INTEGRATION OF MULTIPLE ENERGY SOURCES IN A GRID-TIED CHARGING STATION WITH INTELLIGENT FEEDBACK CONTROL FOR LINEAR AND NON-LINEAR LOADS

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Abstract

The development of electric vehicles (EVs) has led to an increased need for charging stations that are not only efficient but also environmentally friendly. One approach is to use renewable energy sources such as solar or wind power to charge EVs. However, these sources can be intermittent, and there is a need for efficient and reliable power management systems that can integrate multiple sources of power to charge EVs. This project aims to address the challenges of integrating multiple sources of power for charging EVs while ensuring high power quality with reduced harmonic distortion This aims to develop a system that combines multiple power sources using a novel four-leg inverter and feed them into the grid with both linear and non-linear loads. AC supply that acts as a charging station for electric vehicles and it is given to a PFC converter that is controlled by a PI controller. Another input source battery converter is also fed into the system. The multiple power sources are then combined using a four-leg inverter that is controlled by an ANN based feedback line controller with DQ theory transformation. The system ensures that the power fed into the grid is of high quality with reduced harmonic distortion. This project has potential applications in industrial, commercial, and residential power systems where multiple power sources are required to be integrated into the grid. The entire work for enhancing charging capacity of the EV through improved MS is carried out in MATLAB 2021 and simulation responses are obtained.

***Key Words*: Artificial Neural Network, PI controller, Electric Vehicles.**

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1. INTRODUCTION

The charging protocol (how much voltage or current for how long, and what to do when charging is complete, for instance) depends on the size and type of the battery being charged. Some battery types have high tolerance for overcharging (i.e., continued charging after the battery has been fully charged) and can be recharged by connection to a constant voltage source or a constant current source, depending on battery type. Simple chargers of this type must be manually disconnected at the end of the charge cycle, and some battery types absolutely require, or may use a timer, to cut off charging current at some fixed time, approximately when charging is complete. Other batter types cannot withstand over-charging, being damaged (reduced capacity, reduced lifetime), over heating or even exploding. The charger may have temperature or voltage sensing circuits and a microprocessor controller to safely adjust the charging current and voltage, determine the cut off at the end of charge. A trickle charger provides a relatively small amount of current, only enough to counteract self-discharge of a battery that is idle for a long time. Some battery types cannot tolerate trickle charging of any kind; attempts to do so may result in damage. Lithium ion battery cells use a chemistry system which does not permit indefinite trickle charging. Slow battery chargers may take several hours to complete a charge.

