Controlling of Wireless Electric Vehicle Charging with Five Phase Inductively Coupled Resonant Converter

P. Venkatesh, B. Venu Gopal Reddy, K. P. Prasad Rao

Abstract: ***The initial 5-phase acceptance induction motor drive framework was proposed in the late 1970s for movable speed drive applications. From that point forward, a significant research exertion has been set up to grow economically achievable multiphase drive frameworks. Since the three-phase supply is accessible in the form of matrix, there is a need to build up a static phase change framework to get a multiphase supply from the accessible 3-phase supply. Along these lines, this paper proposes a 5-phase fixed power and fixed recurrence supply. The proposed five phases what's more, along these lines, can be utilized in applications requiring a 5-phase supply. Presently, the 5-phase induction motor drive is a monetarily practical arrangement. For high power applications like work unit accusing is furthermore achievable of Wireless Power Transfer (WPT) Frameworks. From the previous couple of years, examines on Electric Vehicles (EV) are made increasingly concerned and it picked up prominence since it won't radiate any ozone depleting substances and it utilizes environmentally friendly power vitality. Indeed, even Electric vehicles are having numerous preferences there are a few issues ejected when it experiences with the clients. One of the primary drawbacks is charging foundation. In this way, WPT frameworks region unit higher partner for charging EVs. In this paper, outline of particular sorts of Remote Power Exchange innovations has given and straight forward plan of five phase inductively coupled resonant converter WPT frameworks in tangle lab were given.***

Index Terms: ***Wireless Power Transfer, shapes of coils, Battery charging profile.***

I. INTRODUCTION

Remote Electric Vehicle (EV) running after philosophy is a to earth strategy, which is guaranteed, climate assertion, vandalism affirmation, and can be installed in a road, as referenced recorded as a printed version [1]-[3]. Its application isn't just helpful to supply capacity to EV batteries, yet what's more gives progressively secure perception without a rope [4]. The Electric Vehicles should be conceivable when vehicles are on parking, is called static charging from high power for transports [5]-[6] to little power for electric vehicle charging bikes [7]-[8] overall 90% ability. Particularly, high sufficiency, since quite a while earlier life, and unfazed quality are required in this remote Electric vehicle charging frameworks. The remote charging procedure of Electric Vehicles should be conceivable when vehicles are on streets, called dynamic charging [9]; or left, intimate stationary charging. An occurrence of stationary remote EV charging structure. The charger includes on an exceptionally fundamental dimension of two territories: 1) A AC/DC converter with a rectifier and a Power Factor Correction (PFC), controls the information current to meet the prerequisites for the Power Factor (PF) and inside and Total Hormonic Distortion (THD), and passes on an evident dc voltage as an information voltage hotspot for the second stage, 2) WPT form with an inverter in the essential side and rectifier in the optional side, the dc yield voltage related the battery is furnished always sort out with a high contactless transformer and a genuine impedance arranging structure [10]-[11]. The power stream is regulated utilizing a fitting change mode controller to reprimand the battery for a determined current control (CC) and solid voltage control (VC) errands [12].

II. DESCRIPTION OF CIRCUIT AND WIRELESS POWER LINK

The inductively coupled resonant converter topology is proposed technique for remote EV charger structure is showed in Fig. 1. It includes a climate control system i/p voltage source VAC, AC/DC, PFC converter, distinctive trading legs which is proposed to allow organize control and most extreme streaming streams among trading legs, a remote power interface, rectifier, and a battery.

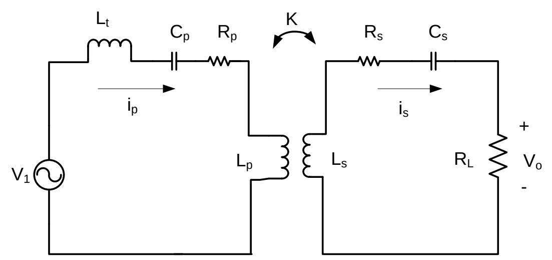

Fig. 1. Equivalent Circuit Diagram for Wireless Power Link.

Coupling Factor:

$$k = \frac{L_M}{\sqrt{L_P L_S}}$$

Where K=1 (it's superbly coupled), K=0(it's not couples).

