Supercapacitor Power Managmenent Using Boost Converter Renewable Energy Fed DC Motor

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Abstract— This paper implements a smart boost converter fed DC motor which is powered by photovoltaic cells/ battery. A 220V, 0.8A universal motor which is driven by boost converter and Supercapacitor is used to deliver required power to the load during transient period. Large electric drives require advanced power electronic converters to meet the high power demands. With the shortage of the energy and ever increasing of the oil price, research on the renewable and green energy sources, especially the solar arrays and the fuel cells, becomes more and more important. How to achieve high step-up and high efficiency DC/DC converters is the major consideration in the renewable power applications due to the low voltage of PV arrays and fuel cells. This converter provides the constant output voltage irrespective of the PV panel output and load. The simulation and experimental results of this system are presented and compared. The performance of the converter is also compared with the conventional boost converter. This comparison reveals that the proposed converter system has the advantages of high gain and high efficiency with the minimum number of components. This thesis aims to explain the knowledge about the performance of the boost converter and the performance is analyzed by way of simulation. The variations at the load is overcome by using Supercapacitor and the balancing of Supercapacitor is done.

Index Terms - Boost converter, DC motor, Supercapacitor, Power management

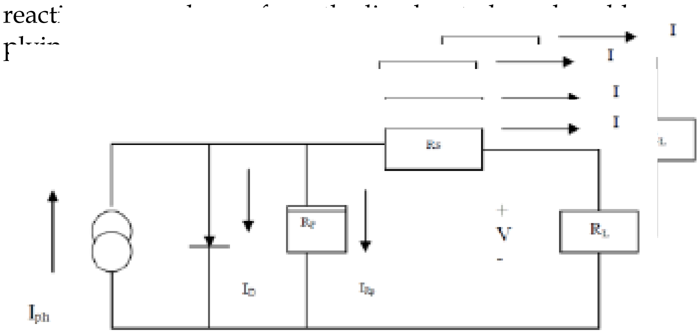
1 Introduction

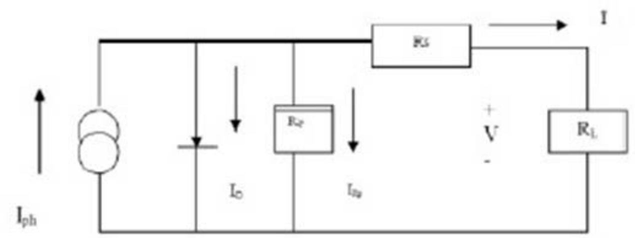
The usage of the fossil fuels, such as the oil, the coal and the gas, result in serious greenhouse effect and pollute the atmosphere, which has great effect on the world. Meanwhile, there is a big contradiction between the fossil fuels supply and the global energy demand, which leads to a high oil price in the international market recently. The energy shortage and the atmosphere pollution have been the major limitations for the human development. To find renewable energy is becoming more and more exigent. Photovoltaic (PV) sources are one of the significant players in the world's energy portfolio and will become the biggest contributions to the electricity generation among all renewable energy candidates by year 2040 because it is truly a clean, emission-free renewable electrical generation technology with high reliability. The task of a maximum power point tracker (MPPT) in a photovoltaic (PV) energy conversion system is to continuously tune the system so that it draws maximum power from the solar array regardless of weather or load conditions. Since the solar array has a non-ideal voltage – current characteristic and the conditions such as insulation, ambient temperature, and wind that affect the output of the solar array are unpredictable, the tracker must contend with a nonlinear and time-varying system. Many tracking algorithms and techniques have been developed.

The limitations of the conventional boost converters are analyzed and the conceptual solution for high step-up conversion is proposed in this paper. Then the state-of-the-art topologies are covered and classified based on the circuit performance. The challenges in high step-up renewable energy applications are summarized to generate the next generation non-isolated high step-up DC/DC converters.

