Dual fast EV battery charger with PID control Action

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Abstract* - *The main aim of this designed system is to design such a charging station coupled with solar energy for urban cities. Simplified EV load models are developed by considering most popular commercial EV in the market. The designed solar powered charging station is tested with the developed EV load models and, would be located in selected urban cities. In this paper, battery of electric vehicle is charge through two source, solar and electricity board. Solar is primary source, if any case solar isn't working (in winter season or rainy season), EV draws power from electricity board.

Keywords— ***Ac to dc converter, dual active bridge converter, PID controller.***

I. INTRODUCTION

Plug-in electric vehicles (PEVs) include both pure-electric and plug-in hybrid electric cars. They are a viable answer to the growing concern about environmental pollution and thermal vehicle energy use. A residential connection or a recharging bollard are used to recharge PEV batteries from the utility. The house connection in Europe uses a single-phase 230V outlet, whilst the recharging bollard uses a three-phase 400V outlet. Almost all PEVs come with dual-outlet battery chargers.

Electric Cars (EVs) of many forms, including Battery Electric Vehicles (BEV), Plug-in Hybrid Electric Vehicles (PHEV) in various configurations, and Fuel-Cell Electric Vehicles, are being developed as alternatives to Internal Combustion Engines (ICE) vehicles (FCEV). The battery charging methods for electric and plug-in hybrid electric vehicles are discussed in this chapter. To make reading easier and to aid comprehension, the terminology of Electric Vehicle (EV) will be used to define these two types of cars from now on in this chapter. EVs are becoming more popular, as evidenced by the large number of vehicles that have recently been released on the market by almost all automakers. Electrochemical batteries, ultra-capacitors, and full-cell batteries are the principal energy storage solutions in these vehicles. However, taking into consideration Because of the current limitations of energy storage in such technologies, the vehicles' range autonomy is restricted. Different energy storage system designs are possible; nonetheless, electrochemical batteries remain the most often utilised energy storage technology. They are, however, frequently employed in combination with ultra capacitors to store energy during fleeting times, such as regenerative braking. In fact, ultracapacitors are employed in this fashion to accept a large quantity of energy in a short length of time and then deliver that energy to the next acceleration or to assist in battery charging. To save money and avoid dangers: Wasted resources and a lack of safety are two of the most significant issues that smart grid addresses. Smart grid technology adoption by families and communities allows for real-time monitoring and control of energy usage, as well as optimization in the best interests of inhabitants and the environment. Simultaneously, improved visibility of all grid elements — loads, equipment, transmission lines, and appliances — allows management to detect any problem in real time or even ahead of time, respond appropriately, and avoid costly and dangerous problems such as outages and downtime due to untimely maintenance.

a. PID controller

Elmer Sperry invented the first version of the PID controller in 1911. The Taylor Instrumental Company (TIC) did not create the first pneumatic controller with a fully adjustable proportional controller until 1933. Control experts solved the steady state error in proportional controllers a few years later by resetting the point to a fake number as long as the error was not zero. The proportional-Integral controller was born as a result of this resetting, which "integrated" the mistake. The first PID pneumatic controller with a derivative action was invented by TIC in 1940, which addressed overshooting concerns. Engineers weren't able to locate and select the suitable settings of PID controllers until 1942, when Ziegler and Nichols tuning criteria were developed. By Automatic PID controllers were widely used in industry by the mid-1950s. Many different types of dynamic plants employ PID controllers to govern their time-domain activity. These controllers are quite common because they generally have strong closed-loop response characteristics, can be modified using very simple design principles, and are straightforward to build with either analogue or digital components.

