Modified Dual input Non isolated Bridge type Converter with Switched inductor for Electric vehicle Battery Charging

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Abstract - *For battery charging purposes an on board or off board based charger is one of the significant supporting equipment. This off board charger is more efficient because it reduces the whole weight of the converter. In which power electronic converter plays a major role, which connects independent equipment and components on a common system. Here introducing a dual input non isolated bridge type converter for EV battery charging purpose. Because of the dual input structure it is possible to integrate different types of renewable energy sources in order to charge the electric vehicle battery. In order to charge the battery packs of 2 identical vehicles simultaneously, atleast 2 set of vehicle battery simultaneously, the inductor in the dual input bridge type converter was replaced by a switched inductor structure. And the desired results were obtained from the MATLAB SIMULINK environment.*

Key Words: Electric vehicle, Charging, Dual input converter, Battery, Maximum power point tracking

1. INTRODUCTION

Main goal of every citizen in the world is to make a pollution free atmosphere for upcoming generations. But in between the busy schedule of each life everyone forgetting about these factors. Pollution is at its peak level at the same time development conquers every single person. So in order to create a pollution free atmosphere a simple thing we can do, that is the replacement of gasoline powered vehicles by battery powered electric vehicles. Nowadays battery powered electric vehicles are dominating over the gasoline vehicles. We already see that during COVID 19 pandemic situation how much atmosphere was improved due to the reduction in usage of fossil fuels. Igniting with electricity offers more advantages not available in conventional internal combustion engine vehicles. Because electric motors reacts more quickly, electric vehicles are more responsive and have very good torque. Another important factor is that electric vehicles are more digitally connected than conventional vehicles. Because now a days most of the charging stations provide option to control charging from a smart phone applications. Just like a smart phone , plug electric vehicle when reached home and have it ready for to use in the next morning Since the electric grid is available almost everywhere, there is a variety of option for charging at home , at work or on the road. By charging any time there is no need to go to filling station. In order to charge the electric vehicle on board or off board charger is the most significant equipment. In this off board charger offers more advantage, because it reduce the overall weight of the vehicle and also wide range of charging is possible. Petro chemical energy resources are radically reducing due to their insufficiency in demand and pollution caused by them. Replacement of these energy sources by clean and renewable energy source is the only possible solution to this problem. However individual use of these energy sources like solar, PV etc. not recommended for reliable power generation. Since their availability highly rely on varying climatic conditions. So a power electronic converter plays a crucial role to integrate these energy sources.

The Hybrid Energy System (HES) shall accommodate more than one distinct voltage-current characteristic non-conventional energy sources like solar-PV, wind, etc., and storages like a battery, ultra capacitor, fuel cell, etc. [1–3] . A power electronic interface is mandatory to integrate these input energy sources. Parallel connected single-input DC-DC converters are widely used in the conventional scheme, and this results in substantial complexity in control strategies, increased cost, loss of compactness and system efficiency. Hence, the idea of multi- input DC-DC converters (MICs) has been introduced to surpass the demerits of conventional methods. Simple and compact structure, lower system complexity and reduced cost are the main attractive features of MICs.

Different type of multi input D to DC converters are studied in literature search. Multi input converters are majorly classified into isolated and non-isolated types. The complexity of isolated converters is high compared to non-isolated converters due to the presence of single winding or multi winding transformers. Thus in order to minimize the complexity and cost of the overall system, most of the applications require a multi input DC-DC converter which eliminates the use of transformers in their circuit [4]. A non-isolated MIC for solar-PV application is described in [4]. But the drawback of the converter is that it delivers power from one energy source at a time, and simultaneous power delivery from the input sources is not possible. The converter in. [5] is applicable in hybridizing alternative energy sources in electric vehicles. By hybridization of different energy sources, advantages of different sources are available. This converter has several outputs with Drawbacks found from this converter are higher component count. Regenerative braking is not possible. Complexity in control. The voltage of one input source should be always greater than the other source. So, a large number of DC-DC converters are reported in the literature. The converters reported in the literature can be effectively used for hybridization of different energy sources for various applications. Some have limitations for simultaneous power delivery from the input energy sources; while others require sophisticated control strategies even though they are capable of individual and simultaneous power supply. In line with work on non-isolated bridge type converter reported in [8] this paper aims at analyzing the performance of different type of dual input converters for battery charging applications in electric vehicle and the modification of dual input bridge type converter with switched inductor structure in order to charge the two packs of battery of electric vehicle.

