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"Grid-Connected Solar-Based Charging Systems for Electric Vehicles: Design and Optimization Review"

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Abstract: Electric vehicles (EVs) are increasingly adopted due to their advantages such as easy maintenance, low operating costs, and environmental friendliness. In EVs, electrical energy stored in rechargeable batteries serves as the primary source for driving electric motors. Photovoltaic (PV) panels are capable of converting solar energy into electrical power, making them a sustainable source for EV charging.

The charging station proposed in this work integrates solar PV panels with grid connectivity to form a hybrid charging system. Such hybrid charging stations are designed to be efficient, safe, and adaptable to varying operating conditions, thereby offering greater flexibility to EV users. The inclusion of a battery storage system (BSS) allows energy buffering and load balancing, which helps reduce stress on the utility grid while supporting diverse EV charging demands. This integrated approach enhances overall system performance, reliability, and cost-effectiveness.

This article presents an overview of solar energy systems, electric vehicles and their types, and discusses various methodologies and procedures for designing a grid-connected solar charging system for electric vehicles.

Keywords: Electric Vehicles (EVs), Grid-Connected Solar Charging, Photovoltaic Systems, Battery Storage System (BSS), Hybrid EV Charging Stations, Charging System Optimization.

1. Introduction

The 1880s was the year of the invention but popularized in the 20th century as an advance of internal combustion engines. In 1987, electric cars found their commercial use in the USA and it does not require gear exchange when compared with conventional vehicles. Characteristics of an electric vehicle depend on the battery size and electric range of utilization [1]. There is no tailpipe emission when compared with IC engines which in turn reduces the greenhouse gas emission-related issues. Significant reduction of air pollution in city

areas is the result of EV usage because they do not emit pollutants including soot, hydrocarbons, carbon monoxide, volatile organic compounds, ozone, lead, and oxides of nitrogen. The pollutant emission is based on the emission intensity of charging sources as well as there is an energy wastage during the charging state. High power to weight ratios is the output of electric motors which require a heavy current supply. Fixed ratio gearboxes and clutch absence are the reason for the reliability and simplicity of the EV's. Acceleration capability is based on the size of motors and has constant torque [2]. Especially at low speeds, acceleration performance will be more relative to that of the same motor power internal combustion engine. The power rate increment relies on motor-to-wheel configuration because wheels directly have the connection with motors for propulsion & breaking.

1.1. Renewable Energy

Easter, Biczel and & Klos (2009) Polish energy law, which regulates renewable energy such as the use of renewable energy, solar energy, hydropower, wave energy and waves, energy from rivers, biomass energy and energy in the conversion process produced in the process of burial biogas and treatment of contaminants and treatment of decay or damage to plants and animals. According to Musgrove (1983), wind energy is an independent form of solar energy, because wind is due to the presence of the equatorial surface of the earth more sun than Polar Regions, which will cause large tumors in the atmosphere the total amount of solar energy per year is enormous.

1.2. Wind Energy

Wind is defined as a series of wind waves, in which there are numerous aerial movements on Earth. Due to the irregular heat of the sun on the ground, the pressure difference in the wind leads to the wind. Rotation due to the power of Coriolis. (Getachew, 2009). The use of wind energy is an ancient technology; its history can be traced back to the Middle East 1400-1800 years ago. The first application of wind energy includes the use of wind energy for agriculture, navigation and other irrigation.

1.3. Solar PV Electricity Generation

Solar power is the conversion of energy from the sun to electricity. Among the main expansions in converting solar power into useful energy, the forms include the direct conversion of solar energy to electricity using the photovoltaic effect (Garcia-Lopez et al., 2015). Another wide application of indirect solar energy conversion is the manufacture of heat mostly in form of Concentrated Solar Power (CSP).

