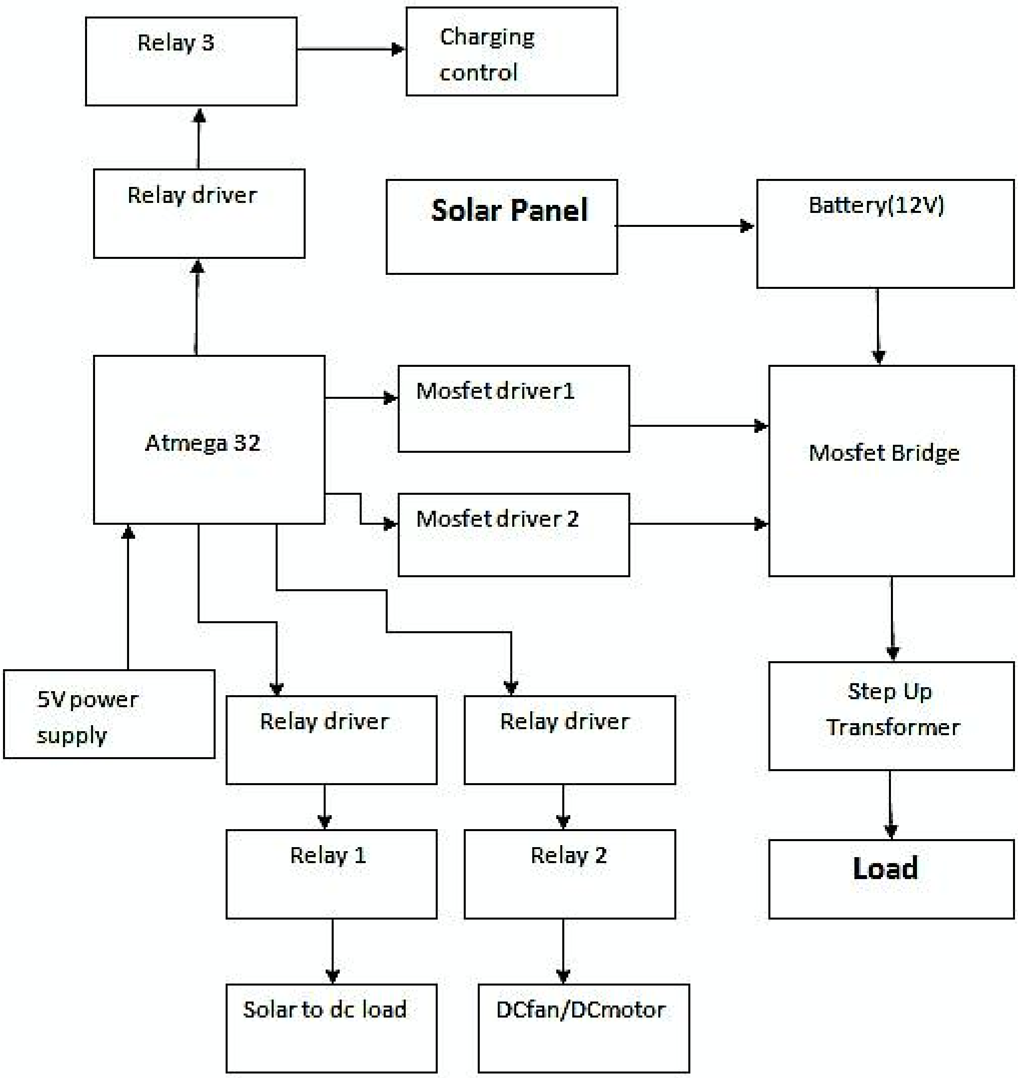

Fig 1. Block Diagram.

Waveform ‘V’ is grid voltage and ‘I’ represents as the inverter current injected to grid for active power transfer. From the figure the current and voltage are in the phase which will inject the active power to the grid. The rms voltage is 220 V and current is 1.5 A Peak.

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2. MOSFET

The metal oxide semiconductor field effect transistor MOSFET a voltage control current device. It differs from junction field effect transistor JFET that it has no pn junction structure. It has a metal gate, which insulates the conducting channel with silicon oxide SiO2. In the modern design, metal gate has been replaced by either p+ or n+ poly-silicon. MOSFET not only can be used to design amplification circuit. It can also be used as a capacitor and a resistor. This capability makes the VLSI design simpler because there is no need to use other element for capacitor and resistor in the design In this proposed inverter, IRF3205 MOSFET is taken into application. These transistors can be used in various switching application. Advanced HEXFET® Power MOSFETs from International Rectifier utilize advanced processing techniques to achieve extremely low on-resistance per silicon area. This benefit, combined with the fast switching speed and ruggedized device design that HEXFET power MOSFETs are well known for, provides the designer with an extremely efficient and reliable device for use in a wide variety of applications.