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Coil Inductance

$$N_e = \frac{1}{K}\sqrt{\frac{L_S}{L_P}}$$

Voltage Gain:

$$\frac{V_2}{V_1} \propto K\sqrt{\frac{L_S}{L_P}}$$

The trading legs and the dc input voltage VD structure square-wave voltage sources in the remote association. Since the resonating streams i_1, i_2, i_3, i_4, i_5 at the trading leg yields are sinusoidal, simply the force of the essential piece of every information voltage source is traded to the yield. Thusly, the square wave voltage sources can be superseded by sinusoidal voltage sources V_1, V_2, V_3, V_4, V_5 which address the basic parts as showed up in Fig. 1. The real pieces of the voltage sources in the circuit are

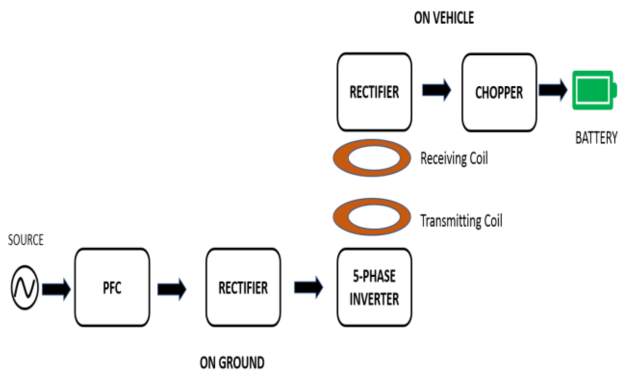

Fig. 2. The proposed high power wireless EV battery charging modeling.

$$V_1 = V_m \sin(\omega t + \phi_1)$$
$$V_2 = V_m \sin(\omega t + \phi_2)$$
$$V_3 = V_m \sin(\omega t + \phi_3)$$
$$V_4 = V_m \sin(\omega t + \phi_4)$$
$$V_5 = V_m \sin(\omega t + \phi_5)$$

Amplitude

$$V_m = \frac{2}{\pi} V_D$$

$\varphi_1, \varphi_2, \varphi_3, \varphi_4, \varphi_5$ these are the phase shifts from 0 to π

$$V_1 = V_m e^j \left(\frac{-N+1}{N}\right) \varphi 1$$
$$V_2 = V_m e^j \left(\frac{-N+2}{N}\right) \varphi 2$$
$$V_3 = V_m e^j \left(\frac{-N+3}{N}\right) \varphi 3$$
$$V_4 = V_m e^j \left(\frac{-N+4}{N}\right) \varphi 4$$
$$V_5 = V_m e^j \left(\frac{-N+5}{N}\right) \varphi 5$$

III. SPECIAL 5-PHASE DESIGN AND CONFIGURATION

High power applications skilled for utilizing multi-phase machines. The innate favorable circumstances of multi-phase over customary three phases are an improvement in clamor qualities. Proficiency can be expanded as multi part results in a lessening in stator loop copper misfortunes. The plentifulness, phase, and recurrence of the voltages of five leg inverter ought to dependably be controllable and Most of the applications require sinusoidal voltage waveforms. The five-phase 180° mode VSI topology is appeared in Fig. 2. It ought to be guaranteed that the switches of any leg of the electrical converter (S1and S6, S3and S8, S5and S10, S7and S2 or S9 and S4) can't be exchanged on at the same time as this would result in a short circuit over the dc connect voltage supply. Correspondingly, so as to maintain a strategic distance from unclear states in the VSI, and subsequently air conditioning yield line voltages, the switches of any leg of the electrical converter can't be turned off at the same time as this will result in voltages which will rely upon the few line flow polarities . The thyristor conducts for 180° in a cycle. Thyristor join in each arm is turned on with a period interim of 180°. The thyristors in five leg

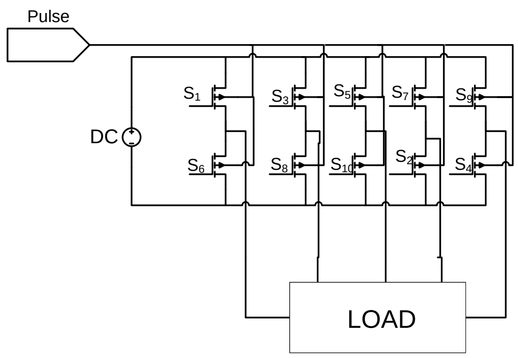

Fig .3 Five Phase Inverter Circuit Diagram

The circuit completely clarified with ten phases.

