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Integrated EV Charging System with Renewable Energy Sources and Grid Connectivity

Abstract: - The configuration of a grid-connected EV charging station that is integrated with a renewable energy system is explained in this study. It reduces grid stress by serving as a contingency plan for supplying the power needed for An electric vehicle charging station and is a solar PV rooftop installation. Renewable energy sources are the best option for energy production because they generate power locally, which helps charging stations operate more economically. They work with grid-connected charging stations, which use the grid's power during off-peak hours to operate. During these times, The sun photovoltaic system charges the backup batteries that are connected to the station to provide power to charge EVs during peak hours. Additionally, EV batteries may be switched out for a backup battery bank that uses a solar PV system to charge all day. The renewable energy-powered EV charging station that is linked to the grid is simulated using MATLAB/SIMULINK, which aids in the simulation model's output.

Keywords: backup battery, charging station, solar photovoltaic system, and electrical vehicle.

1. INTRODUCTION

Current global warming is becoming worse every day, and one of the primary causes of this is carbon emissions from conventional vehicles. Electrical vehicles are one of the finest alternatives to conventional vehicles because of its many benefits, including zero carbon emissions, a reduction in greenhouse gas emissions, eco-friendliness, and zero usage of fossil fuels. Since EVs can balance energy resources, they are the ideal answer to energy emergencies that need for very little in the way of traditional energy sources. People are concerned about the short driving range, lengthy charging times, and cost of EV technology before embracing it. Prior to adopting EV technology, the necessary infrastructure, such as charging stations and EV service stations, should be built up to ensure EVs operate dependably.

In order to eliminate the constraints associated with EV charging, charging stations should be located in easily accessible areas, EV charging times should be shortened, and ideal battery management techniques should be used to ensure extended driving range. EV charging is a primary and significant issue. There are two methods for charging EVs: onboard and offboard. Table 1 lists the various charging levels specified by J1772 for DC charging. [1] Station for charging A significant quantity of grid electricity was needed to meet station demand. Adopting renewable energy sources is an alternative to putting more strain on the grid. By combining renewable energy sources with EV charging stations, the power demands of the stations may be met.[6]

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Table 1: Charging levels with its V,I & Power

Charging Level	Charging Voltage(V)	Charging Current(A)	Charging Wattage(Kw)
1	200/450	80	36
2	200/450	200	90
3	200/450	400	240

Solar PV systems are more well-known among renewable energy sources since they are easy to set up, dependable, and need less maintenance. Combining solar with EV charging stations is the ideal way to lessen grid strain. Local electricity produced by solar PV systems may be used to conveniently charge backup batteries during grid peak hours, allowing charging stations to operate profitably during those times. This article describes the specifics of a system. The Matlab simulation and the system model of an EV charging station are completed, with part I explaining the system in detail and section II considering circuit design and controlling the EV charging technique. Section III discusses the simulation of an EV station, its findings, and its potential applications.

2. SYSTEM DETAILS

The primary components of an EV charging station are an inverter that interfaces with the grid, a transformer, battery chargers, a DC bus feed, and an RCL filter [1,2].

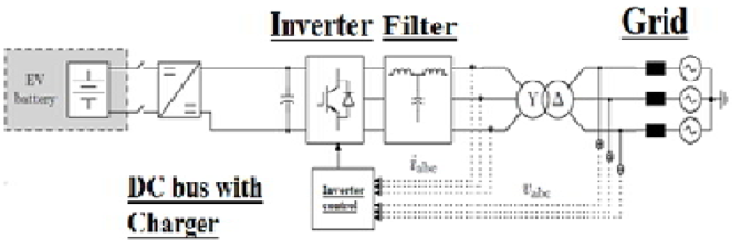

Fig 1: Block Diagram EV charging station

According to VAR, the rated capacity of Stated is

$$S_{Rate} = \frac{K_{Load}\ N_{Slot}\ P_{Ev}}{COS\varphi}$$

where N_{slot} is the number of charging slots, P_{ev} max power rate, and cosΦ and K_{load} are overload factors to account for temporary overload. [10] The block diagram displays an inverter that is connected to the grid via an LCL filter. The inverter is managed by a control system that uses the grid's reoffered value. At the conclusion, a DC off-board charger with a battery is displayed. The voltage of the DC line is established based on grid voltage.

$$V_{DC} \leq \frac{V^{min}}{m_{min}}$$

where mmin is the minimal modulation index and V min is the minimum battery voltage.

