Open Loop Control of a Novel Power Converter for FuelCell assisted Photovoltaic Power Systems

S. Ramya, A.Napolean

Abstract— A novel DC-DC converter is proposed in the work carried out powered from multiple sources such as PV and Fuel Cell while the Battery is used as the Back-Up source.The power conversion circuit consists of less number of active power switches with associated passive components. By adjusting the duty-ratio of the active power switch, the power sharing between sources as well as the output voltage regulation can be made.According to various situations, the operational states of the proposed converter can be divided into three states based on battery utilization .In order to ensure that the system operates with high efficiency, this paper proposes a power management control scheme, which controls the bidirectional converter operating under boost mode according to the operation condition of the PV/Fuel Cell, so that the battery can be charged or discharged. The system performance under different solar Irradiance has been verified by carrying out simulation studies using a load demand of 2.5 KW.The integration of the hybrid renewable power system is implemented and simulated using MATLAB/SIMULINK.

Index Terms— Alternative energy, DC-DC Converter,Multiple Sources,Power System

1 Introduction

The ever increasing energy consumption, the soaring cost and the exhaustible nature of fossil fuel, and the worsening global environment have created increased interest in green [renewable and/or fuel celll (FC)-based energy sources]. Renewable energy sources like Solar and Fuel Cells have always been due to their clean energy production, the most promising but challenging and thus interesting technologies for power generation[1].

In recent years, a lot of research studies in renewable sources like solar cells, fuel cells and wind energy are being done to improve their efficiency, performance, materials and at the same time to reduce their cost for implementation. Also lately, many research works report solar cells and fuel cells with higher efficiency and reliability. These improvements in renewable energy sources in turn put new challenges to designing power electronics incorporated with the renewable sources.

Batteries are usually taken as storage mechanism for smoothing output power, improving startup transitions and dynamic characteristics, and enhancing the peak power capacity [2]. Combining the photovoltaic generation with Fuel Cell , the instability of an output characteristic each other was compensated. Combining such energy source introduces a PV/Fuel Cell/Battery hybrid power system. Nevertheless, because different alternative energy sources can complement each other to some extent,multisource hybrid alternative energy systems (with proper control) have great potential to provide higher quality and more reliable power to customers than a system based on a single resource.[3]. Because of this feature, hybrid energy systems have caught worldwide research attention .

In general, a power electronic converter is supplied from a power source and provides the required voltage or current level to the loads. However, for some practical applications of renewable powers and battery systems, the load may not be powered from single source but from different kinds of power sources specified by dissimilar voltage, current, and power ratings[4].In Many Hybrid Power Systems with various Power Electronic Converters have been proposed in the literature up to now. However, the main shortcomings of these integrating methods are complex system topology, high count of devices, high power losses, expensive cost, and large size.

In [5] three multi input converters are proposed based on structure of the DC-DC Boost Converter. The DC–DC Boost Converter in [6] is useful for combining several Energy sources whose power capacity or voltage levels are different. The Multi-input DC–DC Converter proposed has the capability of operating in different Converter topologies (Buck, Boost, and Buck–Boost) in addition to its Bidirectional operation and positive output voltage without any additional transformer. Further, phase-shift control method is used to manage the power flow among the three ports in addition to soft switching for all switches over a wide input range.Although the circuit efficiency is greatly developed, the converter does not provide bidirectional functionality and is not able to boost the input voltage to a higher level.

Moreover, the summation of duty ratios should be greater than one and the two input voltages should be in the same level in the dual-power-supply operation state. In [7] power control strategies designed manage the charge balance of the battery in order to regulate the output voltage. The proposed power converter is capable of converting power from multiple sources to the load. The sources deliver power to the load alternatively by switching the active power switch on and off.

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2 Configuration Of the Proposed Converter

The power conversion circuit of the single switch dual-source three-port dc-to-dc converter is shown in Fig.1. The proposed converter Interfaces two Input power sources v_1 and v_2 and a battery as the storage element In the proposed circuit, two Inductors L_1 and L_2 make the Input power ports as two current type sources.