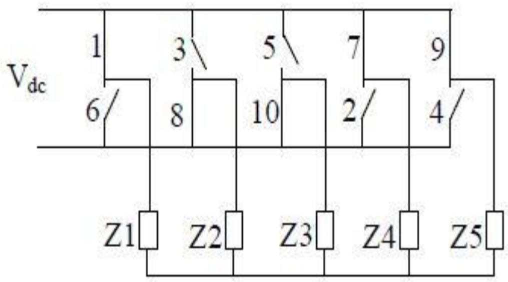

Fig .4 Five Phase Inverter Circuit for switching

Step - 1: 0≤ ωt < 36°

Current

$$I_1 = \frac{V_s}{\frac{5z}{6}} = \frac{6}{5} \times \frac{V_s}{z}$$

Phase voltages

$$V_{a0} = V_{b0} = V_{c0} = i_1 \times \frac{z}{3} = \frac{2}{5} V_s$$

$$V_{0d} = -V_{0d} = V_{0e} = -V_{0e} = i_1 \times \frac{z}{2} = -\frac{3}{5} V_s$$

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Step 2: 36° ≤ ωt <72°

$$I_2 = \frac{V_s}{\frac{5z}{6}} = \frac{6}{5} \times \frac{V_s}{z}$$

$$V_{a0} = V_{d0} = V_{e0} = -\frac{2}{5} V_s$$

$$V_{b0} = V_{c0} = \frac{3}{5} V_s$$

Step 3: 72°≤ ωt <108°

$$I_3 = \frac{V_s}{\frac{5z}{6}} = \frac{6}{5} \times \frac{V_s}{z}$$

$$V_{b0} = V_{c0} = V_{d0} = \frac{2}{5} V_s$$

$$V_{a0} = V_{e0} = -\frac{3}{5} V_s$$

Step 4: 108°≤ ωt <144°

$$I_4 = \frac{V_s}{\frac{5z}{6}} = \frac{6}{5} \times \frac{V_s}{z}$$

$$V_{a0} = V_{b0} = V_{e0} = -\frac{2}{5} V_s$$

$$V_{c0} = V_{d0} = \frac{3}{5} V_s$$

Step 5: 144°≤ ωt <180°

$$I_5 = \frac{V_s}{\frac{5z}{6}} = \frac{6}{5} \times \frac{V_s}{z}$$

$$V_{c0} = V_{d0} = V_{e0} = \frac{2}{5} V_s$$

$$V_{a0} = V_{b0} = -\frac{3}{5} V_s$$

Step 6: 180° ≤ ωt < 216°

$$I_6 = \frac{V_s}{\frac{5z}{6}} = \frac{6}{5} \times \frac{V_s}{z}$$

$$V_{a0} = V_{b0} = V_{c0} = -\frac{2}{5} V_s$$

$$V_{d0} = V_{e0} = \frac{3}{5} V_s$$

Step 7: 216° ≤ ωt < 252°

$$I_7 = \frac{V_s}{\frac{5z}{6}} = \frac{6}{5} \times \frac{V_s}{z}$$

$$V_{d0} = V_{e0} = V_{a0} = \frac{2}{5} V_s$$

$$V_{b0} = V_{e0} = \frac{3}{5} V_s$$

Step 8: 252° ≤ ωt < 288°

$$I_8 = \frac{V_s}{\frac{5z}{6}} = \frac{6}{5} \times \frac{V_s}{z}$$

$$V_{b0} = V_{c0} = V_{d0} = -\frac{2}{5} V_s$$

$$V_{e0} = V_{a0} = \frac{3}{5} V_s$$

Step 9: 288° ≤ ωt < 324°

$$I_9 = \frac{V_s}{\frac{5z}{6}} = \frac{6}{5} \times \frac{V_s}{z}$$

$$V_{e0} = V_{a0} = V_{b0} = \frac{2}{5} V_s$$

$$V_{b0} = V_{c0} = \frac{3}{5} V_s$$

Step 10: 324° ≤ ωt < 360°

$$I_{10} = \frac{V_s}{\frac{5z}{6}} = \frac{6}{5} \times \frac{V_s}{z}$$

$$V_{c0} = V_{d0} = V_{e0} = \frac{2}{5} V_s$$

$$V_{a0} = V_{b0} = \frac{3}{5} V_s$$

Angle in Degrees	0	36	72	108	144	180	216	252	288	324	360
Leg 1	S1					S6					
Leg 2	S8		S3					S8			
Leg 3	S5				S10					S5	
Leg 4	S7	S2					S7				
Leg 5	S9			S4					S9		

Table.1 180° modes of 5-phase.

OPERATION MODES	CONDUCTION PERIOD	No. of SWITCHES TURN ON
MODE 1	0 ≤ ωt < 36°	S1, S5, S7, S8, S9
MODE 2	36°≤ ωt < 72°	S1, S3, S5, S2, S9
MODE 3	72° ≤ ωt < 108°	S1, S3, S5, S2, S4
MODE 4	108° ≤ ωt < 144°	S1, S3, S10, S2, S4