3. EV BATTERY

The Thevenins equivalent base mode, which represents the battery module, uses Rseries for V-I[1] characteristics and RCII to show the battery's transient t response. Voc is the open circuit voltage, which is dependent on soc.

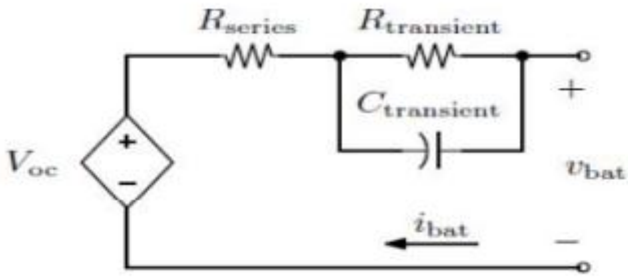

Fig 2: The battery's Thevenin equivalent circuit

Model An EV's battery serves as its heart, distributing electricity throughout the vehicle for operations. There are many different kinds of EV batteries available for purchase. Li-ion batteries, however, are becoming too common for EVs these days. [3].

Table 2 Batteries Storage Systems [5]

Type	Energy Efficient [%]	Power Density[W/kg]	Energy Density [Wh/kg]
Li-ion	85-95	300-2000	100-200
Ni-Cd	60	140	40-60
Ni-MH	50-80	220	60-80
Pb-Acid	70-80	25	20-35
Super caps	90+	5000-20000	25-75
Li-polymer	80-90	300-2000	100-200

4. BATTERY CHARGER

A battery charger featuring a bi-directional converter and power electronic components that worked in tandem with one another using their own control signals. [1] A buckboost operation is performed in a converter; it relies on the tree power electronic switching system. The voltage Vbat on the left side experiences a boost action. Buck mode is engaged when the top s/w is actuated, and lower s/w is operated or triggered.

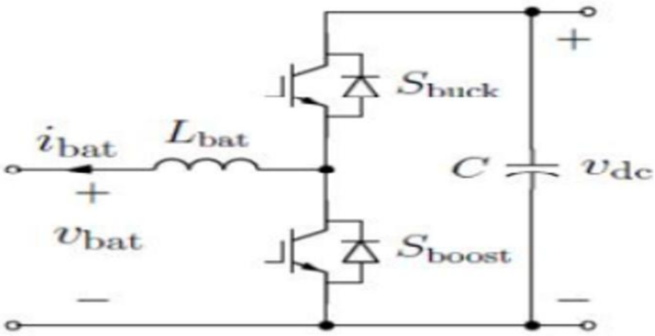

Fig 3: Battery Charger

5. THREE PHASE INVERTER

As seen in figure 4, the inverter is linked to sources and a battery charging module. It is managed by an inverter management system that provides a gate pulse trigger for the invertor and an LCL filter that is also attached to the invertor.

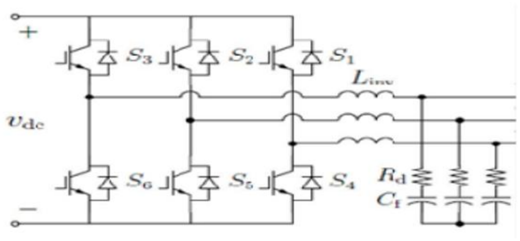

Fig 4: LCL filter-equipped three-phase inverter.