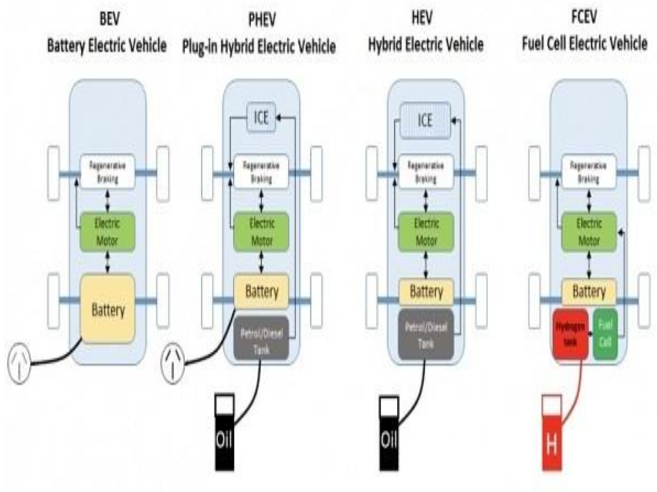

Fig. 1 - Electric Vehicle Architecture

High-rate chargers may restore most capacity much faster, but high rate chargers can be more than some battery types can tolerate. Such batteries require active monitoring of the battery to protect it from overcharging. Electric vehicles ideally need high-rate chargers. For public access, installation of such chargers and the distribution support for them is an issue in the propose adoption of electric cars. A good battery charger provides the base for batteries that are durable and perform well. In a price-sensitive market, chargers often receive low priority and get the "afterthought" status. Battery and charger must go together like a horse and carriage. Prudent planning gives the power source top priority by placing it at the beginning of the project rather than after the hardware is completed, as is a common practice. Engineers are often unaware of the complexity involving the power source, especially when charging under adverse conditions. In a conventional fuel-based powertrain, the wheels are driven by an ICE and the electrical accessories are powered by a low voltage (LV) 12V battery. The control is moderately simple since the mechanical, thermal, and electrical systems have limited interactions between each other. On the other hand, EVs reduce the exhaust emissions and the fuel consumption by using energy storage systems either in combination with the ICE or by themselves to propel the vehicle. Several architectures are currently implemented in commercialized EVs and their performance differ regarding the strategy of the OEMs. They can be sorted in three groups based on their degree of electrification, namely Micro and Mild HEV, HEVs and PHEVs, and AEVs.

2. EV CHARGING POWER CONVERSION

Typically, the use of off-board chargers may reduce the total cost and the size of the vehicle. More recently, AC grids has been utilized to power EVs with embedded chargers. The fast charger as an on-board option for an EV is hampered by the cost of the electronic components required for energy conversion, which increases the overall cost of EVs. However, on-board chargers cannot provide fast EV charging because of the power electronics high costs associated with the EV and the necessity to increase the capacity of the charger in the vehicle. To ensure fast EV charging, off-board chargers providing high DC power are used. It is noteworthy that, for off-board chargers, every AC/DC power conversion is performed through an independent inverter. Therefore, it is essential to raise the power of the converters to guarantee the vehicle fast charging. The findings obtained by numerous published studies have been implemented on EV charging stations to design and develop efficient and reliable EV charging systems. Accordingly, it is relevant to study the concept of a public facility installed with high-power off-board chargers functioning as a charging station. Such a station can provide EVs with the same functionality as a fuel station by supplying the EV batteries with direct current and allow rapid recharging. As for the charging station architecture relying on grid connection, only two options (AC and DC) can be considered. In the first architecture, the secondary side of the step-down transformer is used as a common AC bus where each load is connected to the bus via independent AC/DC stages. In the second architecture, a single AC/DC stage is configured to provide a common DC bus service for the system load. The common AC bus is one of the options suggested to design a charging station, as demonstrated in Figure 1.3 (a, b). In this structure, each charging unit has a separate stage rectifier linked to a common AC coupling point on the secondary side of the transformer. In Figure 1.3 a, a number of charging units have independent rectifiers; a low operating power factor can generate undesirable harmonic impacts on the power grid. It is important to note that the use of renewable systems (such as PV or ESS), which produce direct current electricity, also requires a DC/AC level; this increases the use of conversion levels in the grid. A single AC/DC stage with high power levels is employed as a second option architecture for EV charging, as illustrated in Figure 4.8 b. The DC bus powers several charging units and provides a more flexible structure with the ability to integrate RES and energy storage devices; actually, these systems are mainly DC sources. The charging station based on the DC bus requires fewer energy conversion steps compared to a charging system based on the AC bus.

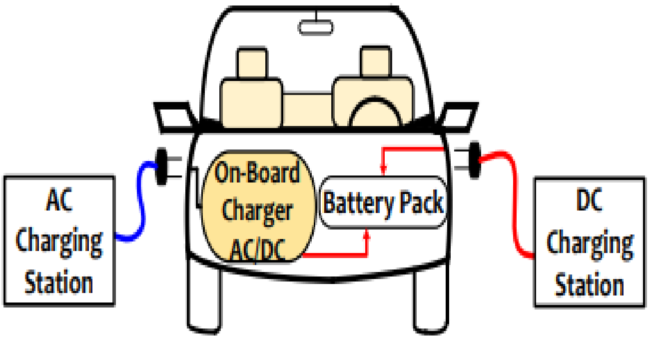

Fig. 2 - On-board and off-board of EV chargers

3. SYSTEM DESIGN

Batteries are widely used energy storage devices (ESDs) in photovoltaic (PV) systems, hybrid electric vehicles (HEVs), DC microgrids, and domestic electronics applications the load that extracts pulsating current from the batteries has small average power. A battery capacity is normally measured by the predicted average power consumption of a typical electronic appliance. A pulsed load (PL) with a peak greater than the projected average value causes a current/ voltage ripple that rapidly discharges the battery. Battery lifetime is specified in charge/discharge cycles PL increases these cycles per day which eventually decreases the battery lifetime. Therefore, the PL needs a higher power rating of the battery than the designated rating In addition, low power density and thermal runaway due to internal heat generation in high current discharge conditions are major challenges.