1.1 Block diagram Representation of Dual input non isolated Bridge type Converter

Figure 1 shows the block diagram representation of overall system .Consist of a Electric scooter which was charged by using non isolated bridge type dual input converter, which act as power electronic interface in EV charging. And the converter equipped with dual inputs. One was from the photovoltaic panel and other was a supply from single phase source.

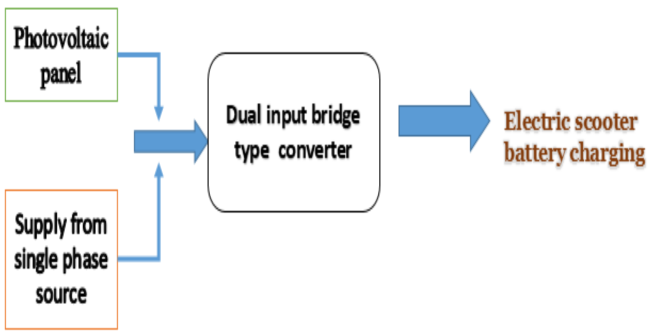

Fig -1: Block diagram representation of dual input converter in EV battery charging.

Main components required for the design of the system were

- Selection of electric scooter
- Selection of battery for electric scooter
- Suitable converter components design
- Appropriate PV panel selection according to the converter design

Selection of electric vehicle and battery

Electric scooter chosen because compared to other vehicles two wheeler is cheaper in price and every common person can buy without spending much cost. And also the maintenance free nature make it more reliable, easiness of driving also one factor. Electric vehicle for the battery charging purpose chosen as two wheeler as shown in the blockdiagram

Battery

In real time application the scooter OKINAWA uses a battery of rating 48 V, 25 A, 1200 Watts hours Lithium ion battery. Lithium ion battery is the most efficient choice for an electric bike because it offers high energy density while remaining relatively light-weight and compact in size so same rating of the battery was chosen for while designing the whole system.

Battery design and Specification [9]

Voltage Rating = 48 V, Current Rating = 25 Ah

So, Wattage of battery = Voltage Rating × Current Rating = 48 × 25 = 1200 Wh, 48V, 25Ah and will charge within 5 hours using

Thus EV can be charged up to 1150 to 1200 Wh using this charger, which will run up to 50 km in single charge with an appropriate speed of 35 to 40 km/hr.

To find the battery Watts hour = 1000Wh × 1.20 = 1200Wh Hence, Current (Ah) in battery

1200Wh ÷ 48V = 25Ah

Selection of battery charger Suppose we have to charge a battery in 5 h. So our required wattage is 1200Wh.

According to above condition,

Wattage of charger = 1200Wh /5 h = 240 W Hence, current rating of charger = 240W/ 48V =5A

As per the above calculation to charge a 48V, 25Ah battery in 5 hour we requires a 48V, 5A charger.

1.2 Converter Operation and Design

For Electric vehicle battery charging power electronic converter plays most crucial role. So here, choose a dual input non isolated bridge type converter .Converter is equipped with dual input. It will be selected according to our requirement .Converter configuration is shown in figure in the figure 2.Two voltage sources respectively, V1 and V2 were considered as input sources in this converter. Here V1 is supply from a solar panel and V2 is DC voltage source. The series and parallel operation of the input sources considered in the converter were controlled by the switches Q1, Q2 and Q3. Based on the switching strategy of switches Q1, Q2 and Q3, there were four operating states of the converter.