6. LCL FILTER

The purpose of the passive filter is to lessen harmonics, which disrupt line current and voltage, leading to poor power quality and having an impact on the system. The source and invertor are coupled to an LCL filter. The filter's objective is to eliminate current harmonics that create equilibrium between the source and the inverter [7]. Third order low pass filters, which offer strong harmonic attenuation and are modest in size, are preferred by LCL filters.

7. CONTROL SYSTEM

An essential component of any system modeling is the control system, which monitors the system's operation at various stages and modifies input values in accordance with system requirements to produce the intended outcomes.

7.1. Inverter control

An inverter is used to transfer electricity from the AC grid to the DC bus. In order to maintain DC bus voltage, the control method employed cascaded control in the dq frame and a PWM generator to provide a gate pulse for the invertor's s/w [1]. There are an outer voltage loop and an inner current loop in the cascade control. Using a phase-locked loop (PLL), grid voltage is synchronized. The figure displays the control.

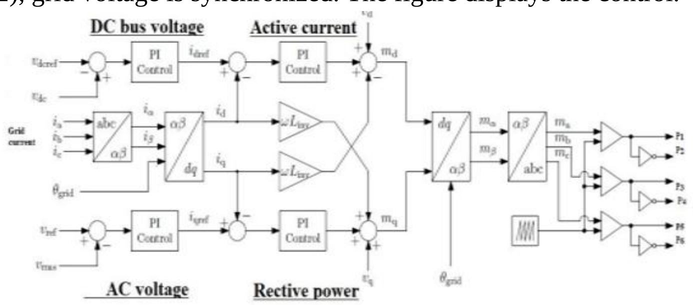

Fig. 5: Inverter control [1]

The three-phase voltage input measurement in the PLL, which uses the output signals vd, $_1$grid, and w for dq frame inverter control, is depicted in fig. 6.

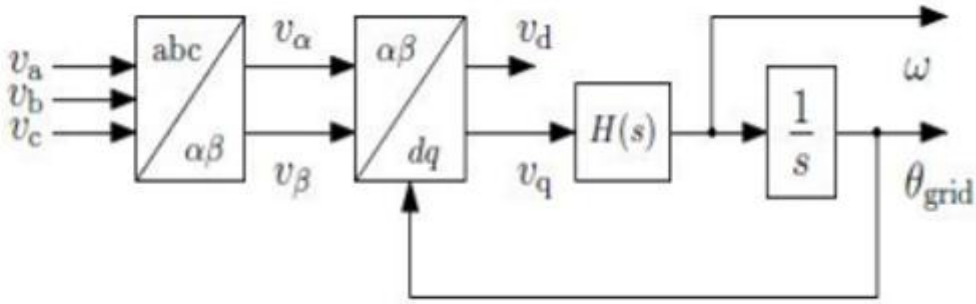

Fig 6. PLL [11]

7.2. Battery control

Constant current and constant voltage are the two suggested controllers for battery charge regulation. Figure 7 depicts the early stage of charging, which is constant current, whereas Figure 8[1] depicts constant voltage.