3.1 Exiting Work

The benefits in hybrid mode can be maximized by operating short-time high power pulses through UCs due to their high power density and a nearly constant but long-run load by batteries due to their high energy density. A hybrid energy storage system (HESS) to enhance battery life is presented for plug-in HEVs in and a wind-solar hybrid energy system in Different control strategies of HESS for EVs which uses a semi-active hybrid topology in the study. A home energy management system (HEMS) with different load outlines is presented in without considering the effect of load on battery life. Adaptive passive control of a hybrid power source is proposed in to regulate the voltage across the load under varying temperatures and load conditions.

The battery provides power to the connected load only when the voltage across UC's terminal drops below the voltage across the battery's terminal but the output voltage is not constant. A supervisory energy management controller is proposed to enhance the energy management control strategy for a UC-battery HESS configuration. It prolongs the battery service life in comparison to the battery-alone system. A semi-active battery-UC hybrid system extracts almost average current from the battery despite a PL. However, lower limits on UC voltage and state of charge (SoC) of the battery are not considered which results in complete discharge of ESD. A model predictive control of a battery-UC HESS is experimentally verified by allocating the fast load current variation to the UC and slow current changes to the battery.

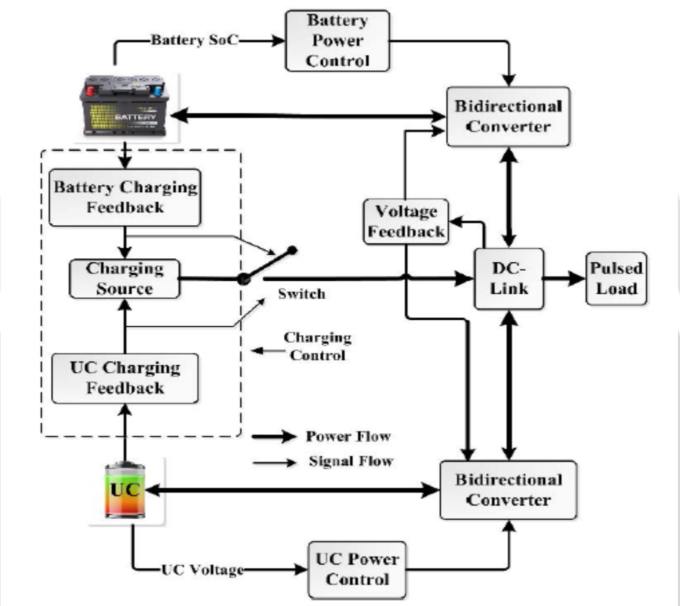

Fig. 3 - Existing block diagram

In this existing system is a combination of a battery system and an array of ultra-capacitors. Both ESDs are connected to a DC-link capacitor through their respective bi-directional DC-DC converters. If the load needs to be powered, the HESS provides the required power to the attached load otherwise ESDs get charged via a control. The main Objective of this system is to analyse the effect of PL on battery life and to analyze the performance of a battery-UC hybrid system for technical and economic limitations/benefits. Output voltage stabilization and energy distribution management are difficult when the UC is directly linked to the battery. To provide UC's voltage a wide range to vary, an active hybrid topology that parallels the output of two Bidirectional DC-DC converters to a common DC-link is used in the system. The battery current is lowered to a minimum to improve the discharge persistence of the battery current. A MATLAB/Simulink model is developed that runs the pulsed part of the load through UCs and the constant part of the load via the battery by controlling the UC's voltage and Battery SoC and UC voltage are monitored by their respective control programs in MATLAB. The program compares the SoC of the battery with its reference SoC and UC voltage with its reference voltage. The program compels the system to work within the pre-set SoC and UC voltage reference limits. The power supplied by the battery is limited within the constant range, so the battery delivers power within that limit while UC handles the remaining pulse load