2. Related Research

Evelyn-Astrid et.al. (2018)- The state-space averaging method is used for the modeling, design, and control of a DC-DC converter, so this is how it's done. As a way to control the flow of power between a battery, an ultracapacitor-based energy storage system (ESS), and a load resistance, DC-DC converters with two half-

bridge topologies could be used, Based on two well- known control methodologies that use alternating current equivalent circuit modeling, the development of converter control systems is based on this.

Mochamad Abdul et.al. (2018) When it comes to charging batteries on BES (Battery Emergency Supply), things are moving very quickly in the modern world. So, there are many different types of power converters in use now. For the sake of efficiency, the battery charger's manufacturing process is being worked on. This is true: But these converters can only be used to charge batteries. This means that even when people share the load, a converter is still needed to keep the voltage consistent. Some converters, on the other hand, still have switching losses.

Karri Hemanth et.al. (2019) In this paper, we show bidirectional dc-dc converters that can charge electric vehicles (EVs). A converter that can be used in both a buck and a boost mode has a wide voltage conversion ratio because it has a lot less parts than traditional unidirectional and bidirectional converters. This section shows waveforms that are stable and how the converter works. Dc voltage and current transfer functions, the stress on semiconductor components in terms of both current and voltage, and converter passive component design expressions all come from this process. A 3.2 kW, 380 volts (LV) and 48-

Milad Babalou et.al. (2019) DC power supplies are used to test the batteries in electric cars, mobile devices, and renewable energy sources. It has been a while now that modular multi-level converters (or MMCs) have been looked at and used in practical applications, like high and medium voltage DC–AC and AC–DC power converters. MMCs are a new type of technology. In contrast to DC-AC and AC-DC conversions, the widely used MMC topology has a big problem when it comes to making a DC-DC converter. It can't balance the voltage of each cell's capacitors. They usually use an AC-DC converter and a DC-AC converter to make most of the MMC-based converters.

Hossein Gholizadeh et.al. (2021) In this work, a high step-up converter that doesn't need to be changed has been proposed. If you want to make a boost converter, you start with an ordinary one and then add two voltage multiplier cells. The converter in question was made to run on a steady stream of electricity. Both ideal and non-ideal modes have been used to find

Jun Mei et.al. (2021) an energy storage system-friendly, non-isolated, bidirectional dc-dc converter is shown here. These two boost converters, which are linked together in series, make up the power source for this converter. A switched-capacitor cell is set up on the side with a lot of electricity. One of the converter's low-voltage sides has two separate inductors removed in favor of one that is linked together.

Kun Qu et.al. 2021 in this study, an ultra light electric car with sliding mode control and a prototype non-isolated bidirectional buck-boost DC-DC converter are shown off. Also made are control and power systems. The voltage and current sensors, as well as the output comparator, send signals to the operational amplifiers and the microcontroller unit. They also get signals from the output sensor.

3. Electric Vehicle Overview

It is the holy grail of electric cars because it doesn't need internal combustion engines to move them. At 90%–95% of the total energy they use, electric motors are very energy-efficient. When an electric car has a battery, a

port to charge it, and a charger, these three parts are very important. Other important parts are the DC/DC converter and the power electronics controller, as well. This is another important part of an electric car. Battery-powered electric cars are moved by an electric motor that converts the stored electricity into mechanical torque. When electric cars (EVs) are charged with low-emission power sources, they help the environment. When the batteries run out, the grid comes in and gives them a boost. It must have a battery that can store the energy it needs in order for an electric car to work, Because lithium-ion batteries are light and don't need a lot of attention, they are often used in electric cars. In order to make these lithium ion batteries, they cost more to make than nickel-metal hydride and lead-acid batteries.

There are some Li-ion batteries that have a shelf life of up to 12 years if they are properly cared for. In order to recharge the battery, the car's charging connector connects to an outside power source through a charger. It takes an alternating current supply from the power source and turns it into a form that can be used to charge the battery through a charging port. When the battery is being charged, it keeps a close eye on the battery's voltage, current, temperature, charge status and other important things like that. The car's DC/DC converter converts the high voltage direct current (DC) from the battery to low voltage direct current (DC) for the car's accessories to run on (DC). By controlling the flow of electricity from the traction battery, the power electronics controller makes sure the traction motor runs at the right speed and has the right torque. Regenerative braking is a must if you want to keep the car's strength and make it more energy efficient. Uses the mechanical energy from the engine to make electricity that can be sent back into the battery.