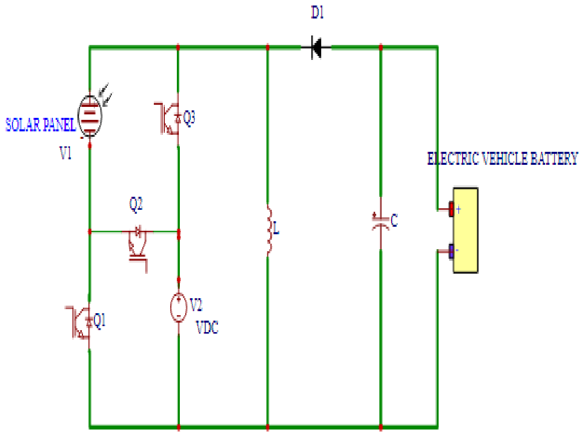

Fig -2: Configuration of Dual input non isolated bridge type converter

Main features of converter of the dual input converter were

- Basic operating principle is similar to dc–dc converters
- L1, C1 present in the converter charges for a specific period and transfer the stored energy in the elements to the load for the rest of the period
- Input sources can deliver power to the load either simultaneously or individually with the proper operation of the power switches
- Sources are sharing a common inductor.
- Anyone of the switches Q1 or Q2 or Q3 or diode D1 is in conduction at a time.

Design of the converter

Converter was designed for power rating of 240 Watts and in order to charge the EV scooter battery of 48Volts, 25 Ah. So the input voltage required to produce 60 V was chosen as V1=20V,

V2=16V.

$$V_1 d_1 + V_2 d_2 + (V_1 + V_2)d_3 - V_o(1 - d_1 - d_2 - d_3) = 0 \quad (1)$$

From the above equation, the output voltage of the converter is,

$$V_o = \frac{V_1 d_1 + V_2 d_2 + (V_1 + V_2)d_3}{(1 - d_1 - d_2 - d_3)} \quad [10] \quad (2)$$

Input power and output power assumed to be equal for ideal condition

$$V_O I_O = V_1 I_1 + V_2 I_2 + (V_1 + V_2)I_3 \quad [10] \quad (3)$$

$$I_O = \frac{V_1 I_1 + V_2 I_2 + (V_1 + V_2)I_3}{V_o} \quad [10] \quad (4)$$

$$I_O = \frac{V_1 I_1 + V_2 I_2 + (V_1 + V_2)I_3(1 - d_1 - d_2 - d_3)}{V_1 d_1 + V_2 d_2 + (V_1 + V_2)d_3} \quad [10] \quad (5)$$

After substituting f=20 kHz and d1=d2=20% d3=30%

$$L1 = \frac{V_o(1 - (d_1 + d_2 + d_3)}{\Delta iLf} = 0.233mH$$

Capacitance is,

$$C1 = \frac{V_o(d_1 + d_2 + d_3)}{\Delta V_o fR} = 0.675\ \mu F$$

Design of photovoltaic panel

Converter was designed for 240 W, so the same rating of panel was chosen here. In order to produce a 20V forms the panel, the panel specification and rating are shown in the Table 1.

Vmp is voltage at maximum power that was about 30.2 V, Imp is the current at maximum power.Voc and Isc are short circuit current and voltage respectively. Switching pulses for the 3 switches were generated using MPPT. By the appropriate control of duty ratio of switches output voltage can be controlled accordingly.(P&O) based maximum power point tracking (MPPT) of a solar photo-voltaic system was used here.The PV power system, will be able to optimally track maximum power points with minimum possible oscillation.

Table -1: Panel specification.

PANEL SPECIFICATION	
Maximum Power at STC	240 W
Vmp	30.2 V
Imp	7.95A
Voc	37.2V
Isc	8.43A
Temperature Coefficient	-0.33/degree Celsius

According to the designed parameters dual input non isolated bridge type converter was simulated in MATLAB SIMULINK software in order to charge the EV scooter battery of 48 V 25 Ah.

Table -2: Simulation parameters of dual input bridge type converter.