2 Literature Survey

Electric motors have broad applications in such areas as industry, business, public service and household electrical appliances, powering a variety of equipment including wind blowers, water pumps, compressors and machine tools. In industrially developed nations and large developing nations, electric motors account for a considerable proportion of total national power consumption. Statistics indicate that electric motors are generally responsible for about 2/3 of industrial power consumption in each nation, or about 40%of overall power consumption By introducing variable speed to the driven load, it is possible to optimize the efficiency of the entire system, and it is in this area that the greatest efficiency gains are possible Power factor correction equipment that can be applied at the motor level will not only decrease energy use but will significantly extend the life of the equipment. Additionally, it also maximizes the capacity of the power system, improves the quality of voltage, and reduces the power losses. In order to decrease the cost and to improve the efficiency, the react





An ideal is modeled by a current source in parallel with a diode. However no solar cell is ideal and thereby shunt and series resistances are added to the model as shown in the PV cell diagram above. RS is the intrinsic series resistance whose value is very small. RP is the equivalent shunt resistance which has a very high value. [2]

Applying Kirchhoff's law to the node where Iph, diode, Rp and Rs meet, we get

$Iph = I_D + I_{Rp} + I$ … (2.4.1)

We get the following equation for the photovoltaic current:

$I = Iph - I_{Rp} - I_D$… (2.4.2)

$I = Iph - Io\,[\exp(V+IRs/V_T) - 1] - [V+IRs/Rs]$…(2.4.3)

Where, Iph is the Insolation current, I is the Cell current, Io is the Reverse saturation current, V is the Cell voltage, Rs is the Series resistance, Rp is the Parallel resistance, VT is the Thermal voltage (KT/Q), K is the Boltzman constant, T is the Temperature in Kelvin, q is the Charge of an electron.

B. Efficiency of PV Cell

The efficiency of a PV cell is defined as the ratio of peak power to input solar power.

$\eta = (Vmp\ Imp) / I\ (Kw/m^2)Am^2$

Where, Vmp is the voltage at peak power, Imp is the current at peak power, I is the solar intensity per square meter, and A is the area on which solar radiation fall. The efficiency will be maximum if we track the maximum power from the PV system at different environmental condition such as solar irradiance and temperature by using different methods for maximum power point tracking. [2]

C. Boost Converter

Generally Boost Converter is mostly used as a front end converter in many Inverters as well as converters. Coming to its application in Inverters, when a high DC bus voltage is required, Boost converter is the obvious choice for converting low dc voltage in to high dc bus voltage which can be used for inverters. Coming to converters or power supplies, Boost converter is mostly used for Power Factor Correction of the line supply as the inductor current is the input current which will be continuous and also since there will not be high di/dt, there will not be emi issues at the line end[6].

Boost converter for solar installation system may be classified into three type:

- Open loop control [6].
- Open loop system with a disturbance at the input [6].
- Closed loop control [6].

3. Design Of The Boost Converter

(1) CURRENT RIPPLE FACTOR (CRF):

According to IEC harmonics standard, CRP should be bounded within 30%

i.e. $\Delta I1/I1 = 30\%$

(2) VOLTAGE RIPPLE FACTOR (VRF):

i.e. $\Delta V0/V0 = 5\%$

(3) SWITCHING FREQUENCY (fs):

Fs= 40 KHz

GIVEN DATA:

1. Input voltage, Vin =120V

2. Output voltage, Vo =220V

3. Output load current, Io =0.8A

Step 1: Calculation of Duty cycle (D):

Vo / Vin = 1/1 – D … (1)

D=0.45

Step 2: Calculation of Ripple Current ΔI_L:

I_L= 0.8 A

ΔI_L = (0.3 * 0.8) A=0.24 A… (2)

Step 3: Calculation of Inductor value (L):

$L = Vin\ D / FX\Delta I_L$

L=5.625mH…. (3)

Step 4: Calculation of capacitor value(C):