MODE 5	144° ≤ ωt < 180°	S6, S3, S10, S2, S4
MODE 6	180° ≤ ωt < 216°	S6, S3, S10, S7, S4
MODE 7	216° ≤ ωt < 252°	S6, S8, S10, S7, S4
MODE 8	252° ≤ ωt < 288°	S6, S8, S10, S7, S9
MODE 9	288° ≤ ωt < 324°	S6, S8, S5, S7, S9
MODE 10	324° ≤ ωt < 360°	S6, S8, S5, S7, S9

Table.2: modes of operation

Demonstrates the phasor outline, the reference line was red to neutral voltage V_{AN} is taken and the phase succession are red, yellow, blue, green, purple with the goal that the other line to nonpartisan voltages or phase voltages lie as appeared.

IV. PHASOR DIAGRAM FOR 5-PHASE INVERTER

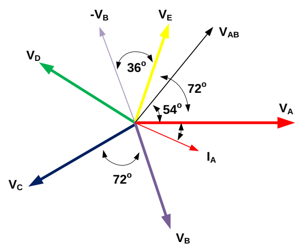

Fig. 5. Phasor diagram of the proposed Five Phase Inverter.

If $V_{AN} = V_{BN} = V_{CN} = V_{DN} = V_{EN}$ and they are equally spaced each phase difference is 72° the voltage of the system is balanced. Let V_L is the voltage in between the two lines and $V_{Ph} = V_{AN} = V_{BN} = V_{CN} = V_{DN} = V_{EN}$ Then V_L = 1.38 VPH or V_L = 1.175 V_{ph} and $I_L = I_P$. Where I_L is the line current and I_P is the phase current. The power per section is P = V_P information processing $Cos\varphi$ and the total power is that the total of the quantity of power in every section.

$$P = 5\, V_{ph}\, I_{Ph}\, Cos\varphi \text{ or } P = 4.25\, V_L\, I_L\, Cos\phi$$

$$\begin{bmatrix} V_a \\ V_b \\ V_c \\ V_d \\ V_e \end{bmatrix} = \frac{1}{sin\,\frac{\pi}{3}}\; X \begin{bmatrix} Sin\left(\frac{\pi}{3}\right) & 0 & 0 \\ 0 & Sin\left(\frac{\pi}{15}\right) & -Sin\left(\frac{4\pi}{15}\right) \\ -Sin\left(\frac{2\pi}{15}\right) & Sin\left(\frac{\pi}{5}\right) & 0 \\ -Sin\left(\frac{2\pi}{15}\right) & 0 & Sin\left(\frac{\pi}{5}\right) \\ 0 & -Sin\left(\frac{4\pi}{15}\right) & Sin\left(\frac{\pi}{15}\right) \end{bmatrix} \begin{bmatrix} V_x \\ V_y \\ V_z \end{bmatrix}$$

$$V_a = V(\omega t)_{max}$$
$$V_b = V\left(\omega t + \frac{2\pi}{5}\right)_{max}$$
$$V_c = V\left(\omega t + \frac{4\pi}{5}\right)_{max}$$
$$V_d = V\left(\omega t - \frac{4\pi}{5}\right)_{max}$$
$$V_e = V\left(\omega t - \frac{2\pi}{5}\right)_{max}$$
$$V_x = V(\omega t)_{max}$$
$$V_y = V\left(\omega t + \frac{2\pi}{3}\right)_{max}$$

V. POWER FACTOR

They are two main types to correcting the power factor in inverter 1) it was used in inverter at the zero crossing frequency of the operating system. 2) adding the addition component like capacitor in the circuit. We are maintaining the unity power factor because there is no reactive power the efficiency will increase. So that we are maintain the unity power factor.

