ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com

International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 5, Special Issue 8, March 2018

SOLAR ENERGY FED DC MICROGRID FOR DOMESTIC LIGHTING

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Abstract: Solar DC solution is an innovative technology that provides green solar energy and DC power at a very low cost. The technology gets rid of AC to DC and DC to AC conversions which help in reducing the cost of production per unit watt power. Most of our present day devices run on DC power resulting in losses due to AC to DC conversion. We can harness DC power easily from abundantly available solar energy and later store it in batteries. Solar DC will not only replace the expensive, bulky and inefficient inverters but also save electricity bills adequately. This paper presents ou r project work of Inverter less PV solar power fed to the DC loads interfacing boost converter, microcontroller and storage batteries for ensuring load voltage compatibility, consistency, and sustainability and energy storage. Solar PV panels, Batteries and boost converter were adequately sized based on the load requirements. Simulation results were shown. A transforming power scenario is well brought out through our work.

Keywords inverter less, DC loads, DC micro grid, green energy, solar DC, conversion loss, DC appliances

I. Introduction

Solar DC solutions or DC Micro-grid is an innovative technology which provides green solar energy and dc power at a very low cost. The technology removes the requirement of AC to DC and DC to AC conversions which helps in reducing the cost of production of per unit watt power

A. Why to go for Inverter less solution?

- Solar DC will not only replace the bulky expensive inefficient inverters but also saves 50% of the EB bill (Lot of savings)
- We can harness solar DC power easily and store them in Batteries (Easy to harness and store)
- No conversion losses
- Less Space. Takes 50% lesser space as compared to the AC solutions
- Safe and no worry from electric shocks as the DC appliances are safer than the 230v AC appliances
- Reliability- DC appliances have higher reliability and gives far better life span compared to AC appliances
- Makes going green straight
- Low investments and greater Returns
- DC appliances consume 15 to 60% less power compared to their counterparts

The falling prices of solar panels and of batteries as well are likely to propel the industry into experimentation with new techniques. While it would be presumptuous to state that any one select technology will become the chosen mode for power generation, transmission or distribution, one can confidently state that all the three sectors will have to face fierce winds of change, even redundance. It is well established that access to energy is closely linked with socioeconomic development. India has the largest share of the world's population deprived of electricity with more than two hundred million people lacking access according to the International Energy Agency. At the same time many homes in India that do have access to electricity lack uninterrupted power supply and quality power. A recent study conducted by the Council for Energy, Environment and Water(CEEW) across six states revealed that about 50% of the households had no electricity despite having grid connection. This indicates that there is an immediate need to address the quality, affordability and reliability of the power supply. The CEEW report suggests that, despite thousands of villages being electrified over the past decade, under the

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government's rural electrification program, over 85% of the households in the five or six states considered in the study hadssssss electricity for less than 8 hours (maximum load of 50W) or no electricity at all. Moreover, these households were found to be experiencing blackouts for two to four days a week. Low-income homes in most parts of India have poor access to electricity. Overall, the problem of energy access in India is quite unique and requires a new approach that requires modern technological innovations.

One way India can overturn the whole narrative of energy access to low and medium income households is by adopting novel solar and energy storage technologies and promoting innovations, such as a direct current micro grid which benefits the energy starving.

II. Analysis of Existing Problem

A. Poor economics of power connections

The apparent reason for a large number of homes remaining off the grid and those with the grid having long hours of load shedding is a shortage of power. India generates less power than it would like to consume, but this has been changing over the past few years. Power generating capacity is increasing, whereas the consumption has not been increasing as fast. As a result, the demand-supply gap has been narrowing, and power shortages may no longer be the primary reason for the prevailing situation. Even during the peak-demand hours, the gap is no longer severe. The limitations of the power-transmission grid in some regions of the country were another reason that power did not reach power deficit areas. Even this issue has been considerably rectified, as the power grid in the country has expanded its capacity. The shortage of power is therefore no longer the primary reason for a number of Indian homes having no power or power for limited hours. Another apparent reason for a large number of home being off the grid is that, even when the village has grid connectivity, the power lines have not been extended to each home. In fact as per the definition provided by the Ministry of power, India," a village is considered electrified when 10% of the homes in a village are connected to the grid." Even though it is a serious problem, this bottleneck could be overcome by extending power lines to all since remote homes in a connected village should not be expensive or difficult. The real reason for the current power situation may lie in the economics. First of all, can these homes afford to pay for power even at the currently subsidized power tariffs? Secondly, can the power distribution companies (DISCOMS) afford to supply power to these homes at subsidized rates? The answer to both these questions may not be in the affirmative, and, unless this issue is addressed, many of these homes may remain without access to electricity for a long time.