3.2 Proposed Work

Power generation using renewable resources such as wind and solar energies has been increasing due to the continuous growth of energy demand and the destructive effect of fossil fuels to the planet. Due to the intermittency nature of renewable resources in supplying continuous power, supplemental power such as batteries or fuel cells are required. Often when one of the input sources is a photovoltaic cell, for supplying the load continuously, another input is a fuel cell stack. In this situation, a structure, which gets two or more DC sources as the inputs to make an output, is required. Since AC loads have the highest demand, the structure produces AC voltage (or current) at the output. The terminal voltage of renewable energy sources varies and is inherently too small. Therefore, to increase and control the output voltage, the use of voltage converters as interface between the sources and the consumer (or grid) is unavoidable a multi-port structure is presented which contains two independent dc inputs and one three phase output. This structure only uses one extra switch. The design Of this structure is based on the classic impedance source inverter. Therefore, this converter is a voltage booster. The converter is made from two classic impedance source inverters which connect to each other via some passive and active elements. These two impedance circuits can work with two different switching frequencies, simultaneously. The converter uses two high frequency three-winding transformers. The connections in this converter is such that the leakage inductances of the transformers do not cause problems such as voltage spike on the semiconductors.

In addition, SOC is strongly helpful for forecasting the driving range and charging mode selection of EVs. In Electric Vehicle (EV) applications, due to harsh operating conditions, it is difficult to get an accurate SOC directly from the measured voltage and current. The need for a good fuel utilization and further preventing of greenhouse gas emissions, is shifting automotive industry to electrified vehicles and, thus, electric vehicle (EV) has come into existence to stabilize the transport sector to a greener side. The recent and upcoming vehicle technology comprises an energy storage known as BES (Battery Energy Storage), which charging incorporates certain power electronic interfacing circuit as illustrated. Due to strict rules on emissions, fuel economy, limited energy supplies, and difficulties with global warming, electric mobility has a significant impact on the development of sustainable and efficient alternatives in the transportation sector. The development of electric vehicles (EVs), which have many advantages including reduced fossil fuel consumption, zero emissions, and increased performance, has hastened this. Typically, conventional EV battery chargers acquire power from an AC source through the filtered output of a diode bridge rectifier (DBR). Because of their capacity to interface using electric uses, diode bridge rectifiers are widely used as front-end power converters. Nonlinear properties cause severely distorted current to be pulled from AC mains, increasing system losses. Harmonics reduce product lifespan by overheating, pulsating, and lowering motor and generator torque, as well as by raising the temperature and voltage demands on capacitors. As a result, the electric power system's harmonic content must be decreased. Furthermore, for dc loads, a minimal amount of ripple in the dc output is necessary for proper operation. Therefore, it is crucial to increase the power quality of AC-DC converters.

