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IMPROVED PERFORMANCE AND FUNCTIONING OF ELECTRIC VEHICLE CHARGING STATION

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ABSTRACT

Battery-powered electric vehicles (BEVs) are a promising technology that can be utilized to replace internal combustion engine (ICE). The improvement of total charger effectiveness is critical for the growth and acceptance of vehicle technologies because as charging efficiency improves, charge time and electric prices decrease. Because of the limited space in cars and the growing need for power, chargers must provide substantially more power while keeping their size as small as possible. The front-end AC/DC converter, as a key component of a charging system, took part in reducing input current harmonics, power factor correction (PFC), output voltage regulation, improved efficiency, and higher power density. Many snubber circuits for the front-end AC/DC PFC converter of EV charging are explored and proposed in this paper. This work proposes a PFC known as a bridgeless single-ended primary inductor converter (SEPIC) PFC with fewer active and passive components and lower conduction loss. The new technology tends to keep the power factor constant. Aside from SEPIC PFC, achieving high efficiency and lowering harmonics also requires certain control logic. The Adaptive Neuro Fuzzy Interface System (ANFIS) control technique is used in this paper. This topology has received increasing attention among various control logics due to its rapid growth and accessibility. The presence of a switch also corrects the diode's reduced performance under varying operating conditions. Without a doubt, this unique technology can improve output voltage, meet load requirements, and bring the power factor closer to unity. A 120-volt input voltage is applied and simulated. The system's efficiency and power factor were experimentally validated in follow-up simulation research. This invention's new form of portable chargers may efficiently reduce reactive power in the power system while also developing more power.

Keywords: Internal Combustion Engine (ICE), Power Factor Correction (PFC), Bridgeless SEPIC converter, Efficiency, Harmonics, Adaptive Neuro Fuzzy Interface System (ANFIS)

I. INTRODUCTION

In the past few years, the investigation into PFC AC/DC power electronic converters has expanded [1]. Telecommunications equipment, rechargeable batteries, healthcare, machinery, and military operations, among others, require rectified power electronics converters. The charging is helped by the battery's unidirectional charge, which keeps the grid-to-vehicle flow in a single power mode. BEV is a fairly new platform that has been utilized to transform global transportation in a more environmentally friendly and cost-effective manner [2].

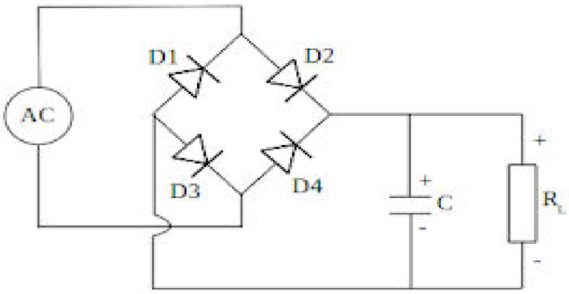

Fig.1: Generalised structure of the conventional full-bridge rectifier

To power electric vehicles, large battery packs with finite energy capacity are adopted, and they're recharged daily, frequently utilizing an AC/DC converter-based battery charger, as shown in Figure 1.

The electric vehicles already available are only tested as a load, and their batteries are still recharged using grid electricity [3]. To achieve power factor correction division, power semiconducting devices as well as a transformer is employed. The PFC step is utilized as a half-bridge converter when a grid line is available, similar to a typical boost PFC converter. The use of power in industry and domestic appliances is determined by the power factor present in it. The power factor is believed to be the most important, especially during power transfer. A power factor is a number that runs from 0 to 1. The power needs for electrical equipment should vary depending on the availability of power factors. Because the power factor is low, the appliances require excess power to compensate. It boosts the economy's rate. More than 0.85 is sufficient, and it reduce the need of additional power. Nonlinear loads use sinusoidal input voltage, but their impedance is not the same. It is constantly changing. Even though the input voltage is claimed to be sinusoidal, it affects the input current. The presence of harmonics and several other limitations are pointed out in this condition. It collides with the fundamental frequency, causing the current to fluctuate. This condition necessitated the use of power factor correction. The power factor alone can compensate for power outages. With a unity power factor, lossless power can be achieved. When compared to ICE vehicles, the number of BEVs will increase by 18% by 2030. Charging stations have recently become barriers to the growth of BEVs. When BEVs are linked to charging stations, the power quality suffers and fails to meet IEEE standards [4].

In the following figure 2, the generalized structure of plugin charging is presented.