Parameter	Specification
Input voltage	V1=20V V2=16V
Output voltage	60V
Power	240 Watts
Capacitor	0.675mF
Inductor	0.233mH
Battery	48V,25Ah, 1200Wh
Switching frequency	20kHz

1.3 Simulation Results of Dual input Non isolated Bridge type Converter

Here the isolated bridge type dual input converter integrating 2 input energy sources such as 240 W PV panel develop 20 V input and 16 V DC supply. Load here using EV battery. This given EV contain a lithium ion battery of capacity 48V, 25Ah and will charge within 5 hour using charger having capacity 48V, 25A. Simulink diagram of converter with MPPT control was done and its MATLAB Simulink diagram is shown in figure 3.

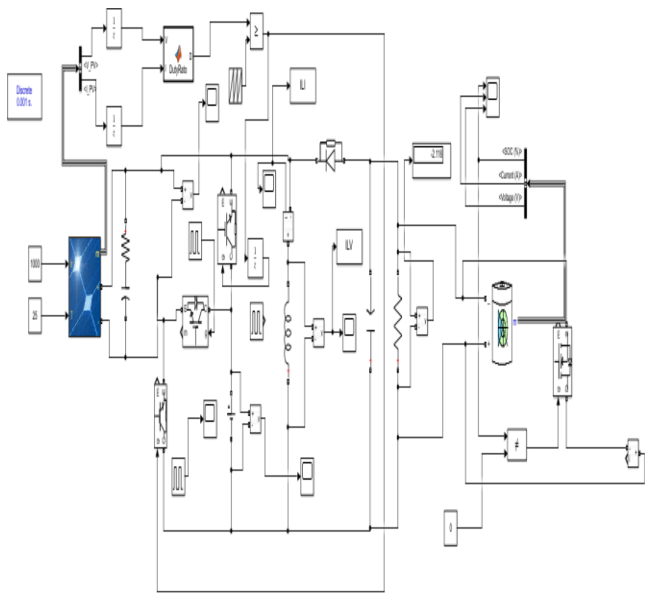

Fig-3: Simulink diagram of dual input converter with MPPT control.

Simulation of dual input bridge type converter was done by using MPPT control. By the proper duty ratio control in MPPT algorithm obtain maximum power 240 W at 1000W/m^2, and same output voltage of 60 V was obtained across the capacitor of dual input bridge type converter converter in order to charge a 48 V, 25 Ah battery is shown in figure 4.

PV and VI characteristics of PV panel

The PV Array block implements an array of photovoltaic (PV) modules. The array was built of strings ofmodules connected in parallel, each string consisting of modules connected in series. Specified temperature was 25 degree Celsius. Due to the erratic characteristics, a typical solar panel convertsonly 30 degree Celsius.40% of the incident solar irradiation into electrical energy. In order to extract maximum power from asolar panel and to refine the maximum power point tracking was used.

Figure 5 shows the V-I and P-V characteristics of 240W panel was used here to integrate with the dual input converter as a source to charge the battery. Here 1 series and 1 parallel string was used to produce a 20 V.

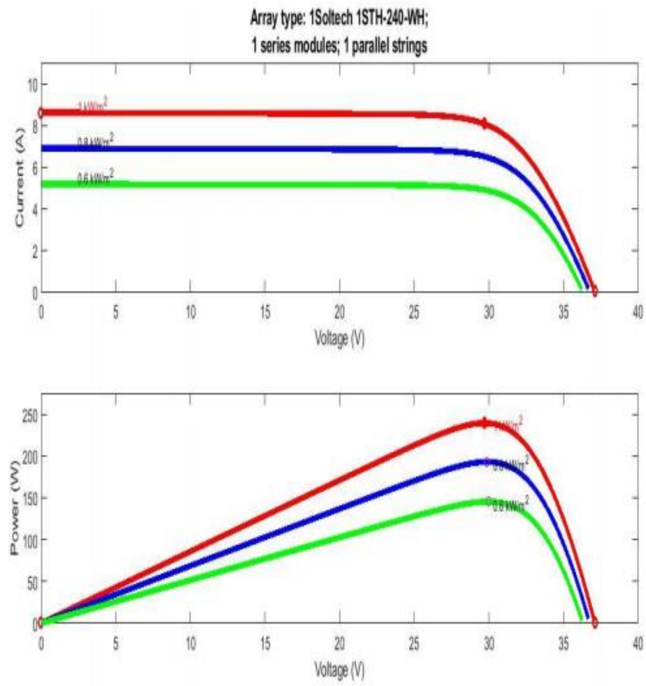

Fig-4: V-I and P-V Characteristics of 240 W PV panel at different insolation.

