SUPERVISORY CONTROLLER WITH DC FAST CHARGING ARCHITECTURE FOR ELECTRICAL VEHICLE USING MICROGRID

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***Abstract* - Energy storage systems are critical part of a microgrid because they allow intermittent renewable energy sources to be integrated. When electric vehicle (EV) batteries are plugged in for charging, they can be used as stockpile in micro-grids.They help in energy storage management by storing the charge that is Grid to Vehicle (G2V) and giving it back during peak demand (Vehicle to Grid, V2G). To understand this concept, we need a proper control system and infrastructure. In this paper level 3 fast charging Architecture is used to execute V2G &G2V system. The Model of microgrid system which employs dc fast charging for interfacing electrical vehicle is done. For demonstrating the power transfer of V2G-G2V simulation studies are carried out. The controller and the injected current provide good dynamic performance. A prototype model is designed to understand this concept**

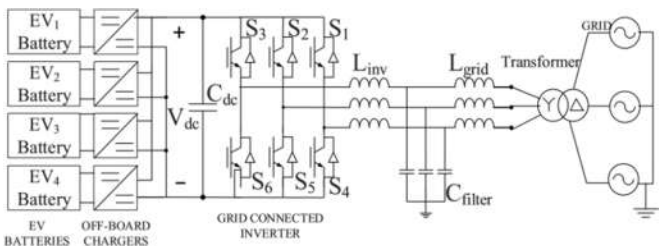
***Keywords* – , DC fast charging, Microgrid, Vehicle-to-grid Grid-to-vehicle, Electric vehicle**

I. INTRODUCTION

The increase in the emission of greenhouse gases is one of the most important problems in the entire world. Controlling the emission of GHG will be challenging in future. Transportation consumes a large amount of petroleum in day-to-day life. Thus, burning of them leads to an emission of GHG. Electric vehicles have the potential to solve a big part of GHG emission and their battery can be used as a battery storage system. In a micro-grid energy storage system play a crucial role because they allow intermittent renewable energy sources to be integrated. When electric vehicle (EV) batteries are plugged in for charging, they can be used as storage devices in micro-grids. Many private transportation vehicles remain parked for about 21 hours every day, making them an idle asset. Therefore, by storing excess energy and supplying back to grid when there is a need, EV can help in energy management. V2G in the power grid faces a variety of challenges, including being difficult to control, requiring a big number of EVs, and requiring a long time to put into practice . A V2G system in a micro-grid is concise to set up in this circumstance. The Organization of Automotive Engineers defines 3 level of charging for electric vehicles. In case of Level 1 charging the EV is plug in to the standard household (115V) outlet. This is the slowest technique of changing and it is mostly suitable for the people who have entire night to charge at home or public station and usually travel less than 60 km in a day. Level 2 charging is quicker than level 1 and it take lesser time to get fully charge the EV. It uses a specialized Electric Vehicle Supply Equipment (EVSE) to supply power at 220V or 240V, up to 30 A. Level 3 charging is the fastest of all 3 levels and it is also known as DC rapid charging. It provides up to 90 kW of charging power at 200/450, which reduces the charging period to 20-30 minutes. Therefore, we have implemented DC fast charging for V2G architecture in a micro grid, because of the fast power transfer required when EVs are used as energy storage devices. The main reason to cover the concept of V2G in general power grid is to help us in peak shaving, valley filling, and regulation. So in this study we have presented a micro-grid infrastructure with dc quick charging stations and V2G capability. The suggested architecture enables high-power two way charging for EVs using off-board chargers. The efficiency of the model presented in both V2G and G2V modes is evaluated using MATLAB/Simulink simulations.

II. V2G CHARGING STATION CONFIGURATION

The model of a dc rapid charging station for G2V-V2G architecture in a micro-grid is shown in Figure 1. Electric car batteries are connected to the dc bus through off-board chargers. We have used a step up transformer, inverters, LCL filters to provide the connection of DC bus to the main grid . The most important components of the charging station are given below.