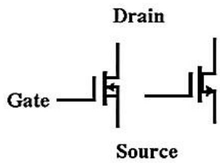

Fig 2. Symbol of Depletion enhancement MOSFET.

3. MOSFET DRIVER

The IR2112(s) is a high voltage, high speed power MOSFET and igbt driver with independent high and low side referenced output channels. Proprietary HVIC and latch immune CMOS technologies enable ruggedized monolithic construction. Logic input are compatible with standard CMOS or LSTTL outputs, down to 3.3V logic. The output driver feature a high pulse current buffer stage design for minimum driver cross conduction. Propagation delay matched to simplify use in high frequency applications. The floating channel can be used to drive a N-channel power MOSFET or IGBT in high side configuration which operates up to 600 volts.

III.MODE OF OPERATION

The circuit diagram of reconfigurable solar inverter is given in the Fig. 4. Though it will reduce the no of power conversion stages but mechanical switches and cable requirement are more for this topology. The modes of operations of the proposed single phase single stage converter are given in Table 1.

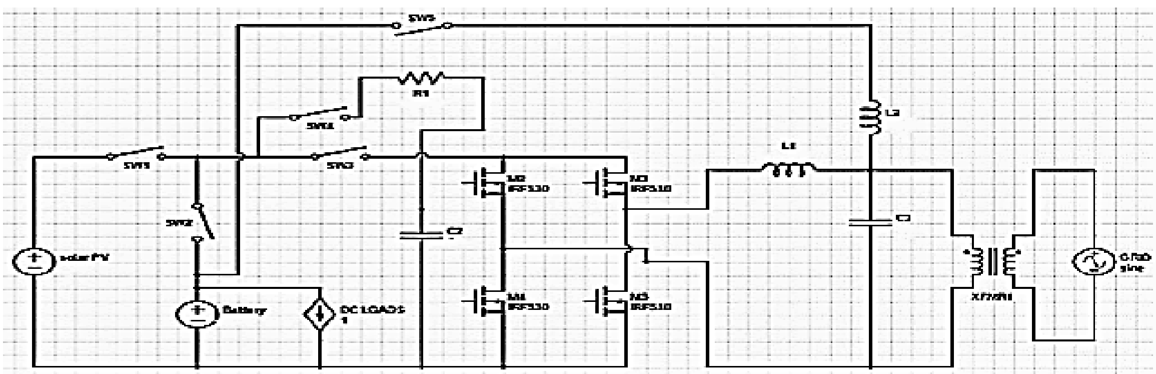

Fig. 4: Schematic of the proposed RSC circuit

MODES OF OPERATION	ON SWITCH	OFF SWITCH
PV-LOAD	SW1 SW3 SW 4	SW2 SW5
PV-BATTERY-LOAD	SW1 SW2 SW3 SW4	SW5
BATTERY CHARGING	SW1 SW3 SW5	SW2 SW4
BATTERY-LOAD	SW2 SW3	SW1 SW4 SW5

Table. 1 Modes of Operation

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MODE 1:

In this mode, the solar panel is directly connected to the DC load, when Switch S1, S3, S4 will be ON and Switch S2, S5 will be OFF. DC load will be connected for better performance.

MODE 2:

In this mode of operation inverter supply power to the grid from both solar PV and battery. This mode operates when there is a shortage of power from the solar PV due to external conditions, e.g., weather etc. One of the drawbacks of this connection is that the battery voltage and PV voltage should always be matching each other.

MODE 3:

In this mode, battery will be charged by solar power.

MODE 4:

In this mode, Battery will be directly connected to AC load through Inverter.

IV. PROPOSED CALCULATION

SOLAR PV SYSTEM SIZING

1. Determine power consumption demands

- A HOD Cabin has the following electrical appliance usage:
- Two 65 Watt Fan used for 5 hours per day.
- Two 200 Watt Computer used for 5 hours per day.
- Four 40 Watt Tube used for 6 hour per day.

1.1 Calculate total Watt-hours per day for each appliance used.

Total appliance use = (2 x 65W x 5 hours) + (2 x 200 W x 5 hours) + (4 x 40 W x 6 hours)

=3610Wh/day

1.2 Calculate total Watt-hours per day needed from the PV modules.

Multiply the total appliances Watt-hours per day times 1.3 (the energy lost in the system) to get the total Watt-hours per day which must be provided by the panels.

Total PV panels energy needed = 3610 x 1.3

= 4693Wh/day.

2. Size of PV modules

Different size of PV modules will produce different amount of power. To find out the sizing of PV module, the total peak watt produced needs. The peak watt (Wp) produced depends on size of the PV module and climate of site location. We have to consider "panel generation factor" which is different in each site location. For Thailand, the panel generation factor is 3.43. To determine the sizing of PV modules, calculate as follows:

2.1 Calculate the total Watt-peak rating needed for PV modules

Divide the total Watt-hours per day needed from the PV modules (from item 1.2) by 3.43 to get the total Watt-peak rating needed for the PV panels needed to operate the appliances.