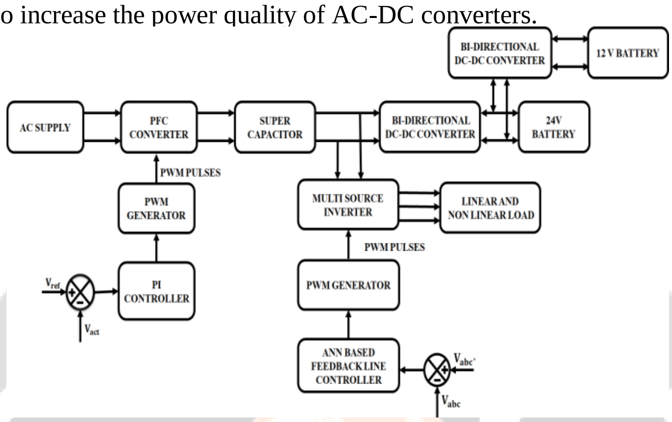

Fig. – 4 The proposed Block Diagram

In this Proposed system aimed at developing a charging station for electric vehicles (EVs) using AC supply. The station consists of a PFC (Power Factor Correction) SEPIC converter that is controlled by a PI controller. The PFC converter stores the energy in a super capacitor, and other battery converters from the EVs are also fed into it. The AC supply is provided to the PFC converter, which ensures that the power factor of the system is improved. The energy from the AC supply is then stored in a super capacitor through the PFC converter. The battery converters from the EVs are also connected to the super capacitor, and their energy is stored in it as well. The multiple energy sources, including the super capacitor and battery converters, are combined using a four-leg inverter, which is then fed into the grid. The feedback line controller with ANN and DQ theory ensures that the inverter output voltage and frequency are synchronized with the grid, and any deviations are corrected in real-time. The combined energy from the super capacitor and battery converters is then used to charge the EVs. Overall, the project aims to develop a charging station that utilizes multiple energy sources and ensures efficient and synchronized power transfer to and from the grid.

4. SIMULATION DIAGRAM

The simulation results are examined using a software MATLAB/SIMULINK. The MATLAB is a high performance language for technical computing integrates computation, visualization and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. MATLAB serves as a best tool for signal analysis. Open the Simulink library browser. We need MATLAB running before open the Simulink browser. Start MATLAB, and then in the MATLAB command window, enter Simulink the Simulink library opens. From the Simulink library browser menu, select file> new > model. Simulation and experimental results of the proposed configuration are presented in this section. The simulation analysis has been performed through MAT Lab/Simulink for control purposes, while PLECS were used for modelling the modulation stage, power converter, grid voltage and PV strings. The analysis was completed by using the same scenarios of the experimental set-up just to improve the concept verification. It is important to highlight that simulation parameters have been selected according to the reduced power experimental prototype. MATLAB is the high-level language and interactive environment used by millions of engineers and scientists worldwide. It lets visualize ideas disciplines including signals and image processing, communications, control systems, and computational finance. In SIMULINK, it is very straight forward to represent and then simulate a mathematical model representing a physical system. Models are represented graphically in SIMULINK as block diagrams. A wide array of blocks are available to the user in provided libraries for representing various phenomena and models in a range of formats. One of the primary advantages of employing SIMULINK (and simulation in general) for the analysis of dynamic systems is that it allows us to quickly analyse the response of complicated systems that may be prohibitively difficult to analyse analytically. SIMULINK is able to numerically approximate the solutions to mathematical models that we are unable to, or don't wish to, solve "by hand.