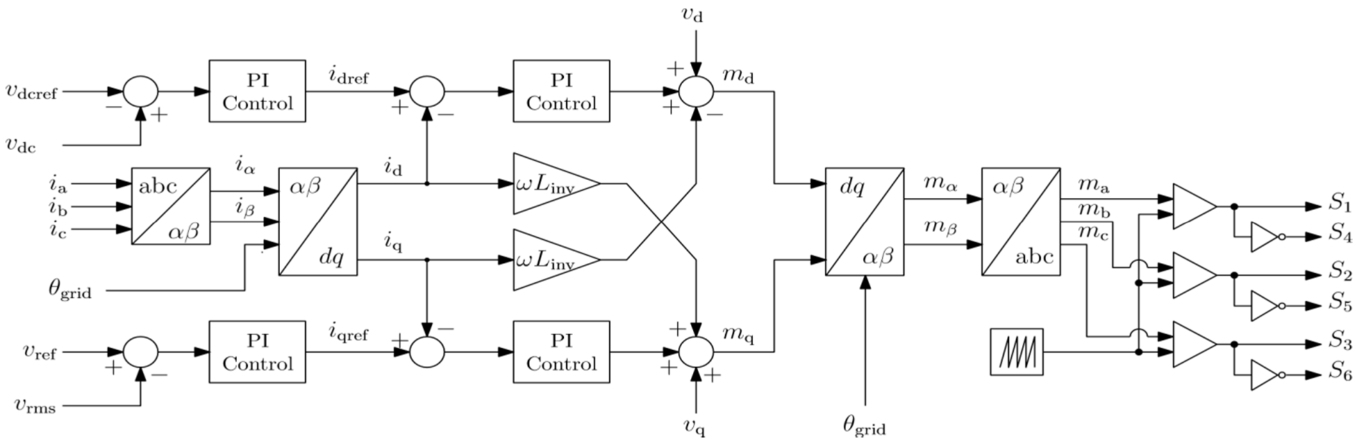


Fig. 1. Fast dc charging station for electric vehicles

A. Battery charging configuration

The dc rapid charging stations are stored in an EVSE and are located off-board. A two way dc-dc converter[1] is a vital component of off-board charger with Vehicle to Grid capabilities. It connects the battery system of electric vehicles to the dc distribution grid. Figure 2 shows the converter configuration. It has two IGBT/MOSFET switches that are controlled by simultaneous control signals throughout.

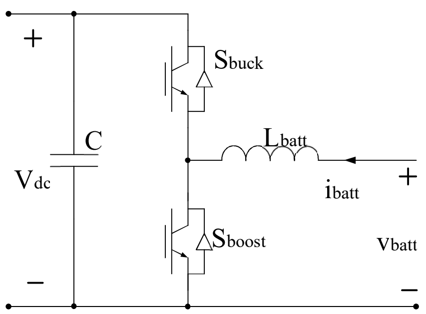


Fig. 2. Battery charger design

1) Buck mode of operation (charging mode)

When the upper switch (S_{buck}) is turned on, the converter becomes a buck converter, then it step down the input voltage (V_{dc}) to the battery charging voltage[1] (V_{batt}). When this process occurs the current flows through the switch and then induded into the battery. This operation is known as grid to vehicle (G2V). The battery voltage is equation (1), where D is the duty cycle of higher switch.

$$V_{batt} = V_{dc}*D \quad (1)$$

2) Boost mode operation (discharging mode);

During this operation, the bottom switch (S_{boost}) is enabled, the converter becomes boost converter by step up the battery voltage (V_{batt}) to the dc bus voltage[1] (V_{dc}). The power flow in this case is from the vehicle to the grid (V2G), and battery is in discharge mode. where D is the lower switch's duty cycle.

$$V_{dc}=\frac{V_{batt}}{1-D'} \quad (2)$$

B. LCL Filter and Grid Connected Inverter

The inverter[1] convert dc bus voltage to three-phase ac voltage and allow current to flow backwards using diodes in each leg of the switches (Fig.1). LCL filter is used to obtain pure voltage, and to reduce harmonics.