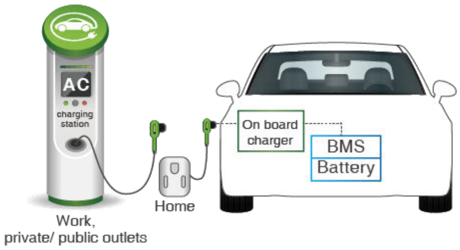

Fig.2: Mode of plugin charging

The major goal of this research is to employ a front-end AC/DC PFC converter to convert grid AC electricity into DC voltage to charge an electric vehicle battery. A diode rectifier with a PFC circuit makes up a unidirectional AC/DC converter. This type of AC/DC converter only allows electricity to flow from the grid to the electric vehicle charger. If the EV battery is intended to release power into the grid for a vehicle-to-grid operation, however, the bidirectional type AC/DC converter or the inverter will be used. Because higher switching frequencies are related to switching losses, they aren't used in power converters. This particular endeavour helps to use greater switching frequency for the AC/DC PFC power converter of EVs with small switching losses by employing ZVS and ZCS soft switching techniques. Soft switching of AC/DC converters decreases switching losses, switches strains, and so enhances the efficiency of a battery-powered vehicle system. To improve the performance and reliability of AC/DC PFC converters, soft switching approaches are used in conjunction with specific snubber circuits [5, 6].When a typical AC/DC converter is used to charge an EV battery, it draws a peak current from the source, causing the entire power profile and indices to deteriorate [7]. PSCAD, a component of power system analysis software, was used in the modelling of an EV charger using Boost-APFC [8]. A three-phase PWM rectifier is used as the input section, and a phase-shift full-bridge converter is used as the output module. Fast-charging units commonly use this DC fast charger [9]. The three-phase PWM rectifier overcomes the limitations of conventional rectifiers, including poor power factor and high harmonics, while also delivering greater wattage than even a three-phase one-switch or two-switch power factor correction circuit. The phase-shift full-bridge converter is indeed a power-handling segregated high-frequency DC-DC converter [9, 10].

The generalized structure of the SEPIC converter for performing DC/DC conversion is represented in figure 3.

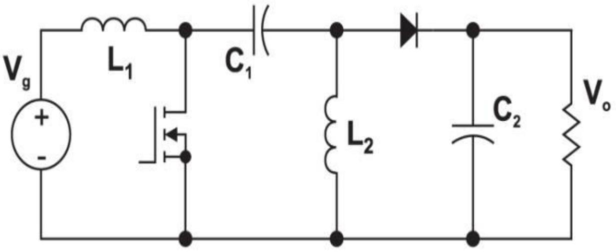

Fig.3: Circuit topology of SEPIC Converter

There appears to be a category of single-phase hybrid SEPIC PFC rectifiers featuring reduced voltage stress on semiconductors and/or higher static earnings that would merely be augmented with a greater number of switched-capacitor cells. As a result, these rectifiers could be used in scenarios where a greater output voltage is required. The input current of the converter is generally excellent in power factor and minimal in actual harmonic distortion. A three-state switch is used in the structure, including three distinct methods [11, 12], two of which are bridgeless types, which potentially increase efficiency.

The capacitor was dealt with by the passive PFC to rectify the power factor. This approach is unsuitable for power factor correction because of its bulky capacitors, wide range of voltage regulation capability, and other drawbacks. According to reports, the whole cost is substantial. Passive power factor adjustment has been less used in power correction. Semiconducting switches are involved in active power factor control. It takes the place of diodes. The diode rectifies the voltage, but the output voltage is not yet sinusoidal. This move may put the appliances involved in jeopardy. As a result, a capacitor is required to fix the problem. Switches are used to tackle this problem instead of diodes. It merely requires some control logic. Because the switches are controllable, and their controllability is linked to the pulse that is provided to them. As a result, proceed to active power factor correction. The number of diodes in traditional methods is shortened by switches in our proposed solution. Within it has grown the bridgeless SEPIC power factor correction rectifier. Bridgeless diodes minimize (or replace) the need for additional diodes. With high power factor correction, the bridgeless SEPIC can boost voltage. The ANFIS controller analyses the outcome from a bridgeless SEPIC PFC and feeds it back to generate a pulse based on the output availability.

Section II dealt with differentiating various types of electric vehicles and all the ways to charge the batteries present in them. The proposed methodology and representing the effectiveness of the proposed system over the conventional method are noted in section III. The flow analysis and operating modes are explained well in section IV. Section V regards simulation work and the result obtained from it, which is explained graphically. Overall system efficiency and its importance in the future are concluded in section VI.

