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Charging and Discharging Mode of Electric Vehicle using Bidirectional Converter

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Abstract:- Energy storage has become a fundamental component in renewable energy systems, especially those including batteries. However, in charging and discharging processes, some of the parameters are not controlled by the battery's user. That uncontrolled working leads to aging of the batteries and a reduction of their life cycle. Therefore, it causes an early replacement. The distributed generating systems are the promising solutions and gaining more attention towards renewable energy which provides a flexible system configuration to integrate the DERs which include solar Photo-voltaic, wind, fuel cell, super capacitors and energy reserves etc. The recent advancement in power electronic converters is grasped much attention in the field of distributed generation, electric vehicle applications and integration of generating systems with islanded/grid-tied. In two-stage EV charging systems, the grid power input is first transformed by an AC-to-DC converter into a constant DC output voltage. In the case of single-phase boost rectifiers, the output voltage varies from 400 VDC to 500 VDC. In this design, the rectifier's and the DC-DC converter's power switches' combined total standing voltage (TSV) equals the DC-link voltage.

Keywords:- Multi-level Inverter, 5-level, Boost Factor, Rectifier, EV Charging

I. INTRODUCTION

Aviation lithium battery pack, as the planes' auxiliary power energy, is used to check the main instruments, supply electricity for the ignition device and emergency energy supplement for a sudden accident. In practical application, it is used with groups no matter in electrical car or in aerospace. But at present, the study of lithium battery's charging and discharging electrical performance aims at researching single lithium battery cell. Thus the conclusion may ignore the inconsistencies between the group work units and a single cell, and then it will influence the status of lithium battery when estimating the group lithium battery status. And finally this process will lead to the wrong estimation of lithium battery state. So it is necessary to study the charging and discharging characteristics of aviation lithium battery in groups.

Power Electronics is the innovation behind the transformation of electrical energy from a source to the prerequisites of the end-user. Despite the fact that it is of vital significance to both industry and the individual resident is present. The necessary hardware for vitality transformation can be isolated into four types namely AC-DC rectifiers, DC-DC converters, DC-AC inverters and AC-AC transformers [1]. DC-AC inverters can be separated into two group: Pulse Width Modulation (PWM) inverters and Multilevel Inverters (MLIs). MLIs were designed in the mid-1980 and grew rapidly. Numerous new topologies have been composed and connected to modern applications, particularly in sustainable power source frameworks. Common circuits incorporate diode clamped inverters, capacitor clamped inverters and hybrid H-bridge MLIs . MLIs overcame the drawbacks of the PWM inverter and paved the way for industrial applications [2, 3]. To date, DC-AC conversion techniques can be sorted into two categories: Pulse Width Modulation and multilevel modulation. Each category has many circuits to implement the modulation. The PWM method is suitable for DC-AC conversion, since the input voltage is usually a constant DC voltage [4].

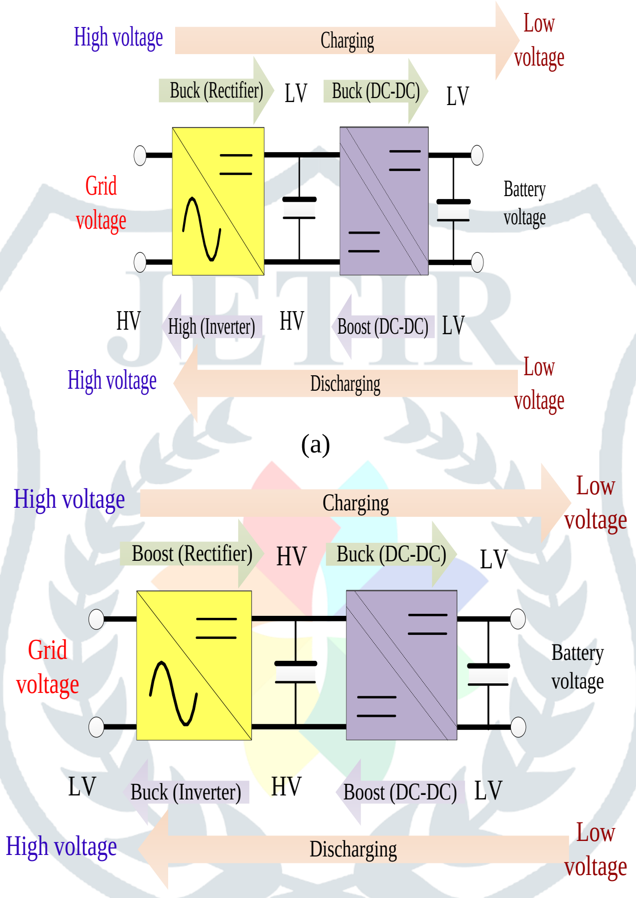
The Pulse Phase Modulation (PPM) method is also possible but is less convenient. The Pulse Amplitude Modulation (PAM) method is not suitable for DC-AC conversion since the input voltage is usually a constant DC voltage. PWM operation has all the pulses. Leading edge starting from the beginning of the pulse period and their trailer edge is adjustable. Multilevel inverters were invented in the late 1970's [5]. The first MLI was constructed using diode-clamped and capacitor clamped circuits. Later, different MLIs were developed. MLIs are an appealing contrasting option to enhance the output by blending a staircase waveform mimicking a sinusoidal waveform. Such a waveform has a low distortion, as well as lowers the dv/dt stress. Also, MLIs can operate at both fundamental switching and high frequency switching using PWM. In this manner, for high power/high voltage applications, a MLI can accomplish better output waveform utilizing medium voltage control switches and henceforth favours over established two-level inverters.