So from the curve it was observed that according to the increase in irradiance the power and current of the PV panel was increasing, at an irradiance of 1000W/m^2 a maximum power of 240 Watts was obtained.

Voltage stress across the switches from MATLAB simulation V_{S1}=20V, V_{S2}=20V, V_{S3}=50V from MATLAB simulation. Voltage stress across the switches of dual input non isolated bridge type converter is found to be less. Because of the lesser number of components conducting over switch cycle, and also for a 60 V output input voltage required is only 20 V and 16 V respectively. Voltage stress across the switches from the MATLAB simulation are shown in figure 5.

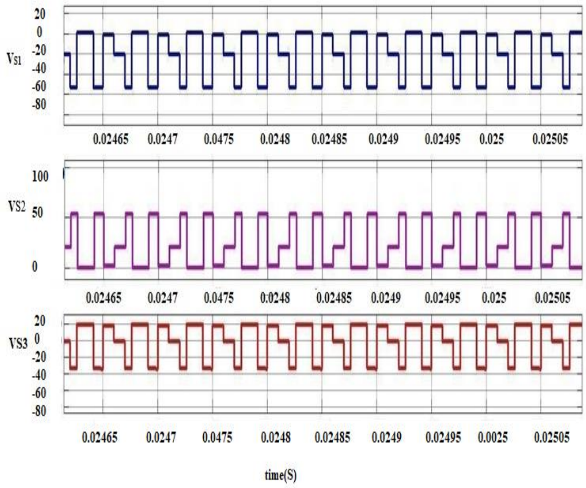

Fig- 5: Voltage stress across the switches

Battery charging characteristics of battery was obtained from MATLAB simulation as shown in figure 6. State of charge (SOC), current, voltage were obtained from the result. When give a simulation runtime of 20 second battery was charged from its initial sate of charge 75% to 80 % quickly.

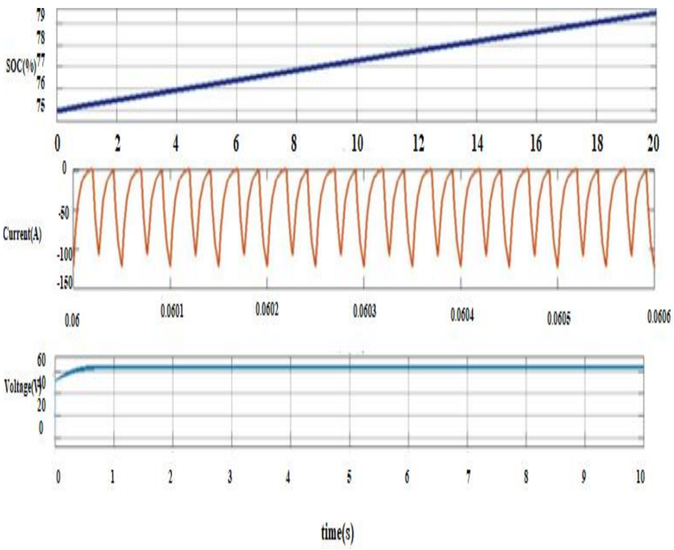

Fig- 6: Battery charging characteristics of dual input non isolated bridge type converter.

- Battery charging current of bridge type converter was about 50 A, so it getting charged more quickly.
- Converter structure was simple, consist of lesser number of components.
- Voltage stress across each switch is less because of lesser number of components operating over one switch cycle.
- More efficiency.