II. ELECTRIC VEHICLE TYPES AND THEIR MODE OF CHARGING

Electric drives are an important resource for manufacturing electric vehicles, and this part also discusses the propulsion requirements. The following is a list of electric vehicle classifications and charging types:

A. TYPES OF ELECTRIC VEHICLES

(i) Battery Electric Vehicles (BEV)

BEVs have a high-capacity battery that can last for a long time with no gasoline engine [13]. It's also powered by an external source. It is non-polluting and does not hurt the environment

(ii)Plug-in Hybrid Electric Vehicle (PHEV)

PHEVs, or Plug-in Hybrid Electric Vehicles, have a battery that is charged via regenerative braking and plug-in charging. These run for around 10 to 40 miles until the gasoline kicks in.

(iii) Hybrid Electric Vehicles (HEV)

HEVs have a gasoline engine and a battery-charging system known as regenerative braking. During retardation, electric energy is generated in the regenerative system. The need for charging between those two computers is defined by an interpersonal computer.

B.TYPES OF CHARGERS

Charging an EV at home is the most convenient option if you can somehow spot an electrical socket or develop a new connection near your parking. The recharging cable is being wired or inserted into a pre-existing socket on the other end. To charge at home, use a 120-volt outlet or a 240-volt circuit (like an electric clothes dryer uses). This is perhaps the most expensive yet handy option, considering practically all EVs come with a 120-volt charging cord and 120-volt sockets are generally common. Using a 240-volt socket or circuit involves the deployment of a home charging unit, along with possible electrical network upgrades. Using a higher voltage charger, on the other hand, allows for significantly faster charging, with speeds ranging from 2 to 8 times faster depending on wattage and vehicle. The method of battery charging by the utility has three parts. The following are the details:

(i) Level 1

The voltage for Level 1 electric vehicle charging is 120 volts. Every electric car comes with the necessary hardware, which consists of a cord with an attached control box. Simply plug it into a three-principle (grounded) wall outlet. Depending on the capacity of the vehicle's batteries, this charging method takes 16 to 20 hours to fully charge them. The benefit of this charging method is that it does not necessitate the addition of any additional hardware. To use the charging cable, simply park near a three-pin wall outlet and plug it in. The disadvantage of this method is that it takes a long time to charge the batteries.

(ii) Level 2

240 volts is the standard for Level 2 charging for electric vehicles. This form of charging necessitates the use of additional hardware. When a customer buys an electric vehicle, some manufacturers will install an AC wall-box charger at their home and, in some cases, at their workplace, either for free or at a reduced cost, to enable level 2 charging. An electric vehicle can be fully charged in as little as 6 hours or a little more with this method, depending on the battery capacity. In comparison to level 1 charging, level 2 charging is much faster. Not only that, but it's also supposed to be more energy-efficient. However, because more sophisticated circuitry is used, this charging method is more expensive.

(iii) Level 3

At public charging stations, level 3 charging for electric vehicles is available. It converts AC into DC for direct storage in electric vehicle batteries and is known as DC fast charging. Normally, it is rated at 480 volts. An electric vehicle can be charged to 80% capacity in less than an hour using a DC fast charger. Within half an hour, Tesla superchargers can reach the same charging capacity. The necessary hardware is quite costly and can usually be found at public charging stations. It is necessary to pay a fee to the service provider to use them.

III. METHODOLOGY

A modified structure of the SEPIC PFC converter with fewer components, lower conduction losses, and a high power factor is shown in this project. The proposed framework accepts power from the AC mains and converts it to DC. Numerous current control strategies can be used to provide a low-distortion sinusoidal input current waveform. Bridgeless converters, which do away with bridge diodes, have recently been popular in the quest for a high-efficiency AC/DC power supply. ANFIS controller approach is employed. Without operating at an excessive duty cycle, a voltage gain can be increased. This makes use of the sinusoidal input voltage to produce a clean dc voltage with no degradation. Overall efficiency and power density are high with the suggested bridgeless rectifier architecture arrangement. Conduction losses are decreased in bridgeless converters because the number of concurrently conducting components on the input current route is reduced. Finally, the dc load receives lossless DC power. The customized topology stabilizes and removes the harmonics.