II. PROPOSED METHODOLOGY

EVs provide a number of benefits in contemporary power networks, including peak power control, peak load shifting, less environmental pollution, and more. In the grid-to-vehicle (G2V) charging mode and the vehicle-to-grid (V2G) discharging mode, respectively, EVs can operate either as a load or a generator. The power converter used in "G2V-only" systems, which include both standard and rapid charging systems, is typically unidirectional. Due of the large power flow, fast charging strains the grid network. Modern conversion must be used by the G2V charger to prevent grid disruptions such undesirable peak loads, harmonics, and low power factor. Energy injection back into the grid is made easier by the V2G technology. The grid-connected AC-to-DC converter, which mandates sinusoidal input current with a high-power factor (near to unity) and permits bidirectional power flow, is a crucial component of the V2G interface.

The idea, design, and validation of a single phase on-board and three phase off-board bidirectional EV charger that can simultaneously charge the vehicle's battery and supply active power assistance to the utility grid are described in this paper. Proposed work having two stages, a bidirectional DC-to-DC converter with a AC-to-DC buck PFC active rectifier.

In two-stage EV charging systems, the grid power input is first transformed by an AC-to-DC converter into a constant DC output voltage. In the case of single-phase boost rectifiers, the output voltage varies from 400 VDC to 500 VDC, which is too high to directly feed the DC-bus of EVs (for example, the traditional active rectifier having three legs of complementary power switches) with an input voltage of 230 V RMS. To lower this voltage to a nominal voltage appropriate for charging EV batteries in the second stage, a DC-to-DC step-down converter is necessary. In this design, the rectifier's and the DC-DC converter's power switches' combined total standing voltage (TSV) equals the DC-link voltage.



(a)

(b)

Figure 1: Basic difference between conventional and proposed AC-DC rectifier (a) Power flow between vehicle and grid with conventional rectifier, (b) Power flow with proposed rectifier

In such a design, a high-voltage DC-bus capacitor is also utilized. On the other side, this work suggests a buck rectifier right from the start. Figure 4.4 depicts the work's design in contrast to the current structure. Such power electronics interfaces may accommodate batteries ranging from 48 V (e-bikes) to 400 V (PHEV) due to the EV battery voltage range of 48 V to 400 V, with the capability to charge the battery in both constant current and constant voltage modes based on the battery's state-of-charge (SOC).

The following code is designed to successfully design a controller, which is user friendly and the user can control the charging and discharging mode based on the State of Charge of the Electric Vehicle Battery.