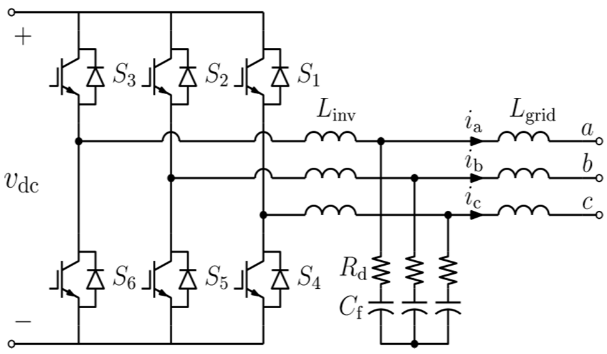


Fig 3. Three phase inverters plus LCL filter

Fig.3 shows the LCL filter configuration where C_f is the filter capacitance, L_{inv} is the inverter side inductance, L_{grid} is the grid side inductance is given by (3), (4), (5) respectively

$$L_{inv} = \frac{V_{grid}^2}{S_{rated} * THD * 2\pi f_{sw}} \sqrt{\frac{2}{18\pi}\left(\frac{3}{2} - \frac{4\sqrt{3}}{\pi} m_a + \frac{9}{8} m_a^2\right)} \quad (3)$$

$$C_f \leq \frac{0.05 S_{rated}}{2\pi * f_{grid} * V_{grid}^2} \quad (4)$$

$$L_{grid} = R.A.RF..AC.fF..+2\pi 1 f_{sw} 2 \quad (5)$$

Where THD is the total harmonic distortion, f_{sw} is the switching frequency of inverter, f_{grid} is grid voltage.

Fig 4 Inverter control circuit

fundamental frequency m_a is inverter modulation index, RAF is the ripple attenuation factor[2].

III. CONTROL SYSTEM

A. Off-Board charger control

The control of a steady current approach employing PI controller is utilised to control the discharge/ charge of the battery charger circuit[1],Fig.5 (a). The controller first compares the reference battery current to zero,to determine the polarity of current signal. Then it allows the circuit to choose between charging and discharging modes. Following mode selection the obtained measured current is then compared to the reference current. The difference between them is passed into a PI controller. which generates the S_{boost}, S_{buck} switching pulses. During discharging S_{buck} is turned off.
During charging S_{boost} is turned off.

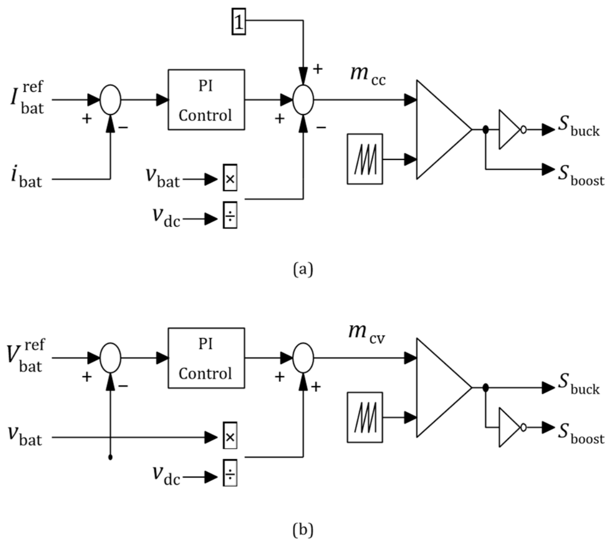


Fig 3,(a),(b). Constant current and voltage control methods for battery charg.

B. Inverter Control

For the inverter controller we have included a cascade control system[1]. The control circuit is made of two inner current loop and two outer voltage control loops. Active ac current is being controlled using d axis inner loop [3,4]. The dc bus voltage is controlled by outer loop. The q axis reactive current is being controlled q axis outer loop and is being regulated by q axis inner loop.

IV. MICROGRID TEST SYSTEM CONFIGURATION

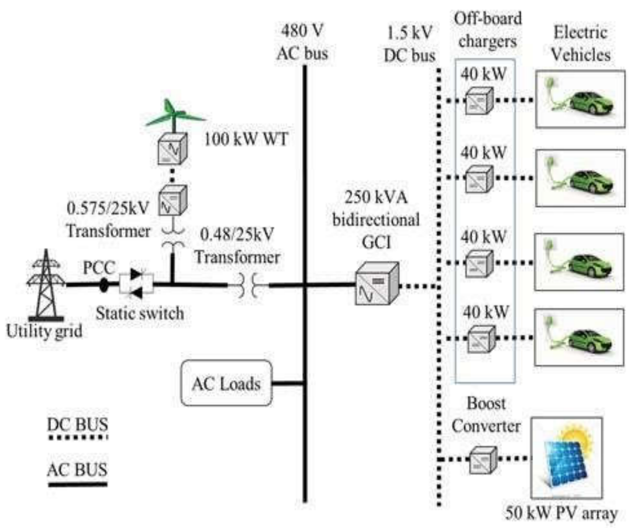


Fig 6. Proposed microgrid test system configuration.