A basic DC motor operates on the idea that a current carrying conductor experiences a mechanical force when it is put in a magnetic field. The armature is the current carrying conductor and the field in a realistic DC motor. The DC motor is frequently used in industry due to its superb speed control qualities, despite its greater maintenance costs than the induction motor. As a result, there has been a lot of research into DC motor speed regulation, and numerous solutions have emerged. A Proportional-Integral-Derivative (PID) controller is introduced to mitigate the loading impact and minimise time delay. By far the most popular type of feedback in use today is the PID controller. The proportional-integral equation is popular because of In the process industries, the derivative controller is commonly utilised. Figure following shows the usual PID control arrangement. Its functional simplicity and performance stability.

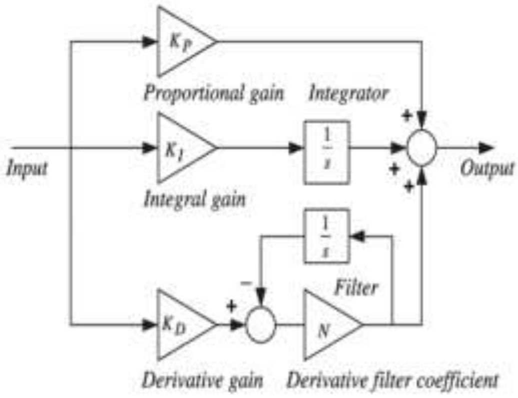

Fig 1.PID controller

This is a sort of feedback controller that generates a control variable based on the difference between a user-defined set point and a measured process variable. A PID controller tries to rectify the difference between a measured process variable and a desired set point by calculating and then producing a corrective action that can change the process. So, by connecting the PID controller to the DC motor, we were able to rectify the DC motor's inaccuracy and adjust the motor's speed or position to the desired point or speed. PID controllers, on the other hand, cannot be tweaked to produce the best step response for various inertia, load, and speed references in order to achieve the required step response. The system's reaction has a short rising time and no overshoot.

$$e_a(t) = e(t) + T_d\frac{de(t)}{dt} + K_i\int e(t)dt$$

..[1]

The Laplace transform of the actuating signal incorporating PID control is.

$$E_a(s) = E(s) + sT_dE(s) + \frac{K_i}{s}E(s)$$

$$or,\ E_a(s) = E(s)\left[1 + sT_d + \frac{K_i}{s}\right]$$

..[2]

II.LITERATURE REVIEW

Hoang Vu Nguyen et al. suggested a single-phase onboard battery charger (OBC) for plug-in electric cars (EVs), which makes use of the low-voltage (LV) battery charging circuit for active power decoupling. By sharing the transformer, switches, and capacitors, the OBC may work in three distinct modes. The LV battery charging circuit acts as an active filter to prevent low-frequency power ripple at the DC connection in a grid-to-vehicle (G2V) or vehicle-to-grid (V2G) mode. At the DC connection, small film capacitors can thus be used instead of huge capacitors. The dual active bridge (DAB) DC-DC converter provides isolation in the third operating mode (H2L), when the LV battery is charged from the HV battery. [1].

Hoang Vu Nguyen and Dong-Choon Lee suggested a single-phase multifunctional onboard battery charger for electric vehicles (EVs), which uses a low voltage (LV) battery charging circuit to offer active power decoupling capabilities. While the high voltage (HV) battery is connected to the grid, the buck converter for the LV battery charger is employed as an active power decoupling (APD) circuit, which filters out the single-phase charger's intrinsic second-order ripple power component. As a result, compact film capacitors may be used instead of big electrolytic capacitors, lowering the cost and volume of the charger for EV applications [2].