Where B_r represents for battery current reference, V_B is the battery voltage, Mode represents for charging and discharging mode of the battery.

```
function B_r  = fcn(SOC,V_B, Mode)

B_r=0;
if (SOC==100)
    B_r=0*Mode;
    elseif (90<SOC<100)
        B_r=(2000/V_B)*Mode;
        elseif (70<SOC<90)
        B_r=(2100/V_B)*Mode;
         elseif (50<SOC<70)
        B_r=(2200/V_B)*Mode;
```

```
         elseif (30<SOC<50)
        B_r=(2300/V_B)*Mode;
         elseif (10<SOC<30)
        B_r=(2400/V_B)*Mode;
       elseif (0<SOC<10)
        B_r=(2500/V_B)*Mode;
End
```

Around six ranges of the battery SOC are considered for this purpose. If the battery is completely degradable or completely discharged, the Soc is 0 to 10% and the extraction of current from grid case is high in this scenario. The power is 2.5 kW as shown. Similarly, another case of SOC between 10% to 30%, power is taken as 2.4 kW and further reduces as SOC goes high. This complete operation is done in BMS. In BMS the SOC is sensed typically and power reference is given accordingly and current is calculated. Three sensors are being used, the SOC, battery voltage and mode. The mode is 1 for charging and 0 for the discharging mode. The output is the battery reference which is the current reference given as the reference to the bidirectional DC-DC converter controller. Figure 4.14 shows the simulation of proposed bidirectional five level rectifier for electric vehicle charging.

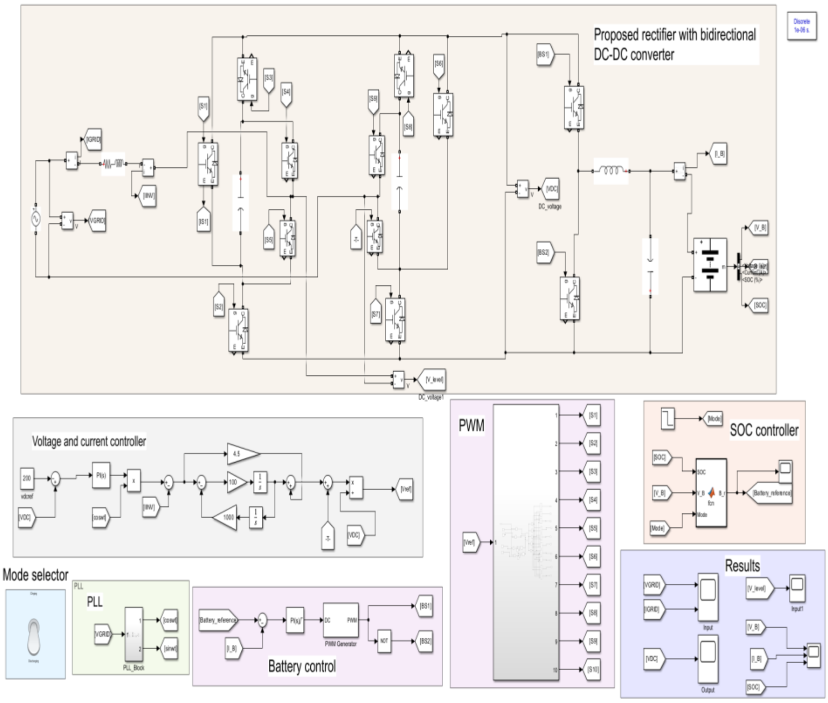


Figure 2: Simulation of proposed bidirectional five level rectifier for electric vehicle charging

III. SIMULATION RESULTS

For operate a vehicle to grid (V2G) operation, bidirectional AC-DC converter act as a inverter i.e. DC to AC. For verifying this operation use a 100V DC voltage as the input of this inverter. This operation validate in two different loads first one use as a resistive load where the load resistance value is 100 Ohm and in the second case use as a inductive load where the load value is 50 Ohm and 50 uF. Figure 5.1 shows the inverter operation in resistive load. In this case 100V consider as a input and generates five-levels at the output terminals i.e., +200, +100, 0, -100 and -200. That means the peak of the output voltage is 200 i.e., double from the input voltage. By this the proposed converter act as a boost inverter here the gain of the inverter is “2”. For resistive load the current are also generates same levels and in phase with the output voltage.