2. MODIFICATION OF DUAL INPUT NON ISOLTED BRIDGE TYPE CONVERTER WITH SWITCHED INDUCTOR

Here inductor of non isolated bridge type converter was replaced by two inductors and three diode introducing such an arrangement we get the advantage of high voltage gain. . It consists of two parts of inductors and three diodes. Working was same as that of integrated bridge type converter without switched inductor. In a switched inductor bridge type converter, the switch operations of the converter can be explained as follows. When the switch is closed, current flows from voltage source through both of the inductors in parallel connection. Both of inductors store some energy by generating a magnetic field. Polarity of the left side of the inductor is positive. When the switch is opened, current will be reduced as the impedance is higher. The current flows source through both of the inductors in series connection.

Circuit diagram is shown in figure 7, structure similar to dual input bridge type converter, and here it consist of normal inductor in place of switched inductor.

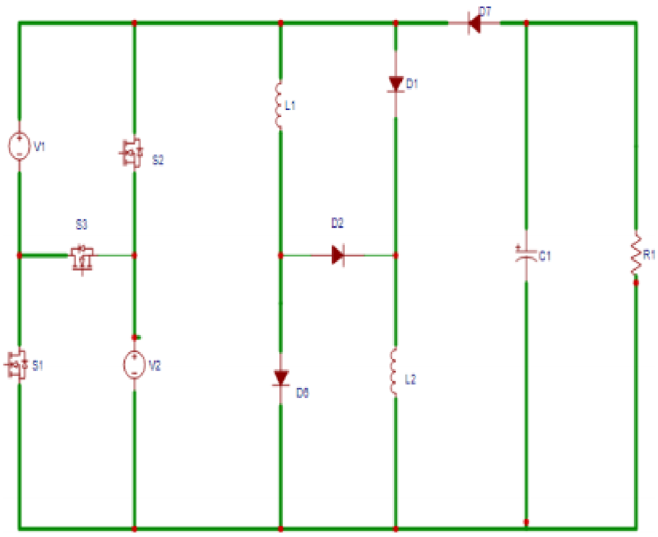

Fig-7: Switched inductor dual input non isolated bridge type converter

2.1 MATLAB SIMULINK DIAGRAM OF BRIDGE TYPE CONVERTER WITH SWITCHED INDUCTOR

For the MATLAB simulation same parameters of Table 1 and 2, except the inductor was replaced by switched inductor with 3.96mH.Simulink model is shown in figure 8.

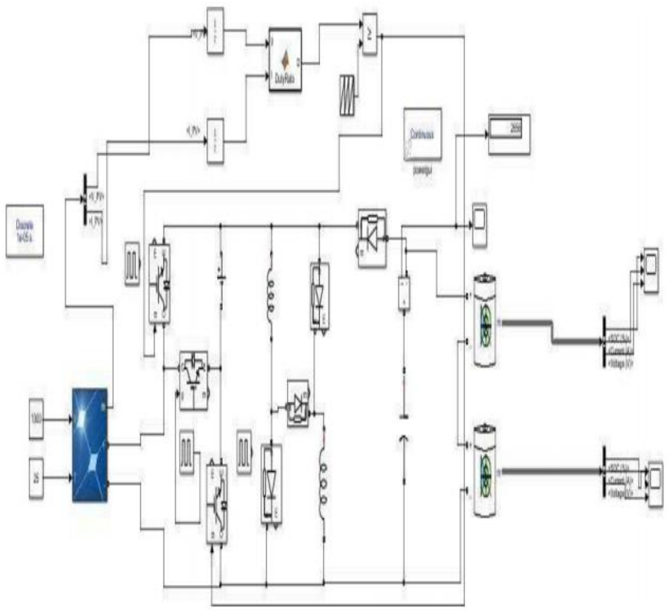

Fig-8: Simulink diagram of dual input non isolated bridge type converter with switched inductor

2.2 SIMULATION RESULTS OF DUAL INPUT CONVERTER WITH SWITCHED INDUCTOR

When non isolated dual input bridge converter was equipped with a switched inductor its output voltage become doubled than that of previous case. It was about 60 V without switched inductor, but it become120V when inductor was replaced with switched inductor structure is shown in figure 9 By connecting switched inductor instead of inductor it was possible to produce 120 voltage. So it able to connect two 48 V, 25 Ah batteries in series across the load. So the converter can able to charge two electric scooter battery at a time.