The power tariff for homes in India is about Rs.5/ unit. A small home that in a day uses two tube lights for 6 hours, two fans for twelve hours, two bulbs, a 24 in TV for 10 hours and cell phone being charged for 4hours consumes a little over three units of energy a day costing Rs.500/- a month. This would be expensive for at least 50% of all Indian homes and an even larger percentage of rural homes. Therefore, in many parts of the country, the electricity tariff is further subsidized for the first 50 or 100 units. However, even half of Rs.500/-month is not affordable for many of these households. It is possible that homes in the lowest-income group may manage with less power and use one tube light, one bulb and one fan instead of two. That will help, but the quality of life would suffer. Many of the households would still not be able to afford their energy bills. At the same time, slightly better-off homes would like to add refrigerators, mixers and computers adding to their energy bill and making it more unaffordable.

On the other hand, DISCOMS lose money even when they supply power at Rs.5/-unit. The cost of power from plants using oil and gas (most of which is imported) is quite high in India. However, India can produce power from coal at a cost of Rs.3/-unit. Therefore even though coal is a pollutant, power production using coal has been increasing rapidly in India. Even then DISCOMS cannot break even when they supply power to homes. First, they have to take into account the transmission and distribution (T&D) losses (for rural homes it varies from 40% to 70%). Secondly, coal power takes time to ramp up and to ramp down. Therefore one cannot size coal plants for peak loads. One needs other power sources with faster responses. These are usually, oil/gas based plants, where the cost of generation is higher. This increases the cost of power for the DISCOMS. With regard to this, once the costs of meter reading, billing, collections (for large number of homes, each paying small amounts) and the overhead costs are added, DISCOMS start losing money. When the state governments push DISCOMS to supply power at subsidized rates (for example, lower tariffs for the first 50 or 100 units), DISCOMS lose even more. They have no incentive to continue to supply power or expand connections to home not on the grid, as they know that these homes can afford (and pay) even less. Hence, at

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peak hours, they find one reason or another to carry out load shedding. One retired chief Engineer of DISCOM remarked, “We are happy when there is load shedding as we lose less money.” This sums up the reality faced in India.

B. Can Rooftop Solar panels address these issues?

Recently rooftop solar panels have been touted as an alternative source for power generation. A 500W solar panel in most parts of India could generate most of the power required. As there would be no T&D losses, the solution looks promising. At an installed cost of Rs.50/- per W_P, the rooftop photovoltaic (PV) would amount a little over Rs.3/- unit, assuming depreciation over 20 years and an interest rate of 7% (In India commercial interest rate varies from 13% to 16% today. Homes may be able to put their savings in fixed deposits and earn about 7%). This would be attractive. However solar power is available only during the day time, and even then, it fluctuates. On the other hand DISCOMS face peak demand both in the day time and in the evening. Hence, they are likely to resort to load shedding mostly during these times. Thus a rooftop solar installation would require a battery, which increases the cost considerably by almost four times, and as a result, solar power remains no longer attractive.

Furthermore, a solar PV produces dc power that needs to be converted into alternating current (ac) and synchronized to the ac grid. When 10kW of solar dc power is converted and synchronized to ac, the conversion loss could be as low as 3%. However when 250-500W solar dc power is used, these losses could be as high as 15% as long as the converter cost is a small percentage of the solar panel cost. The problem gets further gets compounded as the input and output power of a battery is only dc. Alternating current power needs conversion to dc before it charges the battery, and the battery output needs conversion to ac before it drives the load. Each of these conversions is also likely to have a 15% loss. In addition there is battery loss (as high as 8 to 10% loss for low cost lead acid batteries) and over half the solar power is lost before it reaches the load.

The approach looks more absurd when one examines the load to be driven. Some 62% of India’s home load is composed of ceiling fans and lighting. With the advent of brushless dc (BLDC) motors, a dc powered ceiling fan consumes only 40% of the power consumed by conventional ac powered induction motor based ceiling fans. If one uses ac powered ceiling fans, another converter with about 15% loss will be required. Similarly conventional ac powered compact fluorescent lights being replaced by Light Emitting Diode (LED) lighting. LED use dc and best powered by dc. Electronics (such as TVs, cell phones and computers) are increasingly being used in homes, and all electronics need dc power. Taking the solar through multiple conversions to power the ac home grid and then converting it into dc power of these devices indeed is ridiculous. The stage is set for dc micro grids for homes powered by rooftop solar panels having batteries.