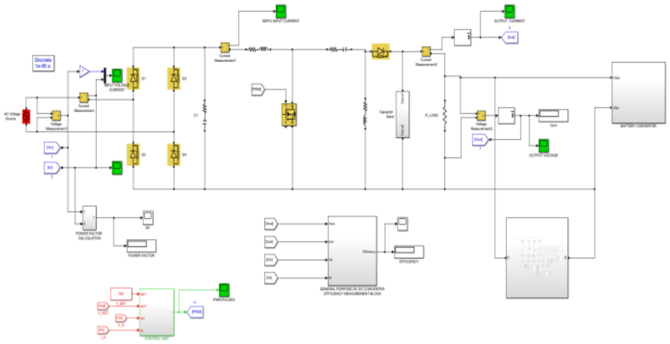

Fig. 5 - Simulation Diagram

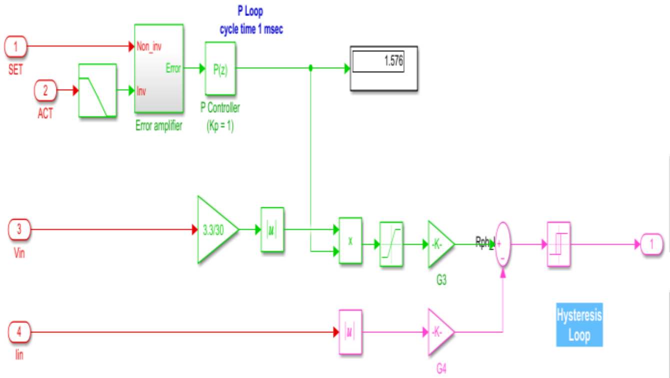

Fig. 6 - Simulation Diagram for control unit

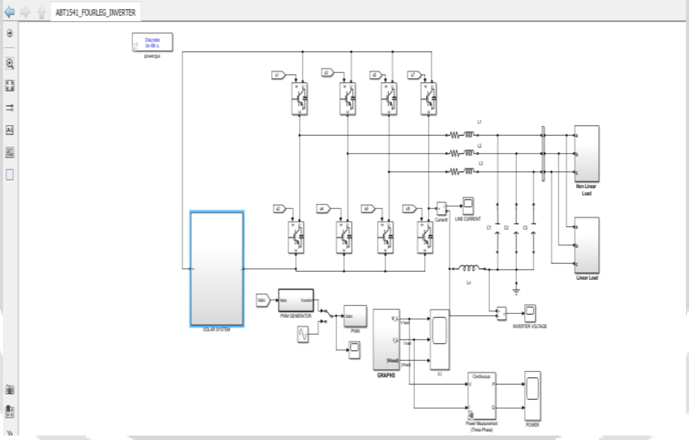

Fig. 7 - Simulation Diagram for 3 phase F-Leg inverter

5. RESULT AND DISCUSSION

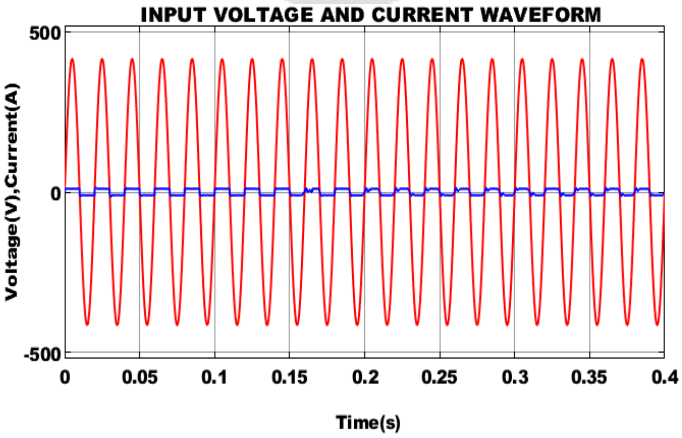

Fig. 8 - Source voltage and source current in phase waveform

The voltage and current waveforms of AC source. Both waveforms are sinusoidal in nature. The range of voltage is fixed from +400V to - 400V.

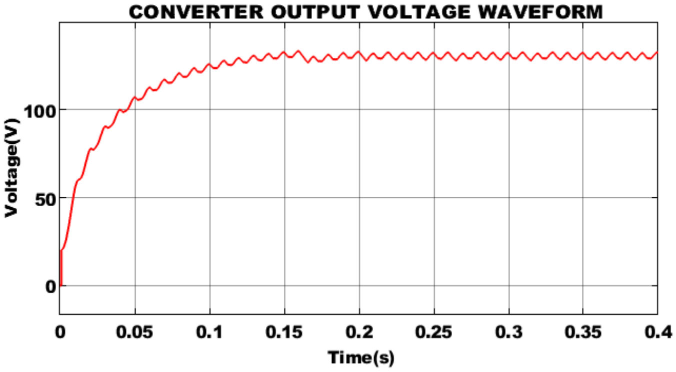

Fig. 9 - Converter output voltage waveform

The power factor correction converter which attains an output voltage of 120v which is given to multi source inverter.

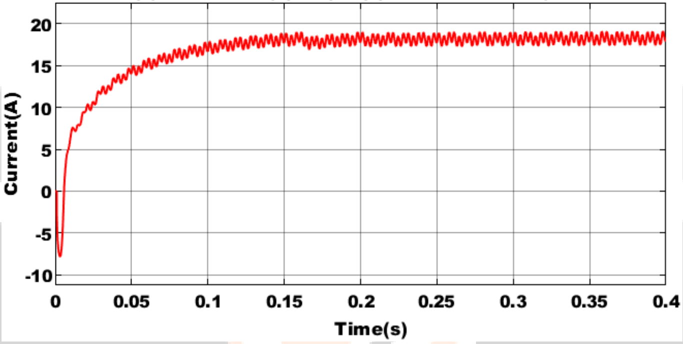

Fig. 10 - Converter output current waveform

The power factor correction converter which attains an output current of 18A which is given to multi source inverter.