Hybrid and battery electric cars both use regenerative braking to help them go further. Regenerative braking is when the electric motor of a car can be used to move it forward while the brake is on. 15% of the energy needed to accelerate can be reused. Even though it's good, it can't fully charge the electric car. The drive system moves the car forward by transferring mechanical energy to the traction wheel. It doesn't matter what parts you use to make an electric car because it doesn't need a traditional gearbox. Some wheel-by-wheel systems use a lot of small motors to power each wheel. Differential housing and an electric motor can also be used to power the rear wheels, but this isn't the only way to go. The parts of a gasoline-powered car are more complicated and hard to understand than the parts of an electric car. Electric cars, on the other hand, won't be able to reach the same speeds as cars that run on gasoline.

If there is a large series of vehicles in operation, the provision of additional services from electric vehicles is a very viable option [40] As Kempton et al. [40] In 2001, due to power restrictions, only one electric vehicle was able to enter the power market or establish a business relationship with the power agency.

There are many reasons behind the installation of electric car chargers. First, in the current market situation, individual participation in small groups is prohibited. In addition, it allows for the simplest connection to the DSO in troubleshooting. The use of appropriate strategies can reduce the risk of traffic accidents.

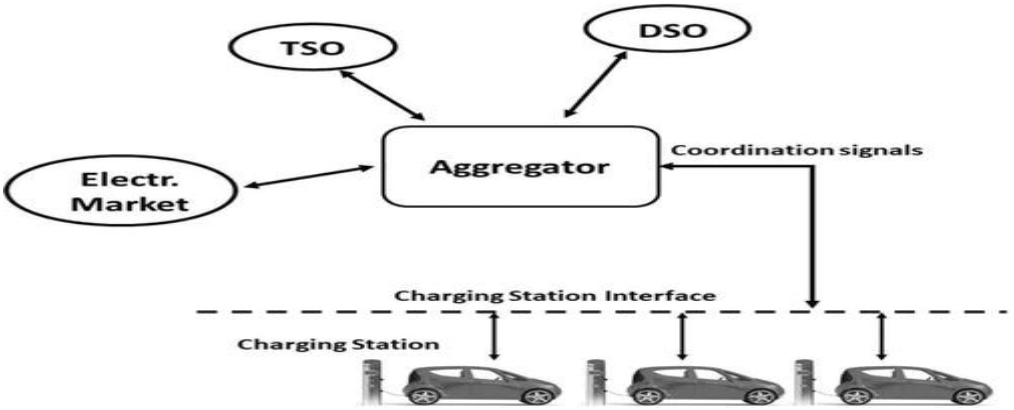

Figure 1. Simplified EV coordination framework: transmission system operator (TSO), distribution system operator (DSO), electric market, and charging stations for EVs.

With the increase in PV penetration of low-power power lines, EV load control can improve feeder performance and reduce investment requirements for infrastructure upgrades. In plates with such a high permeability, there is a constraint to keep in mind. The customer will evaluate the improvement in reliability, quality, and price. We expect a significant change in the quality of power in the near future, which aims to reduce the long-term changes in power growth that occur in the environment of decentralized RES production. In theory, we know that balancing car loads can promote a local balance between production and consumption, which can reduce power shortages and overheat.

4. Types of Electric Vehicles

People in China, the United Kingdom, the United States of America, and Germany still buy electric cars the most. Electric cars are becoming more popular all over the world. BEVs are a subset of HEVs and PHEVs. Hybrid electric vehicles (HEVs) are also a subset (BEV).