A three-phase integrated onboard charger's single-phase charging function is explored in [3]. A three-phase integrated onboard charger may be converted to a single-phase charging mode without any hardware changes. The single-phase operation's circuit structure, operating modes, control strategy, and controller design are all detailed. The authors' three-phase integrated onboard charger is operated and tested as a single-phase charger with a maximum output power of 1.6kW. Experiments reveal that a peak efficiency of 93.7 percent may be attained with unity power factor (PF).A novel single-phase integrated onboard charger is presented in [4], To test the performance of the suggested integrated charging technique, a 3-kW prototype is created utilising a 220-Vrms, 3-phase PMSM. With a maximum efficiency of 93.1 percent, a nearly unity power factor (PF) and 3.96 percent total harmonic distortion (THD) of input ac current are achieved. [5] Proposes an enhanced low-voltage (LV) charging circuit for a single-phase onboard battery charger (OBC), which may function as both an active power decoupling circuit and a current doubler rectifier to charge the LV battery from a high-voltage (HV) battery. The suggested module is utilized as the active filter when the HV battery has to be charged from the grid. This circuit also becomes the LV charging circuit when the LV battery has to be charged from the HV battery.

For plug-in electric automobiles, K. A. Chinmaya and G. K. Singh suggested a buck converter-based integrated battery charger (PEVs). During all modes of vehicle operation, the proposed bidirectional DC/DC converter may perform buck/boost functions. In plug-in charging mode, it acts as a power factor correction (PFC) converter, while in driving and regenerative braking modes, it acts as a normal single stage inverting buck/boost converter. The suggested converter is ideal for use as a PEV onboard charger. Simulations are carried out. A laboratory prototype of the aforementioned converter has been created to test its viability using the MATLAB/Simulink environment [6].

A programmable charging profile consisting of an initial constant current (CC) and a subsequent constant voltage (CV) is anticipated from an IPT battery charger. Two sets of IPT topologies with inherent load-independent CC and CV at the same zero-phase angle (ZPA) frequency are commonly combined into a hybrid topology with a wide load range during the charging process to avoid sophisticated control schemes while maintaining nearly unity power factor and soft switching of power switches simultaneously. This study proposes design ideas with fewer mode switches and compensating components, as well as some available hybrid topologies that are not constrained by LCT parameters. Also examined are the control logic and sensitivity of compensation parameters to input impedance and load-independent output. Finally, to verify the theoretical analysis, a 1 kW hybrid IPT battery charger prototype based on LCC-LCC and LCC-S topologies is created [7].

A DC-DC converter is used to charge both the LV and HV batteries at the same time.is introduced, which shares the LV charging circuit's transformer core and secondary side. As a result, the suggested topology preserves the OBC's functionality while reducing volume and cost by 52.3 percent and 46.9%, respectively, as compared to the standard non-isolated OBC. To prove the correctness of the suggested system, a 2-kW SiC-based prototype was constructed and tested. The OBC and LV chargers have peak efficiency of 96.1 percent and 95.3 percent, respectively [8].

Mehdi Abbasi and colleagues presented the suggested ac-dc charger has a reduced THD and a power factor that is close to unity. Variable switching frequency is employed to manage the 800-V output voltage, and duty ratio control is used to accomplish PFC in the front-end CCM bridgeless boost circuit. The total circuit efficiency is improved by the reduced number of semiconductor devices and gentle switching operations. To emphasise the benefits of the proposed converter, simulation results are presented on both level 1 and level 2 charging systems with 2 5 kW, 120 240 Vac /800 Vdc. The findings of experiments on a 120 Vac/800 Vdc prototype are also provided.to support this work [9].

[10] Describes the design, construction, and functioning of an onboard charger for electric vehicles using an 800 V power supply. In a transformer-less bidirectional charger architecture, the device employs silicon carbide power MOSFETs operating at up to 150 kHz, connected filter inductors, tiny ceramic DC link capacitors, and a Steinmetz circuit for single phase operation.