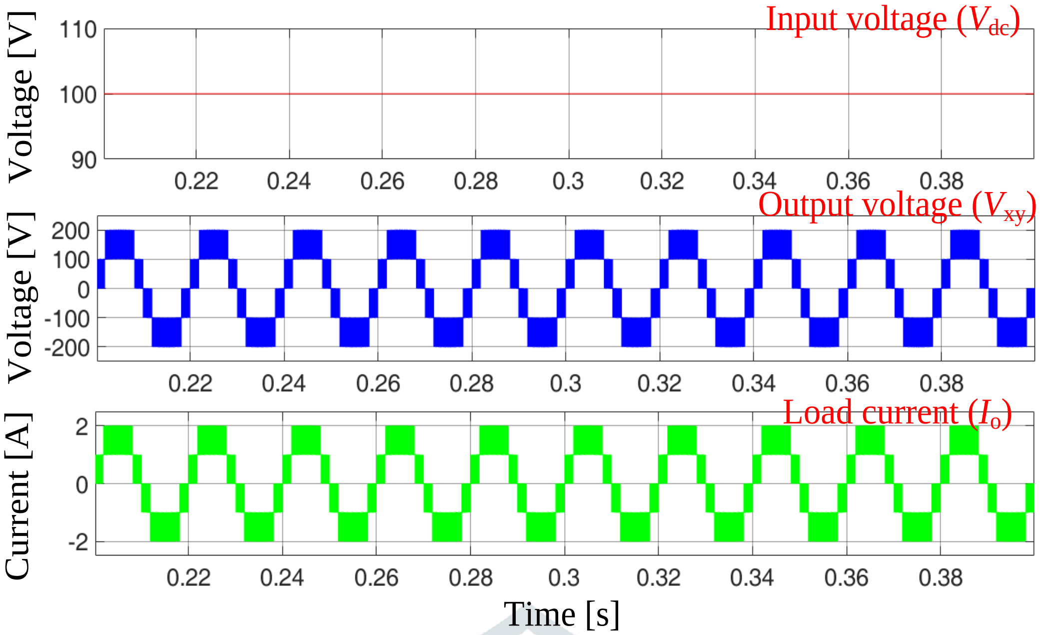


Figure 3: Inverter output voltage and current with respect to resistive load

For inductive load condition, considering the resistive value is 50Ohm and the inductive value is 50 mH. Figure 5.2 shows the output voltage is same as the five-levels are generated with two-boosting gain. Moreover, load current is filtered as the act as a sinusoidal current. As the electric vehicle battery is low i.e., 72V there are requirement of this type of boost inverter. So the proposed inverter most suitable for the electric vehicle discharging mode.