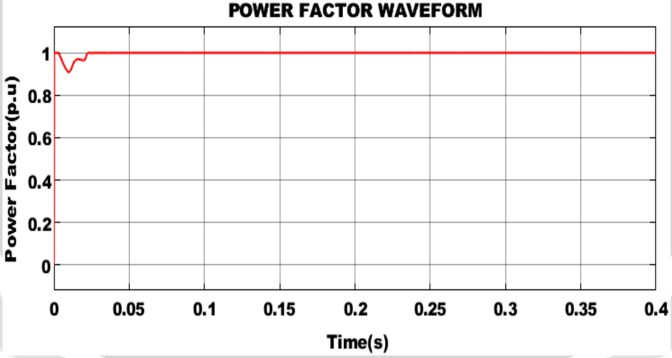

Fig. 11 - Power factor waveform

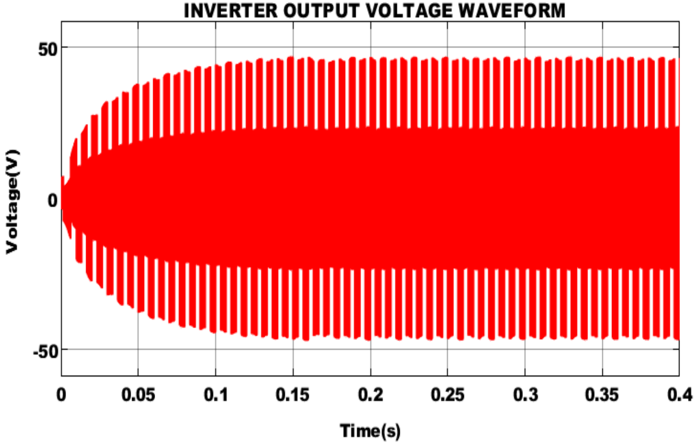

Fig. 12 - Inverter output voltage waveform

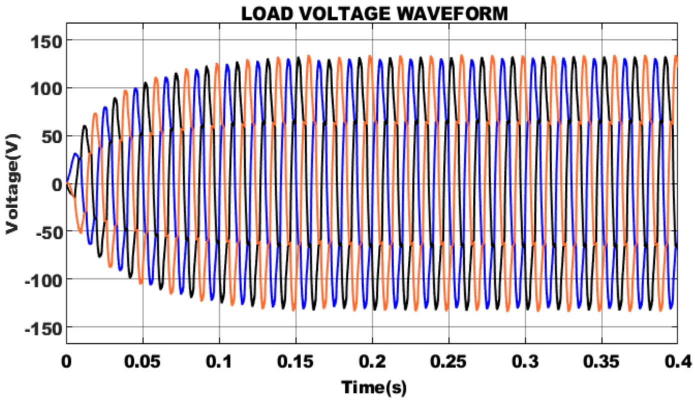

Fig. 13 - Load Voltage Waveform

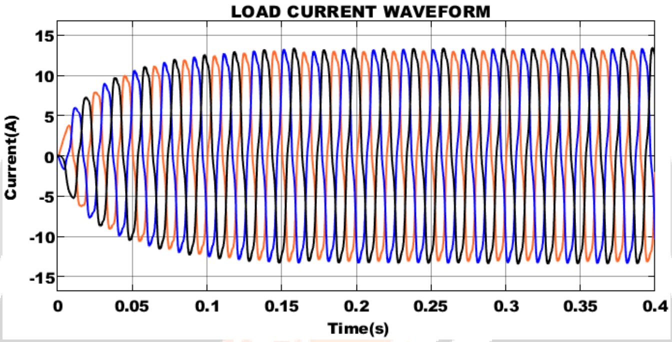

Fig. 14 - Load Current Waveform

The load voltage and current waveforms are depicted. Both the load voltage and current are stable and steady without being affected by any variations which are implemented by controller technique. The voltage and current magnitude of 120V and 13A is observed.