III. PROPOSED SYSTEM

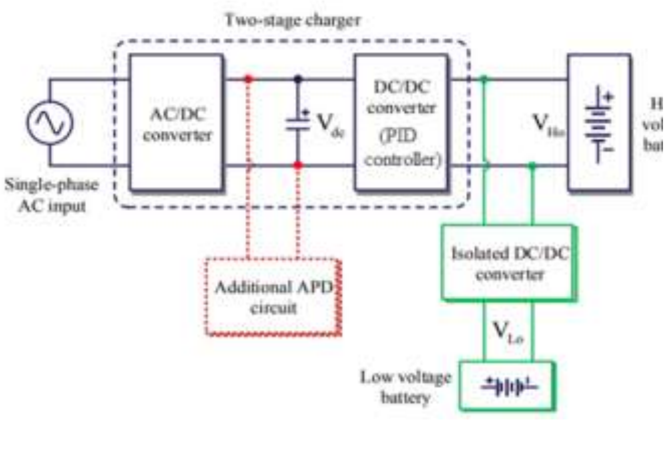

Fig 3.1 Block diagram of proposed system .

Electric vehicles (EVs) have gained a growing amount of interest from car manufacturers, governments, and customers as a result of more rigorous pollution, global warming, and resource limits legislation. The onboard battery charger in plug-in EVs normally charges the batteries from the grid (OBC). In general, there are two types of battery applications in electric vehicles. The high-voltage (HV) battery is used for traction motor drives, while the low-voltage (LV) battery is used to power loads such as lighting and signaling circuits, entertainment systems, automated seats, and other electronic equipment. Because alternators are not employed, the auxiliary charger charges the LV battery from the HV battery, unlike typical automobiles with inbuilt alternators. Engine that burns fuel The DC-link ripple voltage in single-phase HV battery chargers is caused by an intrinsic ripple power component in the DC connection that fluctuates at twice the grid frequency. Large capacitors are frequently required to smooth out this low-frequency ripple power. However, because electrolytic capacitors are unsuitable for EV applications due to their limited lifespan, they must be replaced by a dependable film capacitor, whose size should be at least optimized. For this, the ripple power of the DC link must be diverted to alternative energy storage devices that allow for high voltage variations. As a result, the DC-link capacitor's size and weight may be drastically decreased.

Figure 3.2 depicts a block schematic of the proposed system. A non-isolated or isolated DC/DC converter is generally used with an AC/DC power factor correction (PFC) boost converter. The major purpose of the second-stage DC/DC converter is to manage the HV battery's voltage and current. The two-stage architecture has the advantages of having a high power factor, sinusoidal grid current, and ripple-free charging current. A single-phase OBC with a dual functional circuit for plug-in EVs is presented, which can operate in three modes as well as an active power decoupling function. The LV battery charging circuit acts as an active filter to minimize low-frequency ripple power when the charger is in G2V or V2G mode. To remove low-frequency ripple power at the DC connection, the LV battery charging circuit acts as an active filter. As a consequence, tiny film capacitors may be used at the DC-link instead of big electrolytic capacitors. The size and cost of the single-phase OBC may be greatly decreased with the suggested LV battery charger with active power decoupling capability. For a dual functioning circuit, we're applying PID control action.

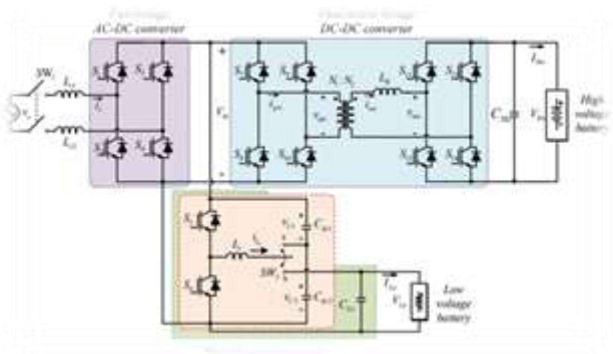

Fig 3.2 Circuit diagram of dual active bridge converter .