VI. CONTROL STRATEGIES

Consolidating the two customary balance, phase move adjustment and recurrence control, phase recurrence half and half control methodology was proposed in this project. The guideline of activity is to use the phase move for directing the framework yield and furthermore the recurrence to control as preparing to the resounding recurrence as could be allowed. The proposed crossover control circles as appeared in Fig.6.

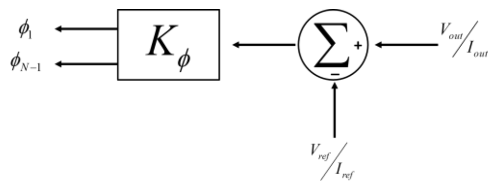

Fig. 6. Block diagram for PI controller

VII. MODELLING OF CASE STUDY MATLAB ARRANGEMENT FOR FIVE-PHASE INDUCTIVELY COUPLED RESONANT CONVERTER

Whenever contrasted with the buyer electronic gadgets, the electric vehicles (EV) charging happens at prominently higher power levels, going from a couple of many W (as on account of the E-bicycle) to a few several kW (as on account of the electric transports). The Wireless Remote Electric Vehicle Charging (WREVC) is still a long way from a full commercialization and institutionalization. By the by, being executed through Inductive Power Transfer (IPT) between two coupled curls, it gives benefits as far as wellbeing and solace to every one of the clients. The EVs can be revived or provided by IPT abusing essentially three elective choices static remote charging, semi dynamic or dynamic remote charging. The static IPT comprises of the EV charging at whatever point the vehicle is stationary and no one remains inside it, for example on account of a left vehicle. In the semi dynamic IPT, the energize happens when the electric vehicle is stationary, yet somebody is inside it, for example on account of a taxi at the traffic light crossing points or a transport at the stop. The dynamic IPT comprises in providing the vehicle amid its movement, for example on account of a vehicle running on an express way or of a moving train. A diagram on research and applications about IPT-based remote charging for some electric methods for transportation will be given in the accompanying.