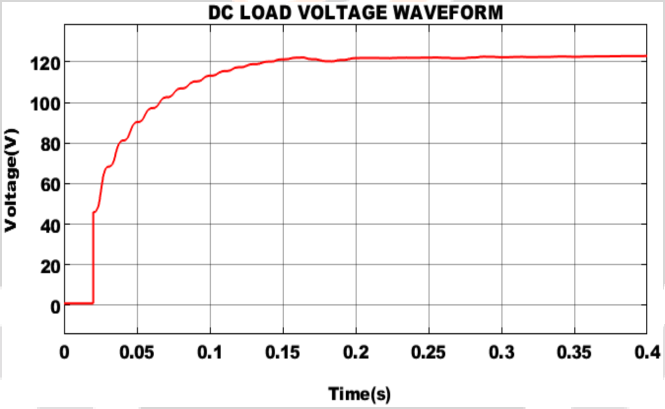

Fig. 15 - DC load voltage waveform

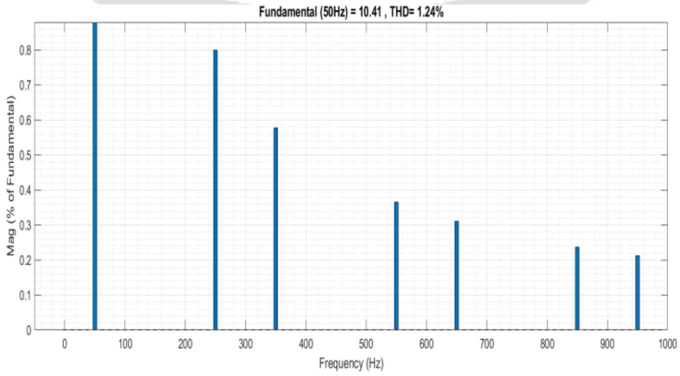

Fig. 16 - THD

The grid current THD obtained by the proposed work is 1.24%, as can be seen from the graph

5. CONCLUSIONS

In conclusion, the project presents a robust solution for efficient and reliable charging of electric vehicles using renewable energy sources. The use of a PFC converter, ANN controller, super capacitor, and multiple sources such as AC supply and battery converter ensures that the charging process is fast and stable while minimizing power losses. The integration of a novel four-leg inverter and feedback line controller with PI and DQ theory allows for seamless integration of the charging station with the grid, irrespective of the load type, linear or non-linear. Overall, this project represents a significant advancement in the field of electric vehicle charging and renewable energy integration. The successful implementation of this system has the potential to significantly reduce the carbon footprint associated with transportation while providing an efficient and reliable means of charging electric vehicles. The proposed work for power factor correction is verified using the simulation obtained by MATLAB.

FUTURE SCOPE

Electrical energy is the most unprecedented inventions of all times. The growing requirement for electricity and inadequate amount of fossil fuel diverts our attention towards renewable sources of energy. Therefore, multiple researches are going on to create power from sustainable power sources like wind, hydro, solar, geothermal and tidal etc. Recently electricity generation from solar photovoltaic is becoming popular as it is free of cost, low maintenance, noiseless, pollution free and its capability of directly conversion from sunlight into electrical vitality. So, Commercialization of solar systems being taking place with a rapid pace all over the world. But it is protectorate on irradiation and atmospheric Condition and its high capital expenses prevents us to make entire utilization of available solar energy into electricity. In the large-scale PV arrays, static reconfiguration increases wiring and installation complexity in locations with optimal irradiation. On the other hand, dynamic reconfiguration leads to a massive increase in the number of switches and sensors required. To overcome these issues, Applying the image processing method instead of the short-circuit current method would be the future of this work. As an advantage, the image processing method eliminates the need for current sensors. To detect shading patterns, PV Subarrays are depicted and analyzed at specified intervals.

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