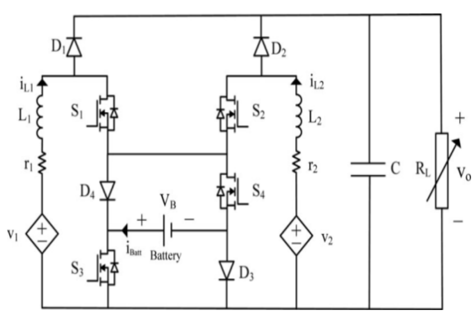


Fig.1. Structure Of the Proposed Converter

It results in drawing smooth currents from the sources. R_L is the load resistance and switches $S_1 – S_4$ are the main controllable element that controls the power flow of the hybrid power system. The $d_1 – d_4$ are the duty ratios controlling the switches $S_1 – S_4$ respectively. The diodes D_1 and D_2 conducts in complementary manner with switches S_1 and S_2. Turning ON S_3 and S_4, makes D_3 and D_4 to reverse bias by the V_{bat}. On the other hand, turn – OFF state of these switches makes diodes D_3 and D_4 able to conduct Input currents i_{L1} and i_{L2}. The steady states and dynamic behavior of the converter is observed in Continuous Current Mode (CCM).

3 Proposed Converter Operation Modes

Utilization state of the battery defines three power operation modes of the converter. The assumptions for the operation modes are considered by utilizing sawtooth carrier waveform for $S_1 – S_4$ and considering d_3, d_4< min (d_1,d_2) in battery charge or discharge mode. d_1 is assumed to be less than d_2 in order to simplify the operation mode investigation.

3.1 First Operation Mode

Basic operation mode which takes place in the conditions that the summation of the PV and Fuel Cell powers can completely supply the load, without battery existence. Here d_1 is used to regulate PV source and d_2 is utilized to regulate output voltage.

3.2 Second Operation Mode

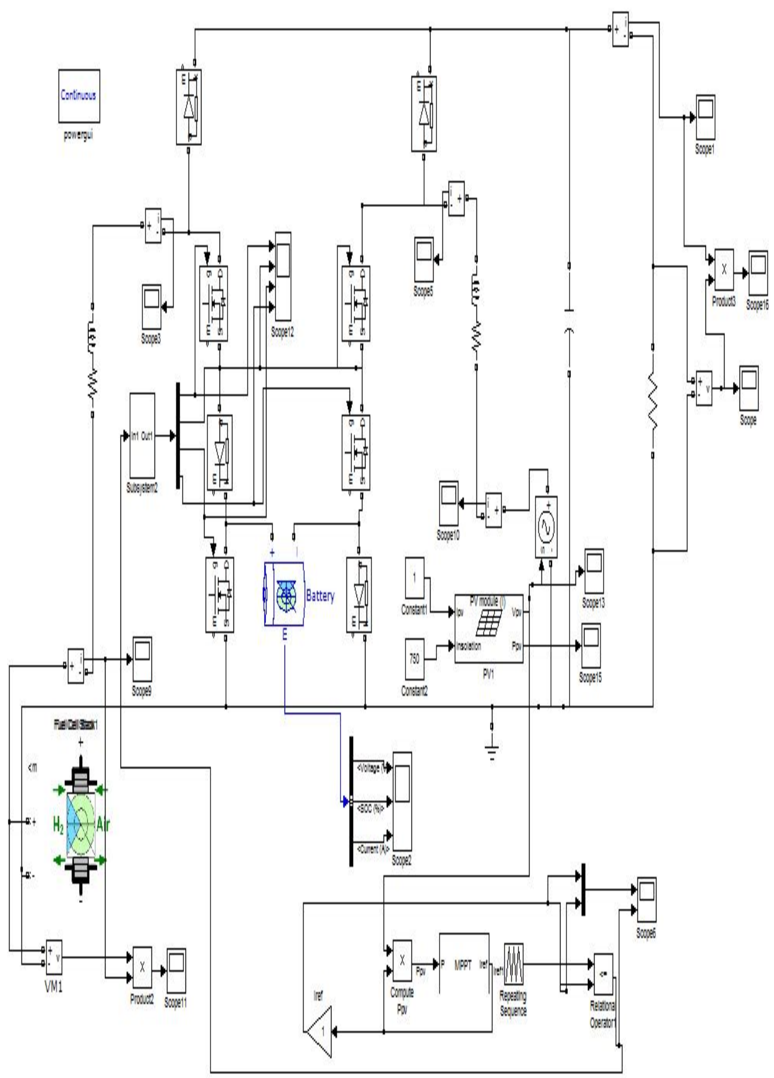
This mode takes place in the conditions that summation of the Fuel Cell and PV powers can regulate the output voltage as like as first operation mode, while the battery is needed to be charged. In this mode d_1 and d_2 regulates power of the input sources, while d_3 is utilized to regulate output voltage through battery charging by the extra –generated power.

3.3 Third Operation Mode

This mode takes place in the conditions that the output voltage cannot be regulated because summation of Fuel Cell and PV cannot completely supply the load and $v_{Batt.Min} < v_{Batt}$ the battery discharging is accomplished. Here, d_1 and d_2 regulates powers of the input sources, while d_4 is utilized to regulate output voltage through battery discharging.