We have

$\Delta V0/V0 = DTs/Roc$

Ro = V0/I0 = 275Ω, C=0.818uF

4. RESULTS AND DISCUSSION

1) Output Waveforms of the Open Loop Boost Converter with Dc Source as Input

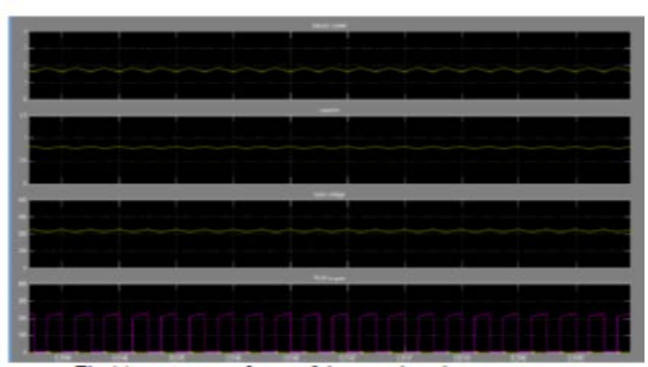


Fig (a) output waveforms of the open loop boost converter

Fig (a) shows waveform of inductor current, filter capacitor,

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boosted voltage and switching of IGBT. Here in order to drive motor we need 220v so the by proper designing of boost converter the boost converter was able to produce 220v with less ripple, inductor ripple was less than 30% as per the IEC harmonics standards.

2) Output Waveforms of the Close Loop Boost Converter with Dc Source as Input

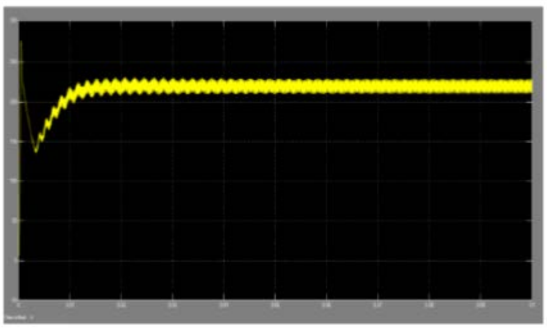

Fig (b) output waveforms of the close loop boost converter

In case of open loop boost converter output may not be accurate output may be high or low so this is overcome by using close loop control, that is PI control which will reduce steady state error of 25%.

Vin	Vout	Duty	R load
120v	130	10	280Ω
120v	150	20	280Ω
120v	175	30	280Ω
120v	219.8	45	280Ω
120v	238.85	50	280Ω
120v	298.1	60	280Ω
120v	391.1	70	280Ω
120v	596.5	80	280Ω
120v	1193.1	90	280Ω

The table shows that for different duty cycle output of the boost converter changes. Here the required output is 220v so the duty cycle is 45% and load considered is 280Ω.

3) Simulation of Supercapacitor: Charging and discharging waveform of supercapacitor

When the source fails to provide required load demand during transient period motor may not run properly this will affect motor. So this is overcome by using supercapacitor this supercapacitors are initial charged when load demands extra energy this supercapacitor will provide required load demand.

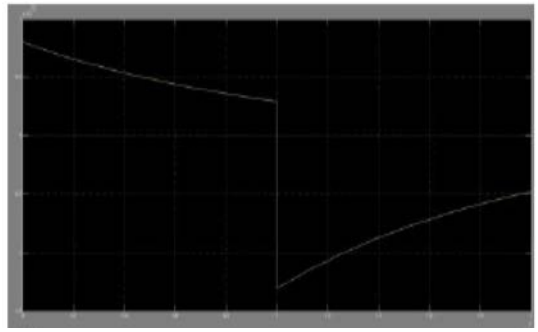

Fig (c) charging and discharging of super capacitor

If a larger value of capacitance were used with the same value of resistance in the above circuit it would be able to store more charge. As a result, it would take longer to charge up to the supply voltage during charging and longer to lose all its charge when discharging.

4) Load current waveform

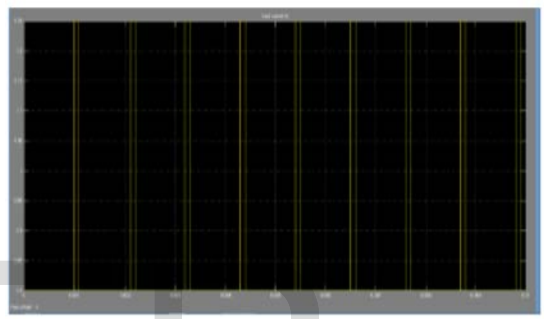

Fig (d) waveform of load current

When load consumes more current the source and the load becomes unbalanced during this condition the required energy will be provided by supercapacitor. In the above fig (d) load demands 0.25amp of extra current. During this period supercapacitor will get discharge to balance the load.