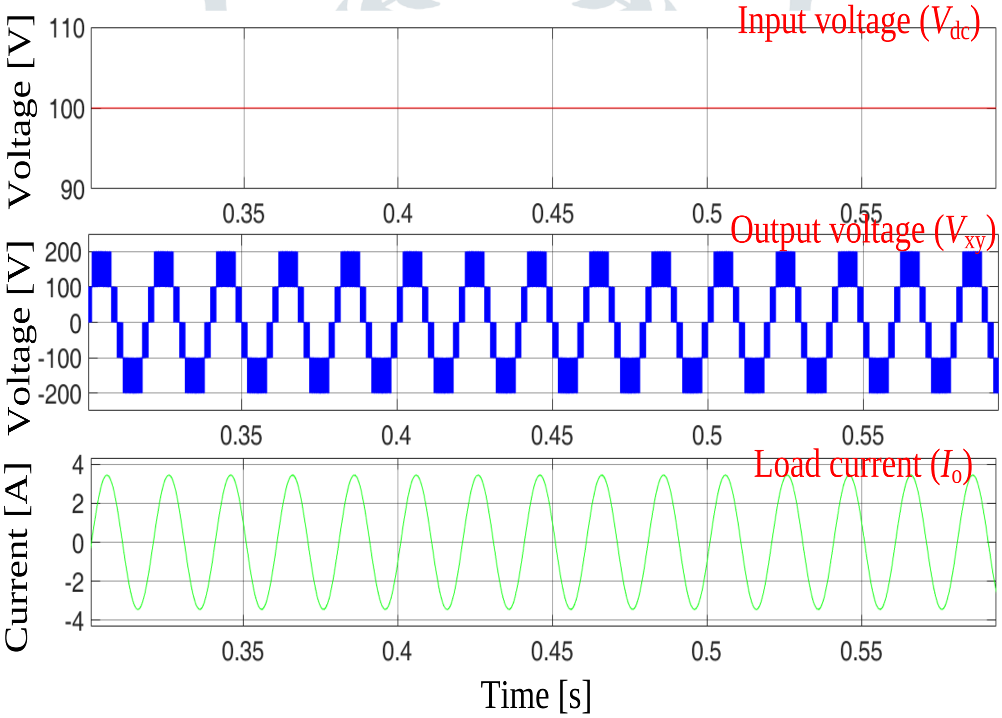


Figure 4: Inverter output voltage and current with respect to inductive load

A Vehicle to Grid that is a bidirectional flow of energy between the EVs and the grid. This work gives a detailed and thorough description of the V2G technology with a broad focus. For electric vehicle charging need to required AC-DC converter for the PFC and DC voltage regulation and DC-DC converter for state of charge (SOC) control. For AC-DC rectification proposed a converter that is operate as a buck mode for charging and boost mode for discharging. Figure 5.7 shows the charging and discharging process. In the case of charging (before the time $t < 1$) grid voltage is in phase with grid current that means angle between both is 0^o i.e., the power factor is unity and current direction is from grid to vehicle. Furthermore, in the discharging mode the grid current direction is reversed so both are in 180^o out of phase. That means the current direction is from vehicle to grid. Figure 5.7 and 5.8 show the phase angle between grid voltage and current for V2G and G2V operation.

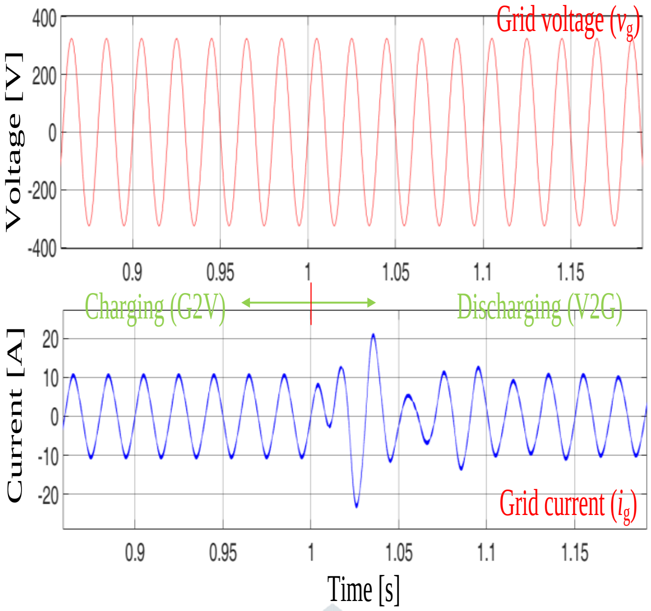


Figure 5: Grid voltage and grid current to verifying the charging and discharging mode

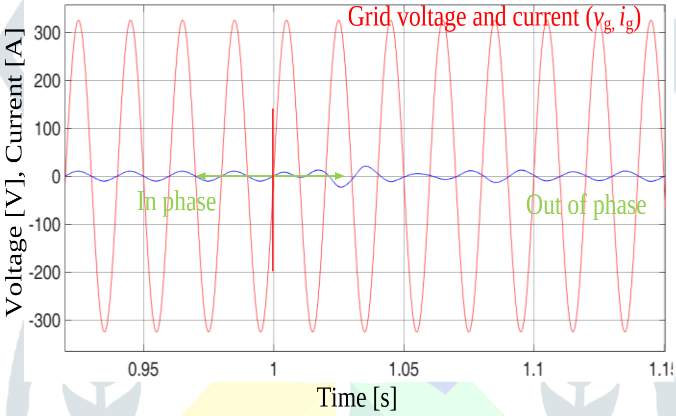


Figure 6: Grid voltage and grid current to validate PFC

IV. CONCLUSION

Multilevel Inverters (MLI) have been under innovative work for over three decades and have discovered useful modern applications. Be that as it may, this is yet an innovation being worked on and numerous new commitments and new commercial topologies have been accounted for over the most recent couple of years. MLI have been drawing in expanding interest because of the fundamental reasons like improved power ratings, harmonic performance and reduced Electromagnetic Interference (EMI) discharge that can be filled with various DC levels that are a combination of the output voltage waveform. Specifically, MLI have an adequate usage in applications such as medium- voltage industrial drives, electric vehicles and photovoltaic systems. The present work gives a solution for planning an active multilevel topology which is suited for medium and high power industrial applications.

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