IV. CIRCUIT CONFIGURATION

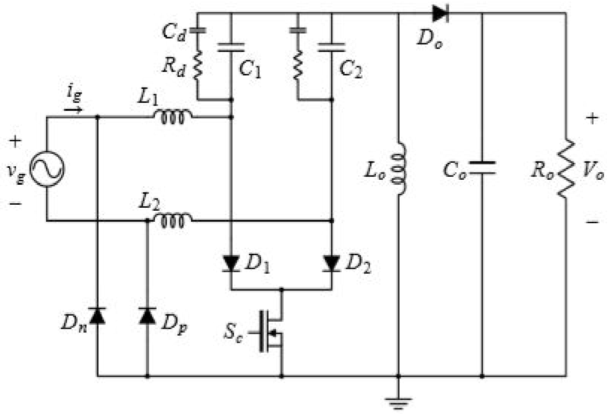

Fig.4: Proposed circuit topology

The circuit configuration of the proposed study is expressed in figure 4. It uses a capacitor and a switch to replace diodes. The switching combination responds to both positive and negative cycles, and the capacitor works as a filter. The process of power rectification is demonstrated in four different ways.

Mode 1:

V_S energies in path 1 are L1 through D_3, switch, and D_2, respectively. C_1 uses the energy stored in L0 in the second path. C_1, C_2, and L_2 are fully activated in the third path. Aside from that, C_1 charges with C_2 discharge. The charge from C_0 in the final step advances further charging.

Mode 2:

When the switch is switched off, D_0 conducts, while D_1, D_2, and D_3 are reverse biased. The filters transfer their energy to the load side (i.e.,) L_1, L_2, C_1, C_2, L_0, C_0 to a battery. The load receives a pure dc output voltage with a greater power factor.

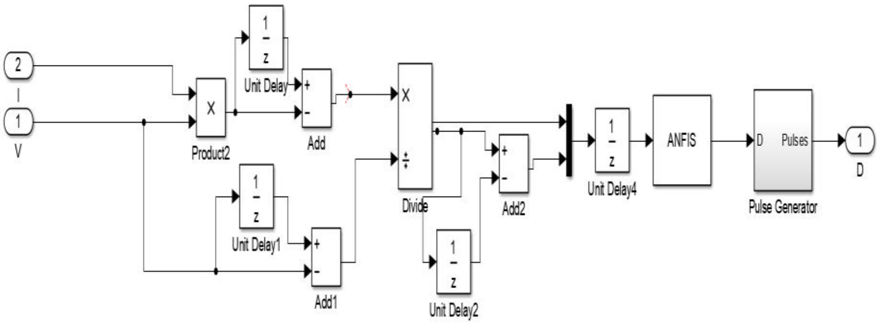

Fig.5: Structure of ANFIS controller

The Simulink arrangement to represent the ANFIS controller is visualized in Figure 5. It operates by tuning the already available rule base by collecting sets of training data [14]. Fuzzification, highly inter-combined functional elements and information, and defuzzification are used by the ANFIS controller to obtain the desired crisp output from the crisp input. With the help of a neural network, the system should be able to classify data and find patterns. The developed fuzzy system produces errors at a lesser proportion than the neural network. The training dataset is composed of a range of input variables and their matching needed desired range of output values for each output variable. The membership function along with training data can make the system reach essential output at any disturbance or variation in load [15]. Also, it is much better than multi-layer perception.

V. RESULT AND DISCUSSION

The Bridgeless SEPIC power factor correction rectifier interface with the ANFIS control technology was the subject of the simulation investigation. This section determines whether or not the performance and output voltage are affected by harmonics. The power factor correction rectifier receives a 120-volt, 50-amp input voltage with no ripple.