The micro-grid test system and a dc quick charging station is shown in Figure. The generating source of the microgrid are 100kw wind turbine and a 50kw solar pv. The batteries of electric vehicle are connected to 1.5kv DC bus of charging station through off board chargers. Solar PV is connected to this DC bus through a boost converter. And the utility grid is made up of 120kv equivalent transmission system and 25kv distribution feeder. The voltage are then linked and stepped up by the help transformers.

V. SIMULATION RESULTS

The charging station design and parameters are value are shown in the appendix. The maximum power output of wind turbine is set to 100kw. The maximum power output is 50kw. The GCI's current reference is set to zero. The state of charge of electric vehicle battery is set to 50%. When all the steady state conditions are obtained the V2G-G2V power transfer is being done by running the batteries of EV1 & EV2. The current set points for the electrical vehicle batteries are displayed in Table 1.

The battery parameters are shown in Figs. 7 and 8 when EV1 is in V2G mode and EV2 is in G2V mode, respectively.

TABLE I. CURRENT SET-POINTS TO EV BATTERIES

Time range (s)	0 to 1	1 to 4	4 to 6
Current set-point to EV$_1$ battery (A)	0	+80	0
Current set-point to EV$_2$ batter y(A)	0	0	-40

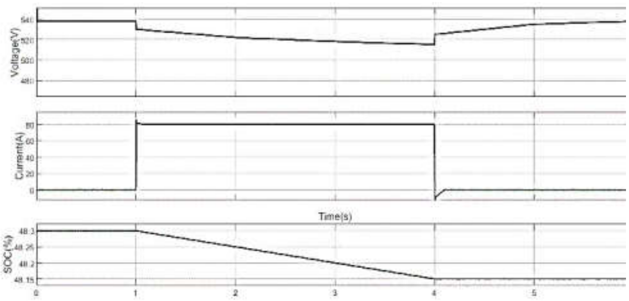


Fig 7. Voltage, current and SOC of EV1 battery (V2G mode)

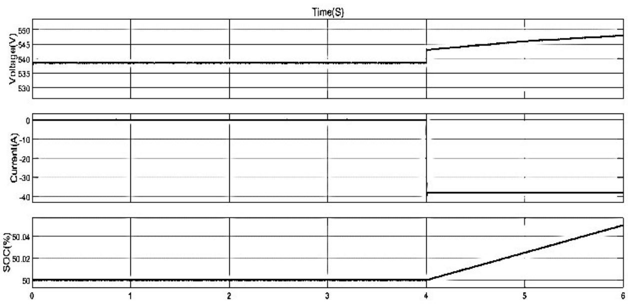


Fig 8. Voltage, Current and SOC of EV2 battery (G2V mode)

Figure 9., illustrate the grid voltage and current at PCC. During G2V operation the grid voltage and current are in phase and out of phase during V2G operation[1], indicating reverse power flow.

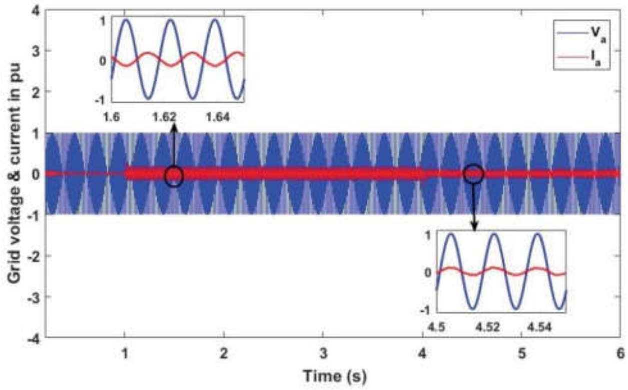


Fig 9. During V2G-Operation grid voltage and grid injected current

VI . HARDWARE PROTOTYPE MODEL

A. Components used.

Fig 10. LCD

LCD: LCD is a liquid crystal display. In our project, a 16x2 LCD is being used. It works with a voltage range of 4.7 to 5.3 volts and current consumption is 1ma. The LCD is 163mm wide, 125mm tall, and 30.5mm thick. It contains 2 rows and 16 columns.