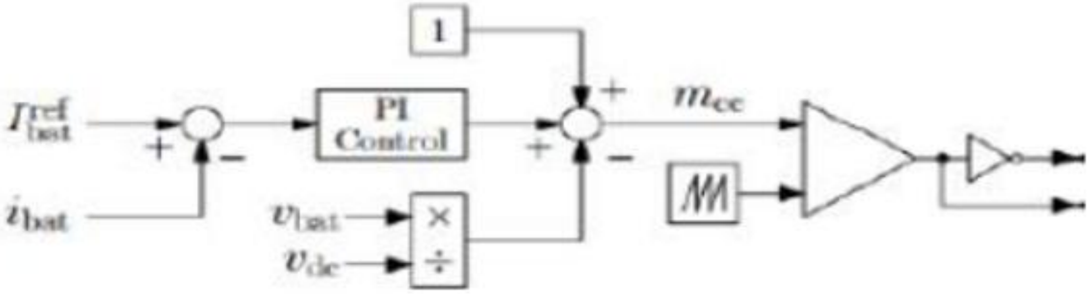

Fig 7. Continuous current

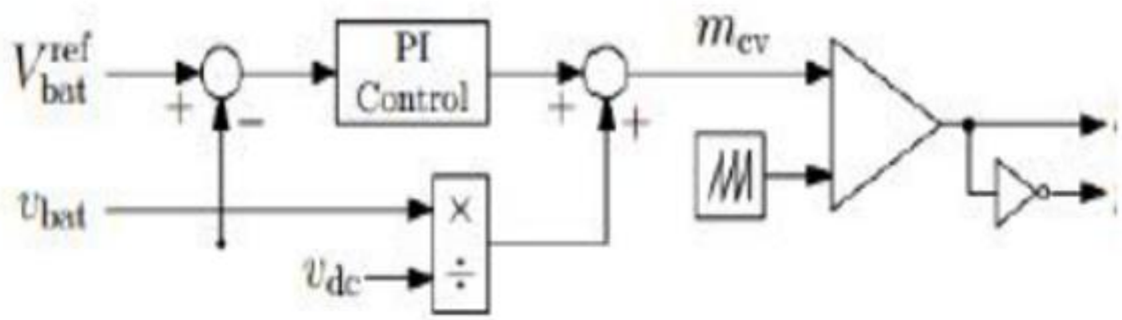

Fig 8. Constant voltage

8. SIMULATION AND RESULTS

8.1. Simulation of SOLAR PV with boost converter

With the use of a boost converter, solar photovoltaic used to charge the backup battery [3]. The 1kw Sun power SPR-X20-255 solar PV module used in the simulation has the specifications shown within the table. 3. The photovoltaic solar production is increased and used for battery charging [4,5]. A 24V Li-ion battery is employed as a backup power source for the charging station. Figure 10 displays the simulation result, which shows that the battery is charged as the SOC increases. The output result of the simulation indicates that the minimum SOC is maintained at 50%.

Table 3: Solar PV specification

Parameter	Values
Maximum Power (W)	256.66
Voc (V)	51
SC current Isc (A	6.33
Voltage at maximum power point Vmp (V)	42.8
Current at maximum power point Imp (A)	5.95
Series-connected modules per string	5
Parallel strings	64

8.2. Simulation of EV charging station

Figure 11 [1] shows MATLAB's simulation of an EV charging station. The entire station is connected to an 11KV grid source, and electricity is supplied to the transformer, filter, inverter, and battery charging unit, which serves as a boot charger, while EV charging operations are performed. The outcome is seen in Figure 12, where a 42V battery is charged with 50% SOC and the output shows a progressive increase when simulated in MATLAB. An increase in SOC indicates that the EV battery is being charged with the appropriate voltage and current. [9] Table 4 displays the results of charging various batteries because different EVs have different battery systems. [4] As an illustration, a 42V, 100AH battery is used, and it is simulated for 60 seconds at an initial state of charge of 50%.

Table 4: Different types of EV Battery charged

Battery type	SOC %
Li-ion	63.6
Lead acid	71.3
Nickel metal hydride	64.1
Nickel cadmium	64.5