2. FUNCTION OF EACH BLOCKS:

a) *RECTIFIER :*

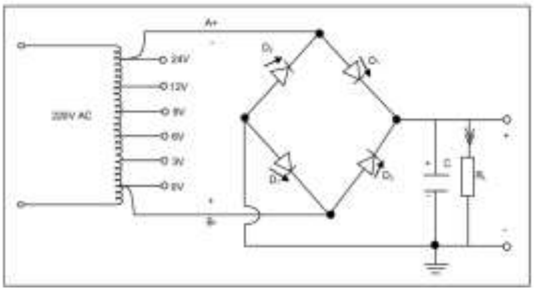

Fig 3.3 Full wave bridge rectifier

A rectifier is a device that transforms two-way alternating current (AC) into single-directional direct current (DC) (DC). Rectifiers come in a range of physical shapes and sizes, ranging from vacuum tube diodes and crystal radio receivers to current silicon-based systems.

The bridge rectifier is made up of four diodes, as seen in Figure 3. Diodes D1 and D2 are forward-biased and conduct current in the direction depicted when the input cycle is positive, as illustrated in section (a). RL generates a voltage that resembles the positive half of the input cycle. Diodes D3 and D4 are reverse-biased throughout this period. D1 and D2 are forward-biased and conduct current during the positive half-cycle of the input. D3 and D4 are skewed in the opposite direction. D3 and D4 are forward-biased and conduct current during the input's negative half-cycle. D1 and D2 are skewed in the opposite direction. Diodes D3 and D4 are forward-biased and conduct current in the same direction along the same path when the input cycle is negative, as shown in Figure (b).RL as during the half-positive cycle's half D1 and D2 are reverse-biased during the negative half-cycle. As a result of this process, a full-wave rectified output voltage arises over RL. A DC power supply, or unidirectional DC power supply, is a device that provides DC voltage and current.

Batteries are one such power source, but their lifespan and cost are both restricted. The use of a rectifier to convert AC line power to DC power is an alternate means of supplying unidirectional electricity.A rectifier is a device that allows AC to be converted to DC by passing current in one direction and blocking it in the other. Rectifiers are crucial in electrical circuits because they only allow current to flow in one direction if a threshold forward voltage is crossed across them. A diode, a silicon controller rectifier, or various forms of silicon P-N junctions can all be used as rectifiers. The anode and the cathode are the two terminals of a diode, and current flows from the anode to the cathode. Rectifier circuits employ one or more diodes to convert bipolar AC voltages and currents to unipolar voltages and currents that may be filtered to produce DC voltages and currents.

b) *DUAL ACTIVE BRIDGE :*

A bidirectional DC-DC converter with identical primary and secondary full-bridges, a high frequency transformer, an energy transfer inductor, and DC-link capacitors is known as a dual active bridge. In the model, energy transfer inductance refers to the transformer's leakage inductance plus any required external energy transfer inductance. Complementary square-wave pulses drive the two legs of both full-bridges. The power flow in the dual active bridge may be controlled by applying phase shift modulation to phase shift the pulses of one bridge with respect to the other. The control distributes power between the two DC buses so that the leading bridge feeds the trailing bridge. The bridges are subjected to square waves, which produce a voltage differential across the energy transfer inductance and guide it in one direction.inductance and direct the energy stored in it When the voltage transfer ratio (M) across the transformer is equal to 1, zero voltage switching (ZVS) can be achieved in ideal instances with dual active bridge converters:
M = Vout / (n*Vin)

where Vout is the output voltage and Vin is the input voltage, and n is the transformer rotation ratio. In non-ideal instances, ZVS is determined by the resonant connection between the output capacitance of each device and the circuit's equivalent inductance at various switching intervals. The current through one of the complementary devices is halted during switching events, but owing to the energy transfer inductance, current is provided through the output capacitor and driven through the device's anti-parallel diode. Control Each switch is on for half of the time it is supposed to be on. The switch pairs in the two bridges have the same switching period, but they are controlled in such a way that a phase shift is introduced between each bridge that changes depending on the modulation.Feedback measurements were used to create this model. A set point value is used to produce an output voltage error signal, which is then sent through a digital PI regulator to provide the phase shift ratio for the PWM modulator. The twin bridge bypass function allows each bridge to manage traffic differently, allowing cars to be accelerated on one bridge on the way in while bypassing the acceleration handling on the way out. Link aggregation combines many bridges into a single link.