Total W_p of PV panel capacity needed = 4693/ 3.4

=1380.3W_p

2.2 Calculate the number of PV panels for the system

Divide the answer obtained in item 2.1 by the rated output Watt-peak of the PV modules available to you. Increase any fractional part of result to the next highest full number and that will be the number of PV modules required.

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Result of the calculation is the minimum number of PV panels. If more PV modules are installed, the system will perform better and battery life will be improved. If fewer PV modules are used, the system may not work at all during cloudy periods and battery life will be shortened.

Number of PV panels needed = 1380.3/ 110
= 12.55modules

Actual requirement = 13 modules
So this system should be powered by at least 13 modules of 110 Wp PV module.

3. Inverter sizing:

An inverter is used in the system where AC power output is needed. The input rating of the inverter should never be lower than the total watt of appliances. The inverter must have the same nominal voltage as your battery.
For stand-alone systems, the inverter must be large enough to handle the total amount of Watts you will be using at one time. The inverter size should be 25-30% bigger than total Watts of appliances. In case of appliance type is motor or compressor then inverter size should be minimum 3 times the capacity of those appliances and must be added to the inverter capacity to handle surge current during starting.
For grid tie systems or grid connected systems, the input rating of the inverter should be same as PV array rating to allow for safe and efficient operation.

Total Watt of all appliances =2 x 65 + 2 x 200 + 4 x 40 = 690W

For safety, the inverter should be 25-30% bigger in size.
The inverter size should be about 862 W or greater.

4. Battery sizing

The battery type recommended for the use in solar PV system is deep cycle battery.It is specifically designed for low energy discharge level and rapid charging or cyclic charge and discharge day after day for years. The battery should be large enough to store sufficient energy to operate the appliances at night and cloudy days. To find out the size of battery, calculate as follows:

4.1 Calculate total Watt-hours per day used by appliances.
4.2 Divide the total Watt-hours per day used by 0.85 for battery loss.
4.3 Divide the answer obtained in item 4.2 by 0.6 for depth of discharge.
4.4 Divide the answer obtained in item 4.3 by the nominal battery voltage.
4.5 Multiply the answer obtained in item 4.4 with days of autonomy (the number of days that you need the system to operate when there is no power produced by PV panels) to get the required Ampere-hour capacity of deep-cycle battery.

$$\text{Battery Capacity (Ah)} = \frac{\text{Total Watt-hours per day used by appliances}}{(0.85 \times 0.6 \times \text{nominal battery voltage})} \times \text{Days of autonomy}$$

Total appliance use = (2 x 65W x 5 hours) + (2 x 200 W x 5 hours) + (4 x 40 W x 6 hours)
=3610Wh/day

Nominal battery voltage = 12 V
Days of autonomy = 3 days

$$\text{Battery capacity} = \frac{[(2 \times 65W \times 5\text{ hours}) + (2 \times 200\text{ W} \times 5\text{ hours}) + (4 \times 40\text{ W} \times 6\text{ hours})]}{(0.85 \times 0.6 \times 12)} \times 3$$

Total Ampere-hours required 1769.61Ah

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So the battery should be rated 12V 600Ah for 3 day autonomy.

5. Solar charge controller sizing

The solar charge controller is typically rated against Amper and Voltage capacities. Select the solar charge controller to match the voltage of PV array and batteries and then identify which type of solar charge controller is right for your application. Make sure that solar charge controller has enough capacity to handle the current from PV array.

For the series charge controller type, the sizing of controller depends on the total PV input current which is delivered to the controller and also depends on PV panel configuration (series or parallel configuration).

According to standard practice, the sizing of solar charge controller is to take the short circuit current (I_{sc}) of the PV array, and multiply it by 1.3

Solar charge controller rating = Total short circuit current of PV array x 1.3

PV module specification

$P_m = 110\ W_p$
$V_m = 16.7\ V_{dc}$
$I_m = 6.6$ A
$V_{oc} = 20.7$ V
$I_{sc} = 7.5$ A

Solar charge controller rating = (13 strings x 7.5 A) x 1.3 = 126.75 A

So the solar charge controller should be rated 127A at 12 V or greater.

V. CONCLUSION

This paper suggested a more suitable converter topology for a solar powered hybrid AC/DC home. The main concepts of this topology is that a single phase single conversion of AC power to DC and vice versa is employed, which improved the efficiency, reduces volume and enhances the reliability. By means of this project we can get hybrid output which means both DC and AC for household applicants. On account of this topology harmonics is reduced to provide an energy in form of ecofriendly manner for the future generation.

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