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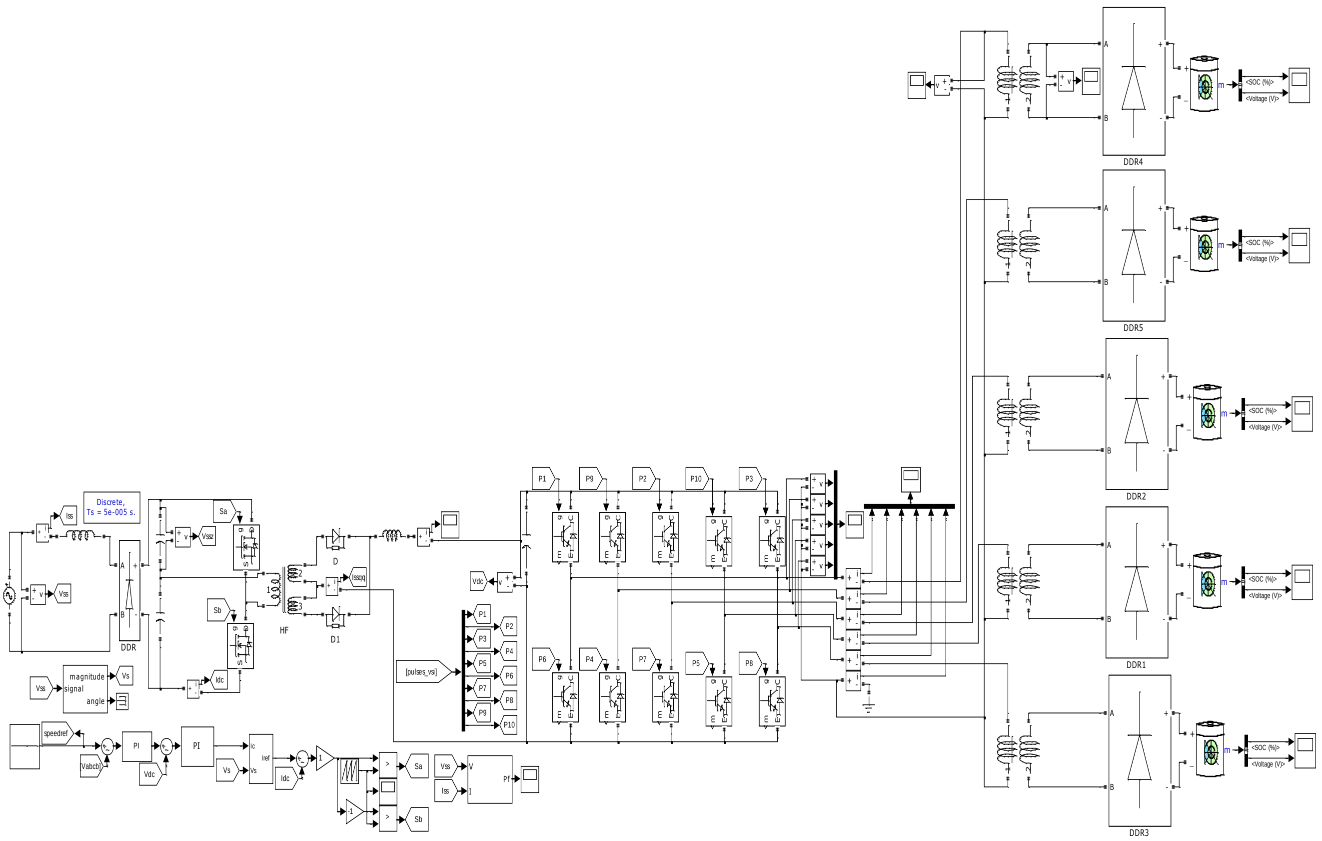

Fig 7: Five Phase Inductively Coupled Resonant Converter wireless EV battery charging modeling.

VIII. EXPERIMENTAL RESULTS

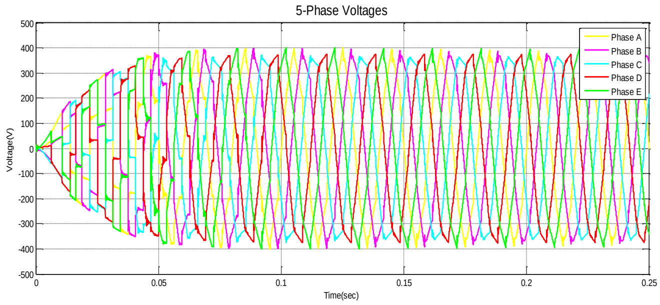

Fig: 7(a) 5-Phase Voltages.

Accessible yield from this rectifier output is sustained to the five phase inverter in which the switches are worked in the operational frequency of 88 KHz utilizing the beat generator as appeared in the circuit. The output of the inverter is ±400 volts that are only the transmitter side voltage.

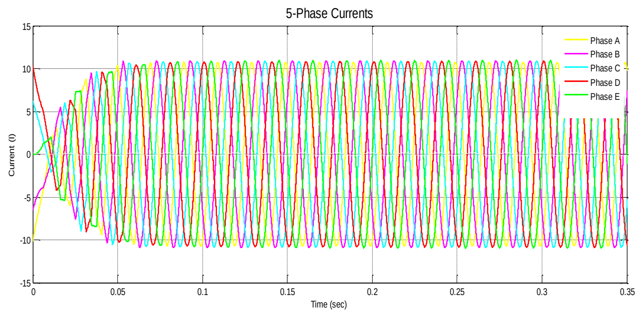

Fig: 7(b) 5-Phase Currents.

Accessible output from this rectifier output is sustained to the five phase inverter in which the switches are worked in the operational frequency of 88 KHz utilizing the beat generator as appeared in the circuit. The output of the inverter is ±10 amps.