The dual active bridge is an eight-semiconductor, high-frequency transformer, energy transfer inductor, and dc-link capacitors bidirectional, controlled dc-dc converter with high power capabilities. A more simple description of the converter is a full-bridge with an adjustable rectifier. This converter's symmetry, with identical primary and secondary bridges, allows for bidirectional power flow regulation, which is why it was chosen for the smart green power node application. Figure 3 depicts the topology. where and are the dc-link voltages, is the transformer's leakage inductance plus any required external energy transfer inductance, and is the number of controlled semiconductor switches.

The dual active bridge has been widely researched in the past.applications that are related Isolated gate bipolar transistors (IGBTs) were often used in past years to support large dc-link voltages (>300V). As a result, antiparallel diodes and snubber capacitors have typically been used to direct current commutation on switching events while also allowing for zero voltage switching (ZVS) via the snubber capacitor and energy transfer. Resonance in inductance.
High voltage MOSFETs were developed because they include an intrinsic body diode and drain-to-source output capacitance, which eliminate the need for additional components and lower the converter's part count. Wide band gap materials, such as silicon carbide (SiC), have been the subject of power electronics research due to their greater voltage and temperature ratings, as well as reduced turn on energy, making them ideal for high frequency switching converter applications.

IV.MATLAB SIMULATION

Simulation of "Onboard Battery Chargers for Plug-in Electric Vehicles with Dual Functional Circuit using PID control action" is shown in fig 4.1. This consists of dual active bridge, couple of switches, low and high voltage battery and input signal.

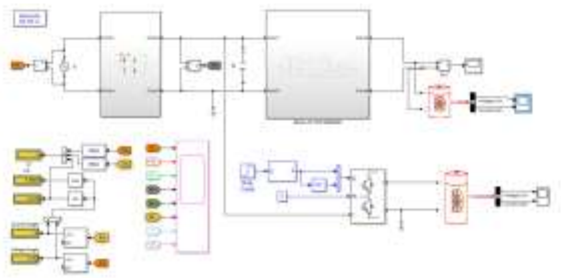

Fig 4.1 Simulation result .

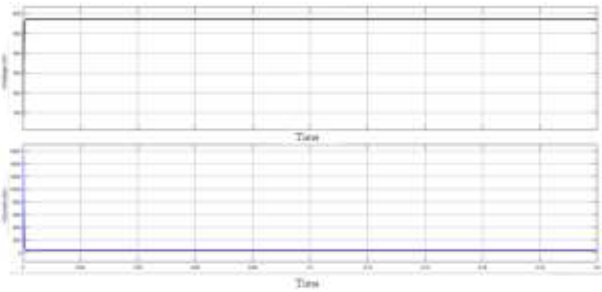

Fig 4.2 high voltage battery

Voltage and current waveform of high voltage battery and low voltage battery are given in fig 5.2 and 5.3 respectively. High DC volt is 550 volt whereas low AC P-P volt is 250 volt.