5) Source voltage and Current waveform

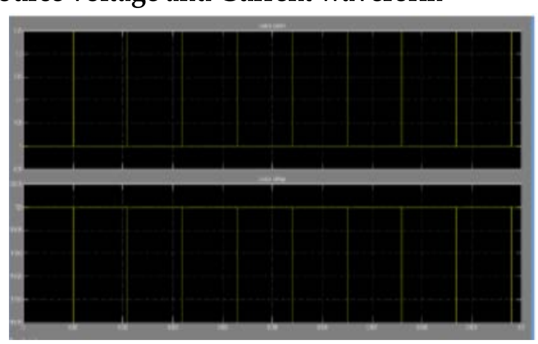

Fig (d) current and voltage waveform

When load draws extra current there is drop in the source voltage as shown in above fig (e) as a result the load is not met this is overcome by using supercapacitor.

6) Supercapacitor charging and discharging when the switch is turned on and off

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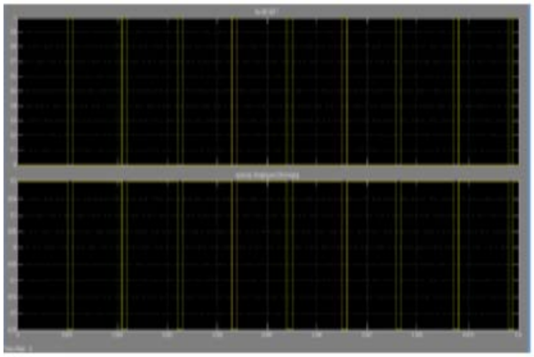

Fig (f) IGBT and Supercapacitor charging and discharging

When the source fails to provide extra current drawn by load. Supercapacitor will be switched using IGBT which creates path to the load and supply's demand. Fig (f) shows supercapacitor charging and discharging as the load draws 0.25amp current supercapacitor discharges and provides 0.25amp of current to load.

7) Armature current and speed waveform of dc motor

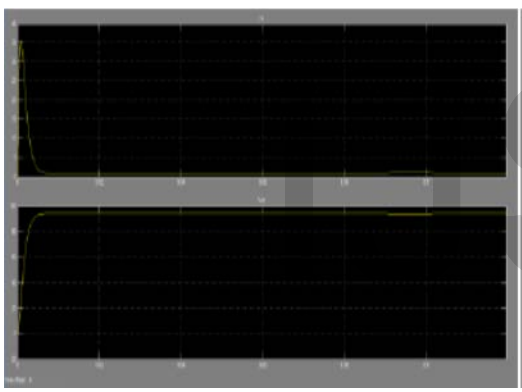

Fig (g) armature current and speed waveform

During starting DC motor draws more current, during this condition supercapacitor provides the required current to the load and the stress on source is reduced. Fig (g) shows armature current and speed waveform of DC motor. Supercapacitor charging and discharging as the load draws 35amp current supercapacitor discharges and provides 35amp of current to load.

8) Source Current and voltage waveform

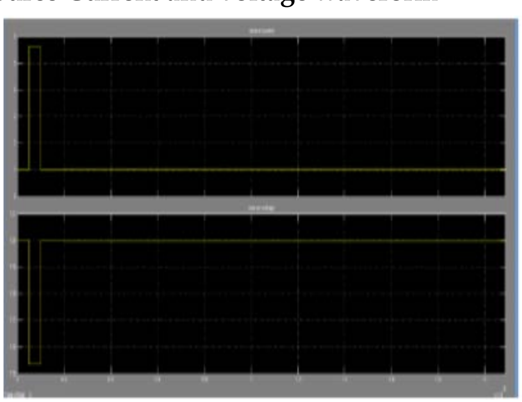

Fig (h) source current and voltage waveform

Fig (h) shows drop in source voltage because of increase in load demand and draws extra current and source failed to supply.

9) Supercapacitor charging and discharging when the switch is turned on and off

When source failed to provide required load demand supercapacitor discharges as show in Fig (i) load demanded 35amp and supercapacitor provided the required load demand.