One of the key challenges in designing such a micro grid is to keep the losses low. The problem is not as straight forward as it appears. The solar PV panel’s voltage [at maximum power point (MPP)] would vary during the day. The battery’s voltage will vary depending upon its state of charge and the load would be expected to operate at a fixed voltage. The design would therefore require some smart power electronics such that the solar PV operates at its MPP and the battery is charged and discharged optimally while driving the load with minimal losses.

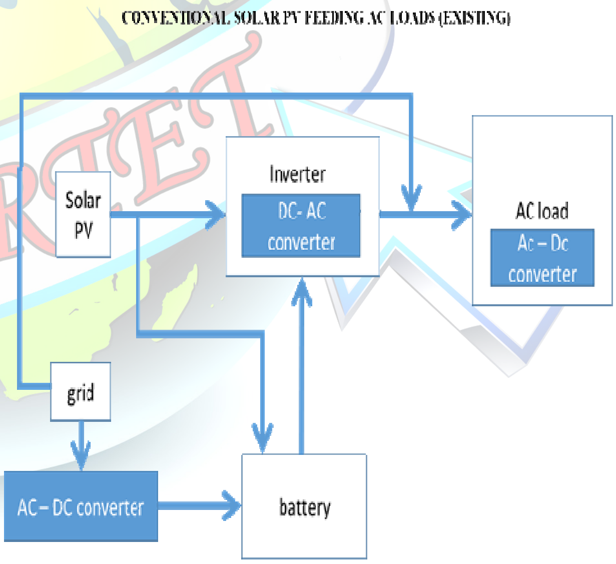

Fig. 1. Block diagram of existing system

Figure 1 represents the block diagram of the conventional solar system with inverter to feed ac loads.

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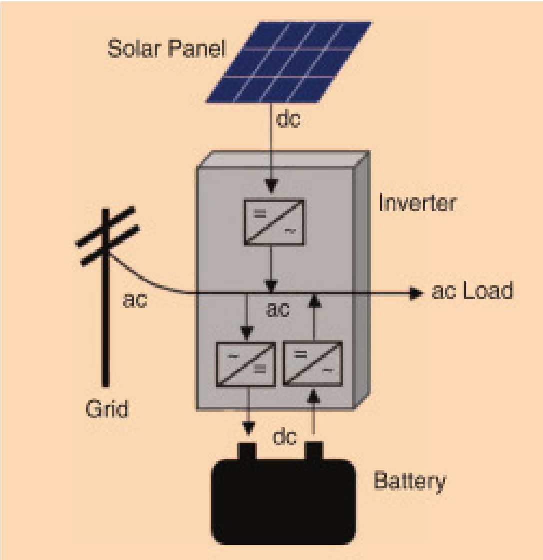

Fig. 2. Solar AC system with Inverter

Figure 2 describes the conventional system and the table-1 compares the power consumption for the ac loads and dc loads for a small home.

Table I
Device Power Consumption,typical number of Appliances in a small home and usage

Appliance	Ac powered appliance (watts)	Dc powered appliance (watts)	Numbers	Number of operating hours/day
Fan	67	24	2	6
Bulb	40	5	2	12
Tube light	36	18	2	10
TV	40	30	1	4
Phone	6.5	5	1	10

Ac powered induction motor fan at an average speed is considered for ac and BLDC fan is considered for dc.

C. Problems in Conventional Solar AC System with Inverters

- Presence of converters
- Conversion losses 15 to 40%
- Reduced performance
- Low operating efficiency

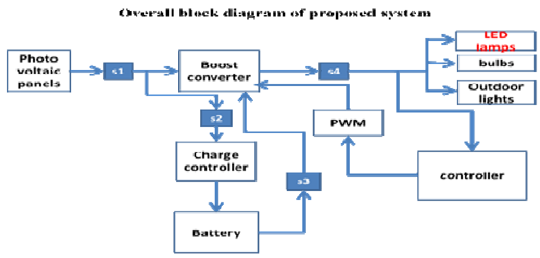

Fig. 3. Inverter less solar dc system for lighting loads

Figure 3 represents the inverter less solar dc system proposed incorporating boost converter, batteries, controller and dc lighting loads for a small home. PV dc voltage charges the battery in s1-s2 mode during the day time and the stored energy will deliver the lighting loads during the night time through s3-s4 mode. Boost converter will maintain the battery charge voltage and the load voltage will be maintained by the controller.