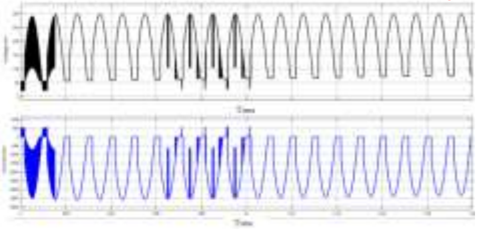

Fig 4.3 Low voltage battery

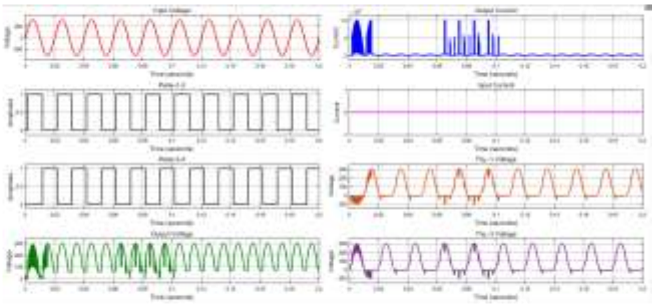

Fig 4.4 Battery waveforms

Fig 4.4 shows dual functionality of circuit which will be used for onboard battery chargers for Plug-in Electric Vehicles. It shows input and output electrical parameter (current and voltage), whereas the voltage of thyristor 1 and 2 along with this, fig shows waveforms of input pulses.

V. HARDWARE IMPLEMENTATION

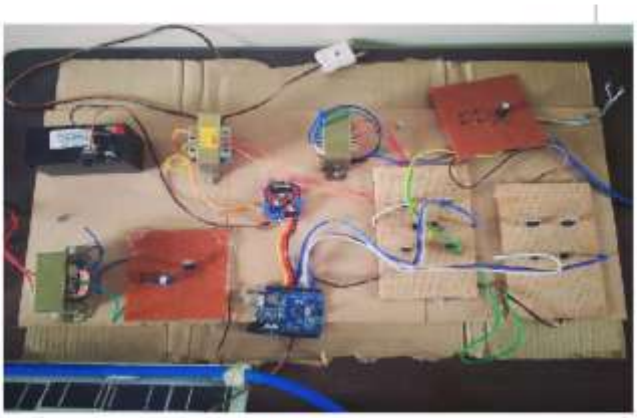

Fig 5.1 Hardware Module

The above hardware module is "Dual Fast Battery Charger with PID Control". The circuit which consists of the battery, Arduino Uno, transformer, inverter circuit, bridge rectifier, and input ac supply is designed to charge batteries with dual functionality without affecting voltage irrgulities to each other battery and PID controlled action which provides smoothness of charging and improves efficiency. When fed 230 volts, the step down transformer steps down voltage to 12 volts, and the 7805 IC provides 5 volt dc supply to the Arduino Uno, and thus step –up transformer, step –up power with using l293DN circuit provides switching action to turn on turn off and converts power into 230 volt AC. pulses are taken from the proposed microcontroller with any voltage references disturbance in the circuit, the PID controller takes action and keeps the voltage reference the same as the i/p voltage. This gives an output of nearly 30 volts DC.

5.1 COMPOENTS REQUREMENT :

- Battery -12 volt 1.3 amp
- Transformer -9 volt 500 mamp
- Trasformer -12 volt 500 mamp
- Inverter circuit –L293D
- Ardunio Uno –AT mega (328)
- Rectifier –Bridge rectifier (diode 1N4007)
- Resiter -10k ohm
- MOSFET-IRF540
- Optocoupler-817
- Capacitor -470uf ,35 volt, 1000uf 25 volt,
- Regulator IC-7805IC

1) Battery -12 volt

5.2 12 volt 1.3 amp

Electric vehicles use lithium-ion batteries of various designs, similar to those used in cell phones and laptop computers, only on a much larger scale. Lithium-ion batteries have a high energy density and are less likely than other types of batteries to lose their charge when not being used. An EV's battery capacity is expressed in terms of kilowatt-hours, which is abbreviated as kWh. More is better here.

2) Transformer : 9 volt 500 m amp

Fig 5.3. Transformer 9 volt 500 amp

Above transformer we have design to used which is step- up transformer which has step power from given iuput power such, input 12 volt ac to given 230volt as primary winding of transformwer.

3) Transformer: 12 volt 500 mamp

Fig 3. 12 volt 500 mamp

The above transformer we have used to design as step – up transformer and given 12 volt step down transformer convert 230volt into 12 volt.