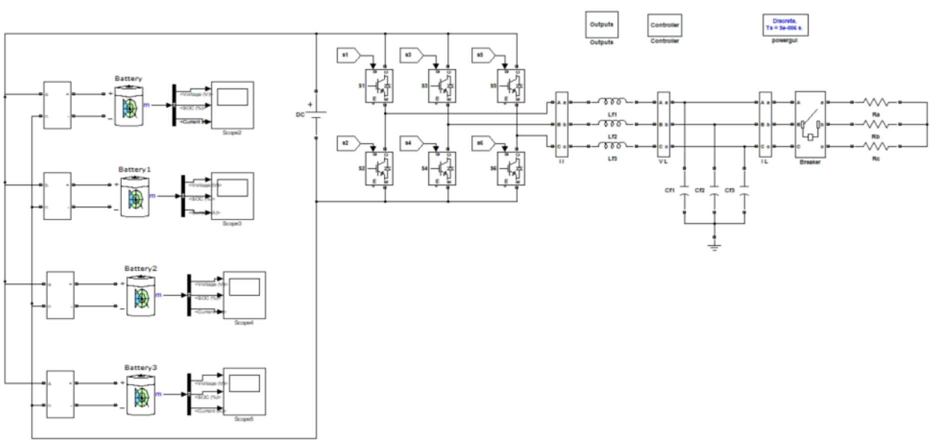

Fig 8: Circuit Diagram

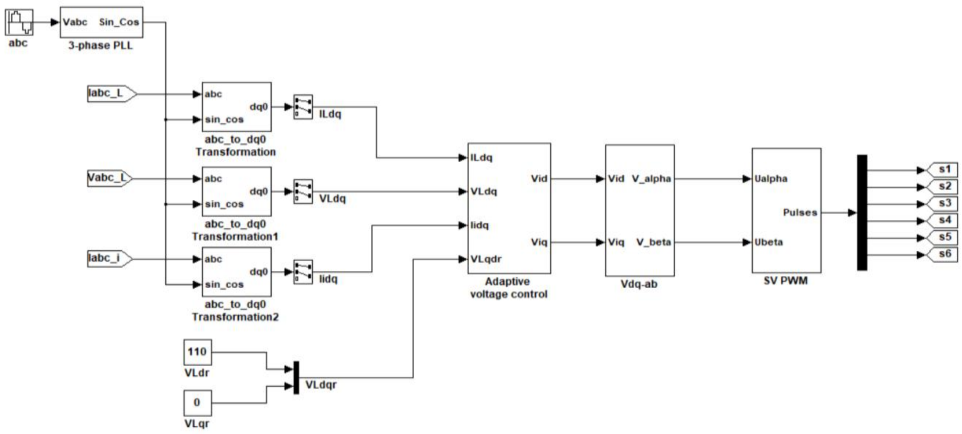

Fig 9. Control

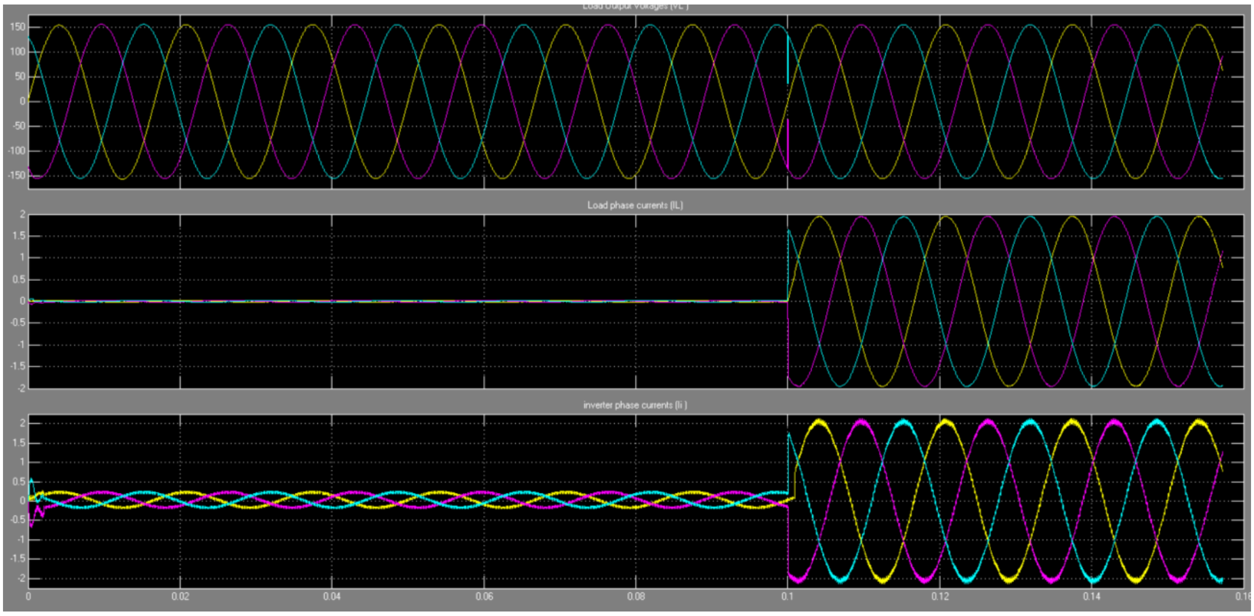

Fig. 10: Grid injected current and grid voltage during V2G-G2V operation

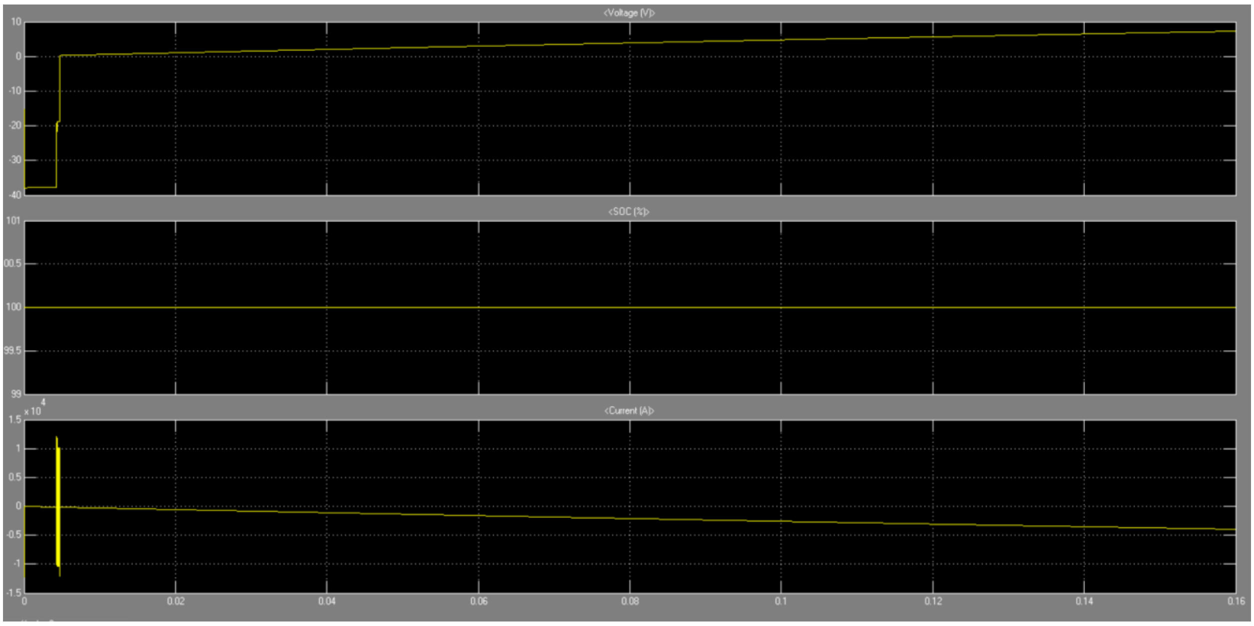

Fig 11. Battery voltage and current

9. CONCLUSION

The different pieces of equipment utilized in the setup of a grid-connected EV charging station powered by renewable energy are described. For clear understanding, the control method employed in the bidirectional inverter is also shown in the article. While backup batteries satisfy the station's power needs during peak hours, thereby reducing grid stress, and battery switching is also possible on-site, the photovoltaic solar system is used with the station for technical and financial reasons. EV charging is accomplished effectively, and the results are shown using several battery types that aid in the study and comprehension of the charging rate behaviour with their individual compositions.

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