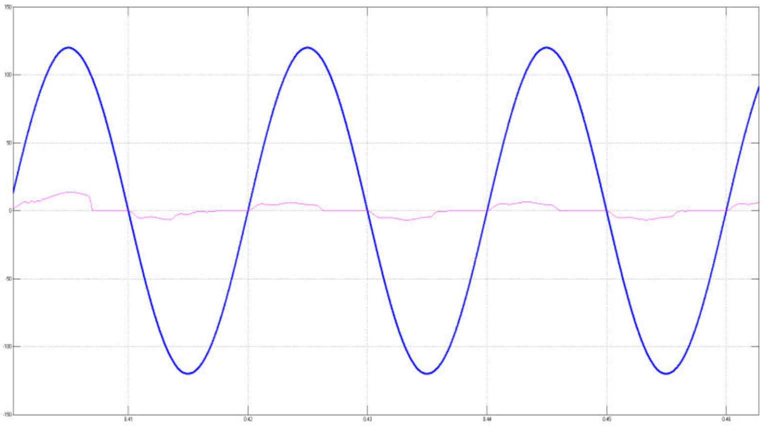

Fig.6: AC supply

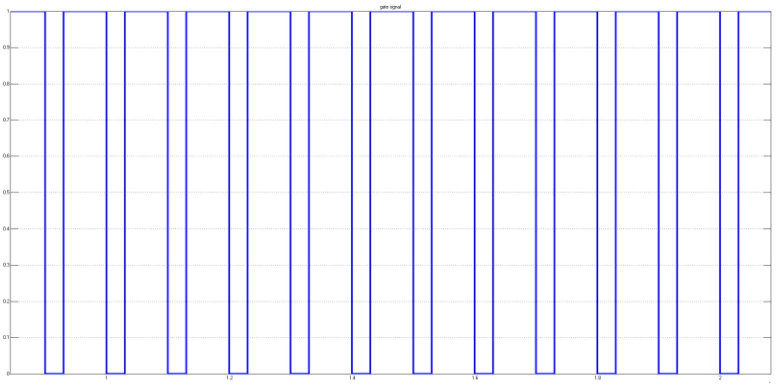

Fig.7: Gate pulse driven towards switches

The quantity of pulses provided to a bridgeless SEPIC PFC created using an ANFIS controller is seen in the graph above. Normally, the duty cycle is between 0 and 1.

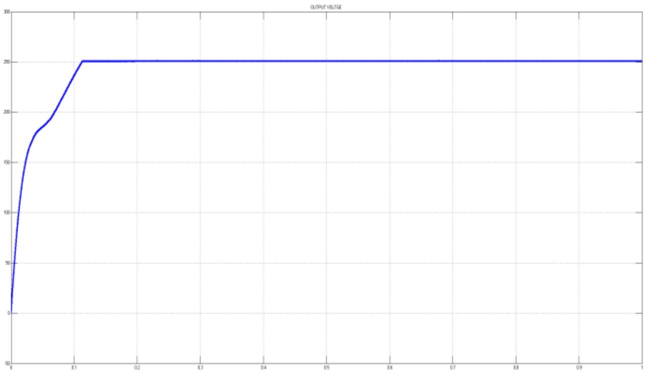

Fig.8: Outlet of charger

The dc voltage gain of proposed framework is presented in Figure 8. Not only does the rectifier improve the power factor, but it also increases the gain. A 120 volt AC input voltage is transformed to a 250 volt DC output voltage. With the ANFIS controller, the switching action responds well. The most powerful factor is usually unity.

The power factor is crucial in determining the network's efficiency and power usage. If the power factor rises, there is no need to inject additional voltage to meet the demand. Alternatively, it may require additional supply voltage. As a result of the foregoing facts, a higher power factor rate approaching 0.9 has developed, as shown in figure 9.

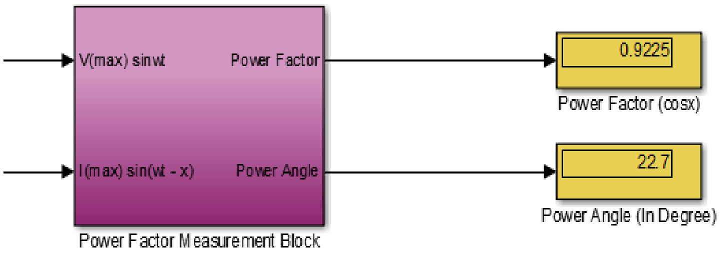

Fig.9: Improved power factor

VI. CONCLUSION

The experimental analysis is carried out and its results are depicted through Simulink software. A 120-volt, 50-amp input voltage is transformed to a 250-volt DC supply with no ripple. That's why, rather than using alternative PFC rectifiers, we use bridgeless SEPIC power factor correction rectifiers. Furthermore, when compared to other rectifiers, it saves money and prevents excessive power insertion as power factor correction becomes more complex. This approach has the ability to meet the current and future needs of electric vehicles. In comparison to traditional mode charging, this converter minimizes switching stress, heat, and conduction loss. With lossless power transmission, this practise may grow in the future. As a result, research into varied control logic that undergoes modifications in a power factor correction rectifier becomes possible and improves power transmission quality in critical situations. Due to its specifications and ease of installation, this will get more notice in the future.

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