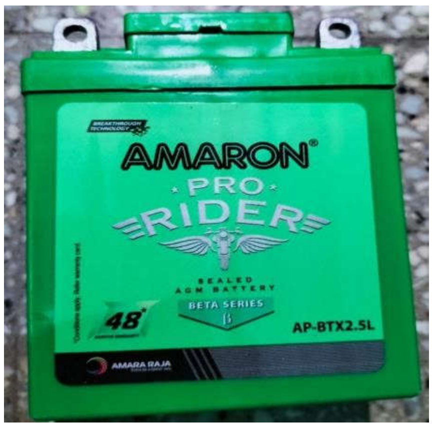


Fig 11. Battery

Battery: we have used Amaron APBTX2.5L bike battery. Voltage rating is 12v and current rating is 2.5Ah. It is a fuel cell battery.

Fig 12. ARDUINO Uno

ARDUINO Uno: The ARDUINO Uno has digital and analogue input and output pins. On the board, there are 14 digital input/output pins. 6 analogue input/output pins. It operates at 5V and provides a 20 Ma dc current per input output pin.

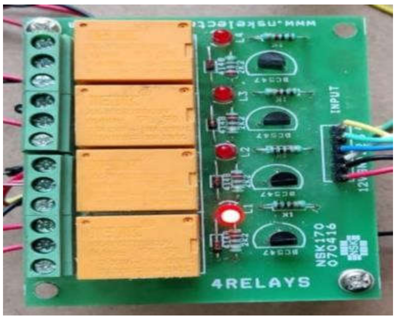


Fig 13. 4 relays setup

10A 250VAC, 10A 30VDC is the rated load. The maximum switching current is 10 amps. 110VDC / 250VAC is the maximum switching voltage. Coil power is 0.45 watts. C:1 (NO/NC) is the contact arrangement. 19 x 15 x 15 mm in size.

B. Working of model

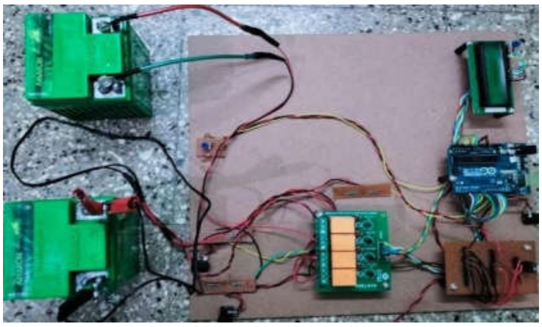


Fig 14. Hardware prototype model

This prototype model is divided into 2 operating modes, G2V & V2G. when model is operating in G2V mode then vehicle is charged by grid. In grid we have 3 sources namely Solar PV, Batteries, and Mains. Automatic switching is done according to priority. If the solar PV output is between the range of 12v to 17v then it is given the first priority. If the voltage is below 12v then battery will be given next priority. If both are not available then supply is taken from mains which is 3rd priority. During V2G operation, we have used vehicle battery as a main charge storing device, so during peak demand we are using this stored charge to full fill the demand. To realise this concept, we have used a pot to reduce battery voltage from 12v to 7v. the Arduino will sense this voltage drop and operates relay in such a way that it uses vehicle battery as a source to charge the grid battery this is V2G operation.

VI. CONCLUSION:

We discussed the architecture of dc fast charging for V2G systems employing microgrid in this research, as well as the methodology for modelling it. To connect the EVs to the microgrid, a dc rapid charging station with off-board chargers and a microgrid connected inverter is planned. This supervisory controller structure allows two way power transfer between EVs and the microgrid. The simulation shows a smooth power transfer between the EVs and the microgrid, with the EVs meeting all necessary conditions for the current pumped into the grid standard. The designed controller dynamically performs well in terms of dc bus voltage stability. Proposed prototype model shows good performance. And helps us to understand the concept more clearly. This research looks at the active power regulation features of microgrids, and this V2G framework can be used for a different range of services such reactive power control and frequency regulation. The design of supervisory controllers that deliver signals to individual EV charging should be the focus of future study.

VII. REFERENCES:

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APENDIX

CHARGING STATION SPECIFICATIONS

Parameter	Value	Parameter	Value
Rated capacity	250 kVA	EV rated power	40 kW
V_{batt}	500 V	Battery capacity	48 Ah
C_{dc}	850μF	C_{filter}	133μF

L_{inv}	0.25 mH	L_{grid}	0.25 mH