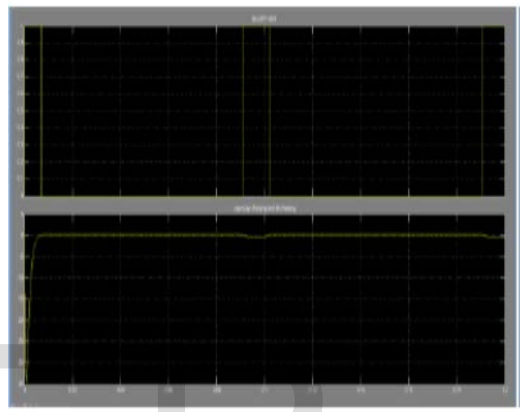

Fig (i) Charging and discharging waveform

5. CONCLUSION

In this paper, an improved boost converter is designed, developed and implemented for a solar installation system. The converter topology is selected after researching and comparing various topologies. The open loop and closed loop system of the converter is presented. The designed circuit is modelled and simulated using Matlab/Simulink and it was implemented using embedded controller and lab tested. The simulation and experimental results of this system are compared with the conventional boost converter, and its time response analysis was made. This improved boost converter can continuously provide constant output voltage even with disturbance at the input voltage side. It was observed that the proposed improved boost converter system has the advantages of high efficiency, fast response, and low ripple content and reduced number of switching component. The experimental results confirmed that the improved DC to DC boost converter gives better performance efficiency than conventional boost converter.

The demand for step-up battery chargers is growing, especially as the demand for charging from solar panels grows. Supercapacitors will replace batteries as the general solution for power storage. This is primarily because presently envisioned supercapacitor systems do not store as much energy as batteries. Because of their flexibility, however, supercapacitors can be adapted to serve in roles for which electrochemical batteries are not as well suited. Also, supercapacitors have some intrinsic characteristics that make them ideally suited to specialized roles and applications that complement the strengths of batteries.

In particular, supercapacitors have great potential for applications that require a combination of high power, short charging time, high cycling stability, and long shelf life. Thus, supercapacitors may emerge as the solution for many application-specific power systems. Especially, there has been great interest in developing supercapacitors for electric vehicle hybrid power systems, pulse power applications, as well as back-up and emergency power supplies.

REFERENCES

[1] O. Wanynezuck: Dynamic Behavior of a Class of Photovoltaic Power Systems, IEEE Transaction on Power Apparatus and Systems, Vol. PAS-102, No. 9, Sept.1983, pp. 3031 3037.
[2] K.H. Hussern, I. Muta, T. Hoshino, M. Osakada: Maximum Photovoltaic Power Tracking: An Algorithm for Rapidly Changing Atmospheric Conditions, IEE Proceedings – Generation, Transmission and Distribution, Vol.142, No.1, Jan.1995, pp.59 – 64.
[3]Athimulam Kalirasu1, Subharensu Sekar Dash2 SERBIAN JOURNAL OF ELECTRICAL ENGINEERING Vol. 7, No. 1, May 2010, 121 130.
[4] Chad Abbey, Student Member, IEEE, and Géza Joos, Fellow, IEEE Supercapacitor Energy Storage for Wind Energy Applications IEEE TRANSACTIONS ON INDUSTRY APPLICATIONS, VOL. 43, NO. 3, MAY/JUNE 2007.
[5] Y. Cheng - Assessments of Energy Capacity and Energy Losses of Supercapacitors in Fast Charging–Discharging Cycles, IEEE Trans. On Energy Conversion, vol. 25, issue 1, 2010, pp. 253-261.
[6] W. Lhomme, P. Delarue, P. Barrade, A. Bouscayrol, A. Rufer, " Design and Control of a Supercapacitor Design Storage System for Traction Applications", Industry applications conference, 2005.
[7] P. Srithorn, M. Sumner, and L. Yao, R. Parashar, "A STATCOM with supercapacitors for enhanced power system stability" 4th IET Conference on Power Electronics, Machines and Drives , 2008
[8] Andersson T. & Groot J. Alternative Energy Storage System for Hybrid Electric Vehicles. M.Sc thesis, Chalmers University of Technology. (2003)