D. Technical Benefits of the Proposed System

- Elimination of inverters
- Energy bill savings
- Easy harness of dc power from PV solar
- No conversion losses
- Lesser space requirements
- Safety and no worry from electric shocks
- High reliability
- Lower cost
- Low power consumption

E. Available DC loads

- LED lamps
- Mobile chargers
- BLDC fans
- Computers
- Mixers
- LED TVs

F. Design of PV panel and Batteries

Typical loads considered	2 x 24W LED lamps
Total consumption	48W
Operating hours	4h
Total watt-hours	48 x 4 = 192Wh
Depth of discharge (DOD)	70%

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Batteries considered 12V, 7Ah
Battery discharge 7AH X 0.7 = 4.9Ah
= 5Ah (approx)
PV panel considered $50W_P$
Voltage rating of 50W panel = 17.5 V_{mp}
Required charge capacity = 192 / 17.5 = 11Ah
Number of Batteries required = (11/ 4.9) = 2.3
= 3 nos
Extra charge capacity = (11x3) / (2.3) = 14Ah
Number of 50W PV panels = 2 numbers
Energy required at the battery
Input side = 192 / 0.85 = 226 Wh
(Considering 85% battery efficiency)
Boost converter efficiency = 90%
Considering this efficiency = 226 / 0.9 = 251Wh
Connection arrangement of
Batteries = 3x12v in series
LED lamps operation voltage = 75V dc
Total Ah to be generated = 251 / (2x17.5) = 7.2Ah
Sunshine hours per day = 5h
Total amps to be generated
by 50W PV panel = 7.2 / 5 = 1.44A

G. PV Panel specifications

Power rating $50W_P$
Open circuit voltage 21.6 V
Current rating 2.858A I_{mp}
Voltage rating $17.5V_{mp}$
Short circuit current rating 3.12A

III. PV Simulation Results in Matlab

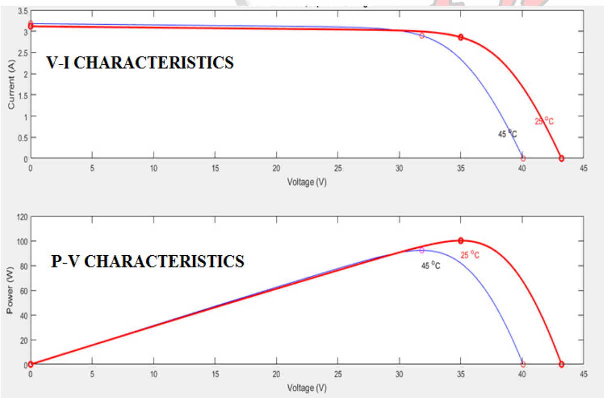

Fig. 4. PV characteristics of solar panel simulated using Matlab

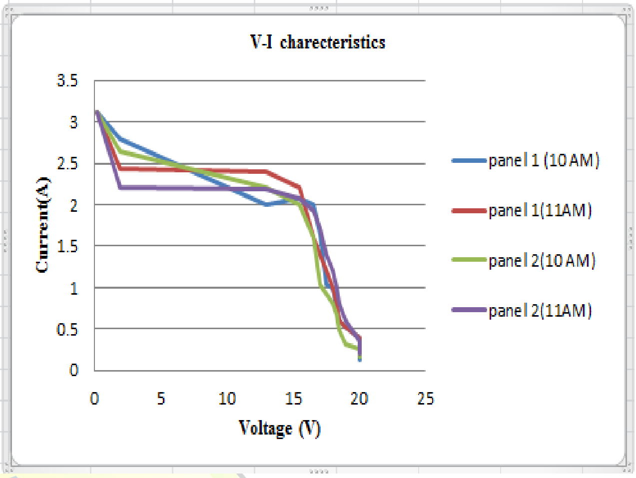

Fig. 5. PV characteristics of solar panel plotted using practical values taken at different times

Figure 4 and 5 represent both simulated and real time PV characteristics of solar panel respectively.