4 Simulation Results

The Evaluation of the performance of the proposed converter is done by simulating all the three operation modes by MATLAB/SIMULINK software. The simulation is done setting $r_1 = r_2 = 0.4\,\Omega$, $L_1 = L_2 = 6mH$,C=200µF =20KHZ.R_L with average power of 2.5KW is supplied at the dc link in the proposed system. The dc-link voltage of the converter is regulated at v_o=350V which is a desired condition.Power of input sources and Load characteristics are discussed below for three



modes.

Fig.2. Simulink Diagram

4.1 First Simulation Stage

In this stage(S=750 W/m[2]), the load power required is P_L = 2.5 KW (R_L= 50 Ω), while the maximum available PV power is Ppv=1.7 KW and there is no need to charge the Battery.

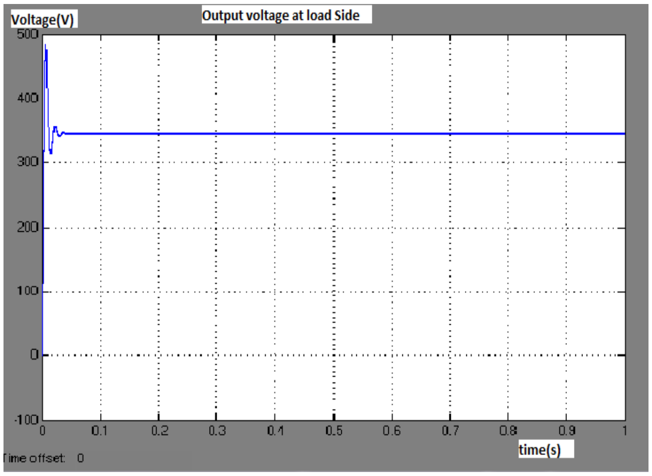


Fig.3. Output Voltage at load side for mode 1

First, second, third and fourth duty ratios are set as d1=0.7, d2=0.75,d3=0 and d4=1. By setting $d3$ = 0 and $d4$ = 1, which result the battery power to be set on zero value. The FC current is regulated by d1, which shows I_{L1} =3.9A. The PV current is regulated by d2, which shows I_{L2} =10.5A .The required load voltage is maintained for its entire operating time.

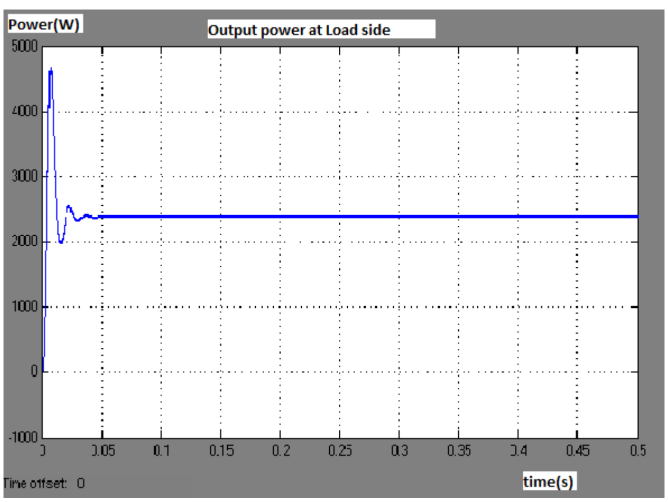


Fig.4. Output Power at load side for mode 1

4.2 Second Simulation Stage

In this stage, the sun irradiation level increase to S =1000W/m[2], while the load power remains constant at P_L = 2.5 KW.In this condition, battery remains in charging due to increase in sun irradiation level. The FC current is regulated on I_{L1} = 6.5 A with duty ratio d = 0.73, while the maximum power of the PV source is tracked with regulating the PV current at I_{L2} =15.72 A and adjusting the first duty ratio at $d1$ = 0.79. Moreover, controlling the third and fourth duty ratios at $d3$ = 0.45 and $d4$ = 0, respectively, results in providing the charging power of the battery in addition to regulating the output voltage .