4) Inverter circuit L298N

Fig 5.4 . Inverter circuit L298N

The half-bridge inverter consists of two diodes and two switches which are connected in anti-parallel. The two switches are complementary switches which means when the first switch is ON the second switch will be OFF similarly, when the second switch is ON the first switch will be OFF. Such this switching action mode which converted i/p 12 volt ac to 230 o/p ac .

5) Ardunio Uno

Fig 5.5 Ardunio Uno

Ardunio Uno is 16 pin and 4 PWM pin (pulse width modulation) which is compatible IC we have used to as microcontroller which has set values having done by programming which has provides pulses to our circuit design and operate and give design parameter values.

6) **Bridge rectifier :**

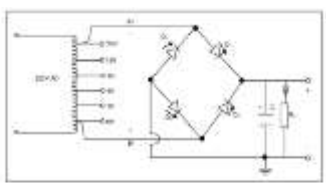

Fig 5.6. Bridge rectifier

The main concerns of such converters are the unity power factor operation and low harmonic distortion of the input AC waveforms that can be ensured by generating a DC voltage higher than the grid peak voltage amplitude, which makes use of switching devices inevitable.

1. Three-Phase Input 208 VL-L 60 Hz, Output 600-V DC Nominal, 1.2 KW
2. Three-Phase Input 400 VL-L 50 Hz, Output 700-V DC Nominal, 2.4 KW
3. 50-kHz Pulse Width Modulation (PWM) Switching
4. Greater Than 98% Peak Efficiency
5. Less Than 2% Total Harmonic Distortion (THD) at Full Load and Low Line

7) Switching Components used :

1) 7805 IC

Fig 5.7 7805 IC

Such as switching 7805 IC we have used For 7805 IC, it is +5V DC regulated power supply. This regulator IC also adds a provision for a heat sink. The input voltage to this voltage regulator can be up to 35V, and this IC can give a constant 5V for any value of input less than or equal to 35V which is the threshold limit. This IC can provides 5 volt DC supply provides to our design microcontroller board.

Fig 5.8.Optocoupler

1. Opt -couplers are used to isolate sections of a circuit that are incompatible in terms of the voltage levels or currents required.

2. They are also used to isolate low-current control or signal circuits from noisy power supply circuits .

The optical link is contained within a chip. A Light Emitting Diode inside the chip shines on a photo-diode, photo-transistor or other photo device. When the photo device sees illumination, the resistance between its terminals reduces. This reduced resistance can activate another circuit.

3) MOSFET –IRF540:

Fig 5.9. IRF 540.

Above figure which has shown A MOSFET IRF 540 which has used power switching devices which taking pulses from given microcontroller and does operate with given signals. and provides accurate voltage.

4) Capacitor -470uf, 35 volt, 250 volt 1000uf,

Fig5.10. 470uf, 35 volt

Fig5.11. 25volt, 1000uf

Above fig which has shown 2 capacitors is their different voltage range are used in design circuit A capacitor is a device that is used to store charges in an electrical circuit. A capacitor works on the principle that the capacitance of a conductor increases appreciably when an earthed conductor is brought near it. Hence, a capacitor has two plates separated by a distance having equal and opposite charges.

VI .CONCLUSION

The major benefit of on-board charging is that it uses readily-available AC power and, via an extension lead, the vehicle can be plugged into any of the billions of outlets installed in every building. In this paper, a single-phase multifunctional onboard battery charger for electric vehicles (EVs) is proposed, where the active power decoupling capability is provided by utilizing the low voltage (LV) battery charging circuit without the bulky DC-link capacitors. The proposed OBC utilizes the LV battery charger as an active power filter to eliminate the second-order ripple power when the EVs are connected to the grid. By adding an inductor on the primary side of the LV charger, the converter can achieve the APC(Automatic power factor correcrction) function without adding additional switches, heat sinks, and gate drive circuits.

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