IV. Boost Converter Design

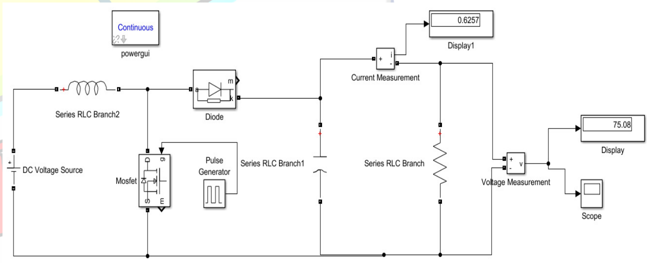

Fig. 6. Boost converter Simulation Model

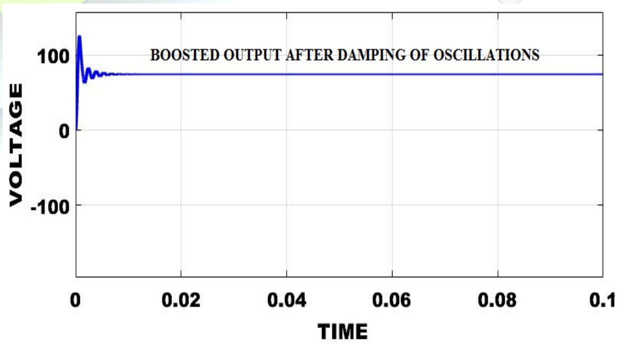

Fig. 7. Boost converter simulated waveform

Figure 6 and 7 represent the simulation set up and waveforms for the boost converter design

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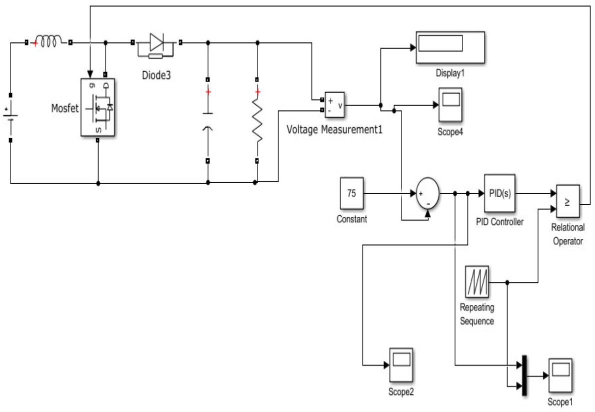

Fig. 8. Closed loop control of Boost converter

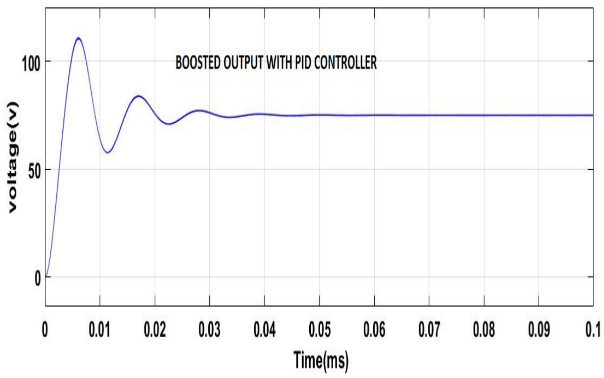

Fig. 9. Boost converter simulated waveform with PID controller

Figure 8 and 9 represent the simulation set up and waveforms for the boost converter with PID control.

A. Future scope

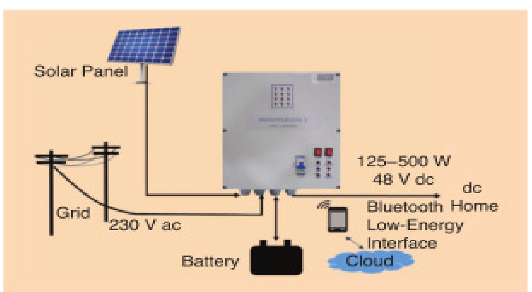

Figure 10. Inverter less solar dc system for all the loads

Figure 10 shows the system for all the domestic dc loads with high efficiency converter.

V. Results and Discussion

- The simulation results for the Boost converter design is shown
- The simulation results of the characteristics of the solar PV panels are produced using mat lab 2016 version
- The current produced by the PV namely 1.44A is lower than the Imp rating of the panel
- The PV panels were tested at different timings measuring the solar irradiations and wind speed ,with our weather station, and real time V-I characteristics were plotted
- The two PV panels were connected in series interfacing boost converter, controller, three numbers of 12V,7Ah series connected batteries along with two numbers 24W,75V LED lamps connected in parallel and tested for satisfactory operation
- The loads (only lighting) and the Ah ratings of the batteries were limited due to economic constraints
- However the proto demo model could be extended to all types of dc loads with reference to figure 6 shown

VI. Conclusion

A large percentage of Indian population, especially the lower and the middle – class homes are denied access to quality power most of the time. The shortage of power and the lack of connectivity to homes were traditionally understood to be the primary causes. Disruptive technology is required to get rid of such issues. Inverter less solar dc could be the appropriate technology in future.

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