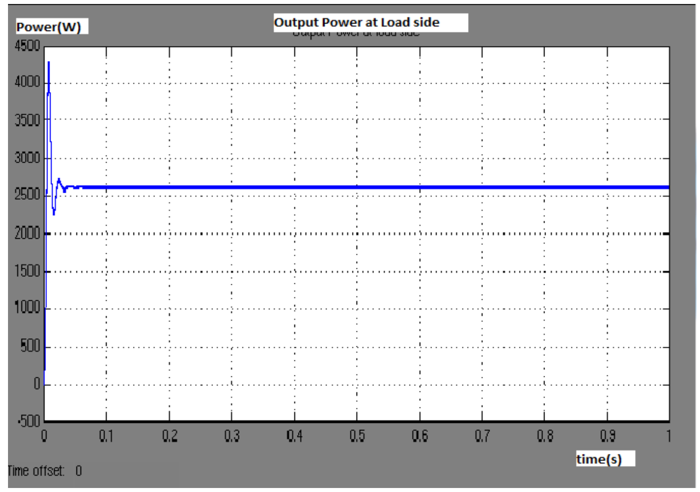


Fig.5. Output Power at load side for mode 2

4.3 Third Simulation Stage

This stage occurs in a condition that solar power decreased to certain value in which (S=500W/m[2]), in which the load requires P_L = 2.5 KW and the PV power is simultaneously decreased into P_{pv}=0.45KW.From the maximum deliverable power of the PV, it is obviously understood that the PV is not able to completely supply the power deficiency. Thus, the remaining power should be supplied by the battery. Regulating its current at I_{L1}= = 5.3A and adjusting the first duty ratio at d1 = 0.71, the maximum power of is delivered at I_{L2} = 15.72A. Adjusting the second duty ratio at d2 = 0.73 and controlling the third and fourth duty ratios at d3 = 1 and d4 = 0.4 results in discharging the battery.

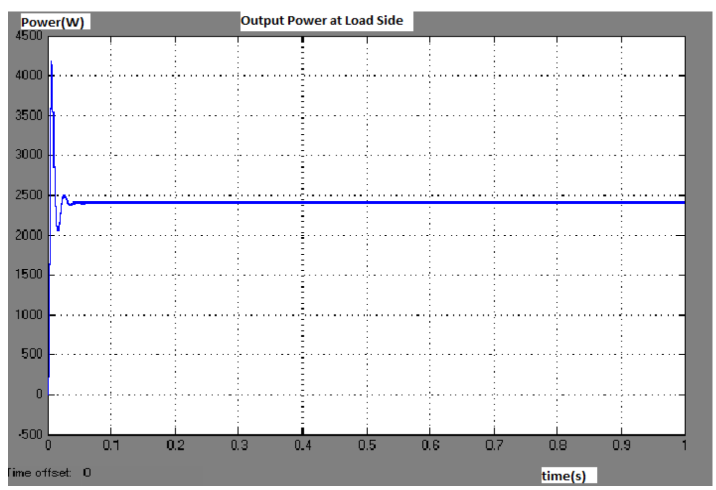


Fig.6. Output Power at load side for mode 3

5 Result Analysis

From the results of three operating mode,it is observed that the converter maintains a constant output irrespective of change in solar irradiance and fuel cell availability.The control signals are given to the four switches according to which the operation modes are selected.

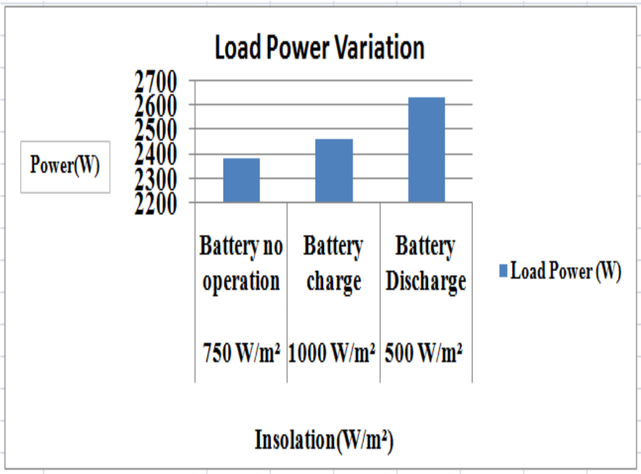


Fig.7. Comparison Of Load power For three modes

6 Conclusion

A complete description of the hybrid system has been presented along with its detailed simulation results showing satisfactory performance of the PV/Fuel Cell/Battery system. The properties of charging and discharging are simultaneously obtained in the proposed converter for reducing the corresponding installed capacity to further save the cost of system purchasing and power supply.The new converter topology provides designers with an alternative choice to convert a power generator with an energy storage mechanism efficiently, and it can also be applied easily to various clean power sources due to the flexible selection of operational states.

7 FutureWork

The future work will be to design the proposed hybrid system integrating with Wind and Also, the system has to be extended to higher ratings and solve for the synchronization issues.

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