4.1 Hybrid electric vehicle

Internal combustion engines and electric motors make up the parts of a hybrid electric vehicle. The battery in this car is charged by the engine and the kinetic energy that is released when the car is going up and down. They are called "hybrids" because of the power converter that they use that combines a gas engine with an electric motor. Hybrid electric vehicles have become very popular around the world because they can run at full speed without needing to be charged. This is because they can run at full speed without needing to be charged.

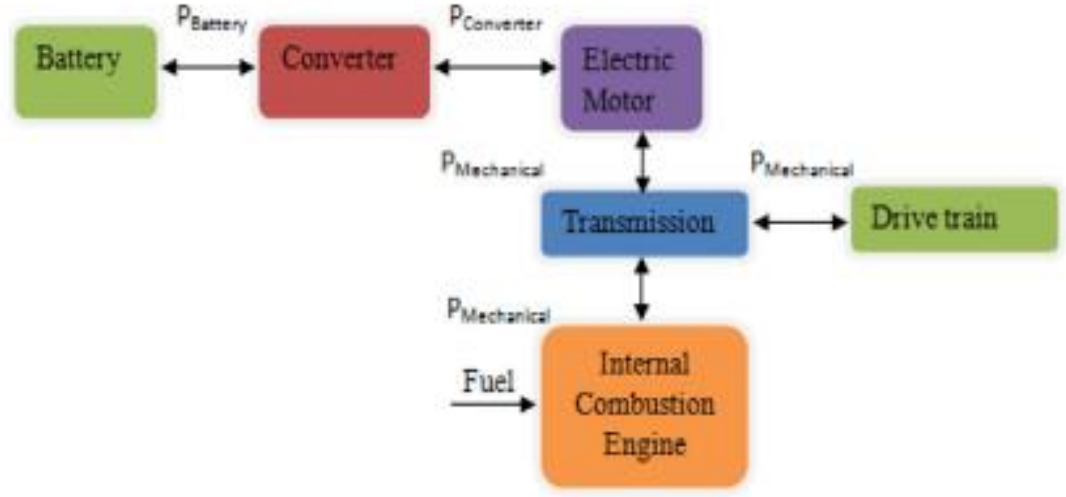

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Figure 2. Power flow of parallel HEV

By electrifying the drive train, they may also drastically reduce their fuel use. The HEV may be connected in a number of topologies, depend on the kind of hybrid system. In a series hybrid, the wheels are powered only by electricity. The motor is powered by the battery or the generator. Either the battery or the generator is used to power the motor. Battery power is supplied to the electric motor via an integrated circuit engine. Battery or engine/generator power is determined by a computer that monitors the amount of energy being generated. Both the engine/generator and regenerative braking are used to power the battery pack [24]. Smaller internal combustion engines are common in series HEVs, which have bigger batteries and larger motors. Using ultra-caps, which increase the battery's efficiency and hence cut down on waste, they may do this. When braking, they store the kinetic energy and release it during acceleration. The following are some of the benefits of a series hybrid drive train for them: Since the internal combustion engine and drive wheels are mechanically decoupled, it is possible for the IC engine to operate within a small range of performance that is optimized for torque and speed. In contrast, there are some disadvantages to using a series hybrid drive train. They are. It will be less efficient because the energy has to go from mechanical to electrical and then back again.

4.2 Plug-in hybrid electric vehicle

PHEVs have both a gasoline engine and an electric motor (PHEV). People who drive these cars use gas, but they have a big battery that can be charged with electricity. There are a lot of good things about plug-in hybrid electric cars: Reductions in the use of petroleum It is thought that PHEVs use 30 to 60% less oil than traditional cars do. A plug-in hybrid car reduces the country's dependence on oil because most of the electricity used in the United States comes from the country itself. Emissions of greenhouse gas It's common for PHEVs to emit less greenhouse gas than traditional cars. Some of the time, however, the amount of gas that is released depends on the process that is used to make electricity.