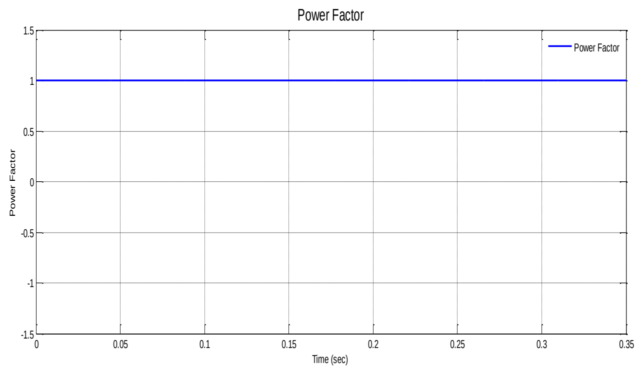

Fig: 7(c) power factor.

According to this output we are maintaining the unity power factor because if there is no resistive power the efficiency will increase.

IX. BATTERY CHARGING PROFILE:

The battery life, power, and vitality thickness relay upon vitality stockpiling capacity, which is imperative for charge and release qualities to be capable quick and secure energizing.

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So as to accuse the battery of superior, charging conditions thought to be controlled, watched, and ensured.

The battery has been charging with two unique modes; 1st consistent present and after that voltage limit control until the battery is completely charged. The battery was charged at the steady current control (CC) until voltage comes to appraised an incentive in stage 1. At that point steady voltage control (VC) is performed in stage 2. At the point when the charging current methodologies a periodic dimension the charging cycle is finished.

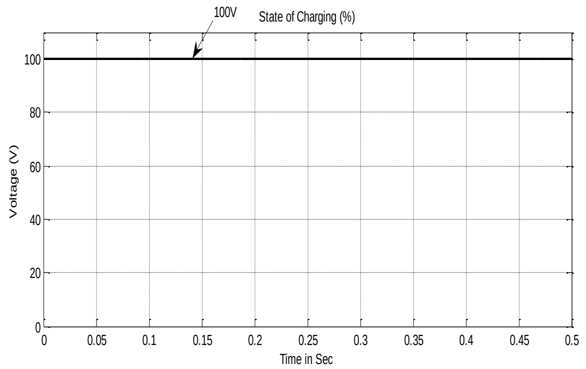

Fig: 8(a) State Of Charging (SOC{%})

This is the output states that how much percentage of charging. It was giving 100% of charging.

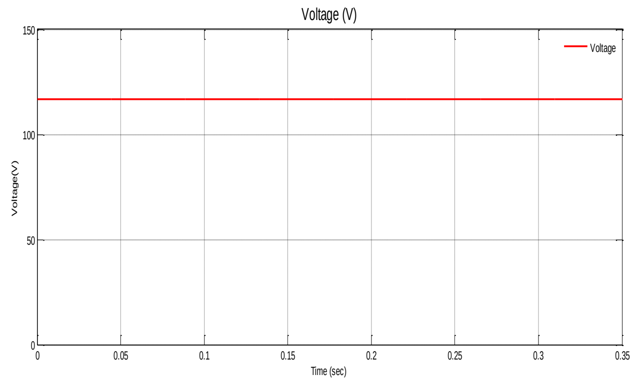

Fig: 8(b) Battery Charging Voltage

Above the output of battery it was charging at 120V volts. The outputs of five phase inverter have five output line voltages each line voltage connect to each mutual inductance total we have five charging ports.

X. CONCLUSION

In this paper, the principle target of this task is to transmit the power remotely with no contact inside a short separation through air medium. the 5-phase inductively coupled resonant converter is used for remote power applications like electrical vehicle. The structure theoretical examination has been performed. The affiliation plot and the phasor graph close by the turn extents are illustrated. The productive execution of the proposed affiliation plot is clarified by using proliferation and experimentation. A five-organize acknowledgment motor under a stacked condition is used to show the appropriateness of the change structure. It is ordinary that the proposed affiliation plan can be used in drives applications and may moreover be also researched to be utilized in multiphase power transmission systems. utilizing Pi controller is input to transmitter side inverter switches and the separation between the curls is in the middle of 20 to 40 cm. By using this inverter, we are getting five ports of charging. This task is going to execute in equipment structure in future.

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