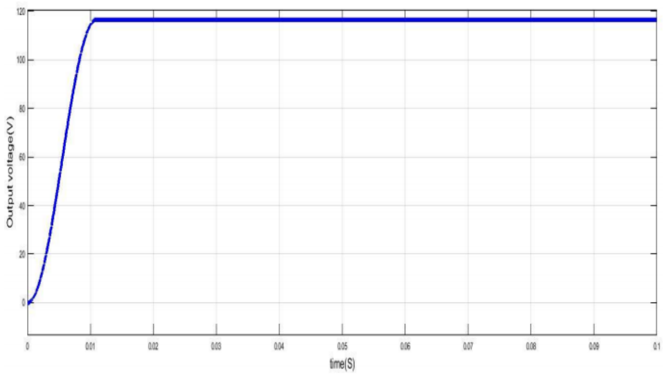

Fig-9: Output voltage across capacitor dual input non isolated bridge type converter

When non isolated dual input bridge converter was equipped with a switched inductor its output voltage become doubled than that of previous case. It was about 60 V without switched inductor, but it become 120 V when inductor was replaced with switched inductor structure. By connecting switched inductor instead of inductor it was possible to produce 120 voltage. So it able to connect two 48 V, 25 Ah batteries in series across the load. So the converter can able to charge two electric scooter battery at a time.

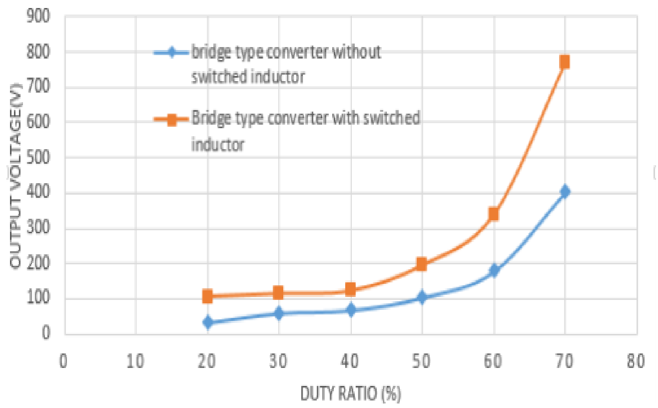

Fig- 10: Output voltage variation of dual input bridge type converter with and without switched inductor

It was observed that when the duty ratio of switch S3 was varied there was wide range of variation in the output voltage. But varying other switches it was observed that there was hardly small change in output voltage. By adjusting the duty ratio of switch S3, series connection of both sources were possible. So output voltage got increased. Initially the duty ratio of switch S3 was taken as 30 % the output voltage across the capacitor was obtained as 60 V, but in the case of bridge type converter with switched inductor output became doubled. When the duty ratio was decreased to 20%, 50 V was obtained across the converter without switched inductor. By varying duty ratio in between 60% to 70% the output voltage across the capacitor of converter with switched inductor was changed from 50 % to 100%.So by adjusting the duty ratio of switches converter application can be extended in wide range.

3. CONCLUSIONS

Non isolated bridge type dual input converter based off board charger was developed for EV scooter charging. Here the converter integrated with the PV panel as step towards renewable energy usage in the transportation sector. By using a PV panel of 240 W, dual input bridge type converter was able to charge the battery of electric scooter having rating 48 V, 25 Ah. It has a simple structure, and the number of components operating over the switching cycle is very low. Hence the cost of converter is less compared to other converters and also conduction losses are less. Hence the efficiency of the converter is high. By using this integrated bridge type converter individual and the simultaneous utilization of both the energy sources are possible.

The modification of dual input non isolated bridge type converter was done by the replacement of normal inductor with switched inductor structure. By keeping all parameters constant, replacement of the inductor with the switched inductor causes the converter output to become doubled. At a time two batteries can be charged by this structure. So the converter can be used to charge the 2 sets of identical battery of the same electric scooter or can charge the 2 identical electric scooters. By adjusting the duty ratio of switches it was observed that voltage gain of the converter having switched inductor was more compared to other, hence application of converter can be extended to wide range.

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