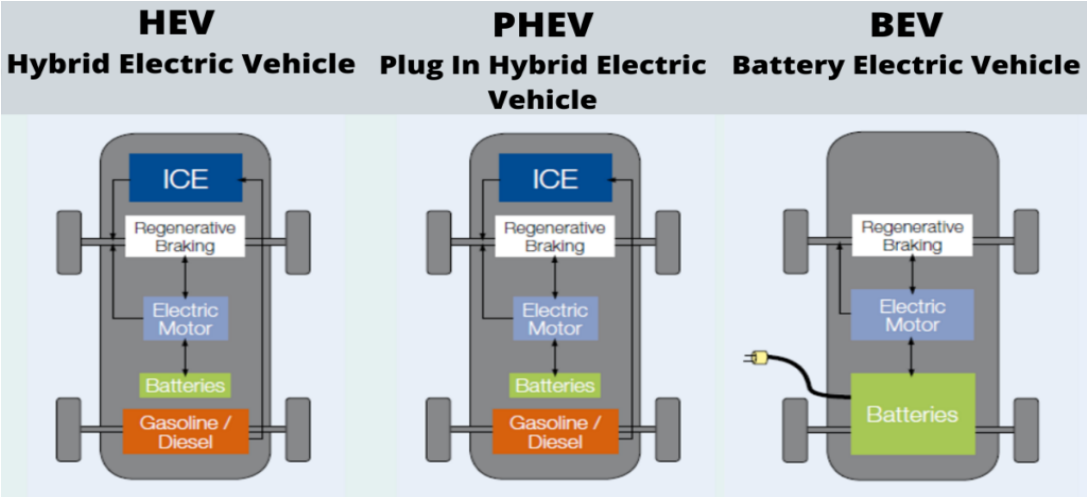

Figure 3. Classification of Electric vehicle[43]

India has a lot of electric vehicles. There are still very few electric cars (EVs) on the market in India. Sales of electric cars haven't changed in the last two years. They've stayed at 2000 units each year. Car sales are expected to grow at a rate of 28.12 percent every single year from 2020 to 2030. This means that all new cars will be electric by then. Even though the Reva (Mahindra) electric car was first shown off in 2001, only a small number of them have been sold so far. In 2010, Toyota made the Prius, and in 2013, they made the Camry, both of which are hybrid cars. Electric buses and hybrid cars are already being tested in a few places.

5. Discussion and Future Scope

The research has focused on the storage system and controlling system of the electrical vehicle. For this research study, a specifically a grid, rated battery, and Solar based energy have been selected as sources, and converters like boost converter, inverter and optimization algorithm have been simulated two different EV station designed with different SOC condition to regulated continuous charging supply to EV.

In this study, a meticulous approach was undertaken to tackle the challenges associated with EVs, particularly focusing on their storage systems and control mechanisms. The research specifically delved into the selection of a suitable battery with appropriate specifications, alongside the utilization of renewable energy sources. Additionally, converters such as boost converters and optimization algorithms were employed to create a robust charging infrastructure. The study further encompassed the simulation of two distinct EV stations, each designed with varying state of charge (SOC) conditions. This configuration aimed to ensure a consistent and uninterrupted supply of energy to EVs, ultimately promoting seamless and reliable charging experiences.

Whenever SOC is more than 90% the grid connected battery supply the power to EVs and less than 90% it will be charge through the grid.

In order to extract and transfer the maximum power from source to stack, the work's future scope will involve using improvement-based MPPT methodologies for PV, wind, and crossover power age frameworks. The project works well for long-term power generation, however force quality problems affect how the framework is presented as a whole. Voltage hang, voltage growth, and music drifters are the problems with power quality that

essentially lessen the benefits of solar and wind energy. Utilizing more potent electronics also alters energy yield through its impacts. Static compensators and UPQC series LC channels are two recommended options to handle power quality issues. DSTATCOM contributes to the heap's optimization, power factor improvement, and noise reduction. The purpose of STATCOM is security. To accurately provide an estimate of force for continuous energy, high-level methodologies should be employed to record data about the sun and wind. There exist multiple MPPT approaches for asset monitoring.

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