CIRCUIT DESIGN OF EFFICIENT THREE-PHASE POWER TRANSFER AND FAST CHARGING FOR BATTERIES

Abstract- **Term WPT that stands for Wireless Power Transmission, has been familiar for decades. But due to less density of the low power along with other limitations like loss of high power, non-directionality, inefficient for longer distance the devices that are powered by battery are frequently facing challenging. This paper proposes a circuit design that is able to provide high efficient power without massive power loss, having a minimum output voltage which can be helpful and three-phase transformer has been included to the design for better output result. The simulation data provides a satisfaction result of battery charging and discharging. It appears that the battery charges comparatively fast and provides and efficient voltage like 30 volt (approximately) and both the voltage and current are much more stable. Even if a battery's initial charging state is set to 50%, the result shows that it will take some minutes to get charged 100% which is quite efficient, less time-consuming. Although more modified and advanced techniques are required to improve the power density and other features for high-power applications.**

Index Term- **inductive coupling, three phase power, wireless power transfer, universal bridge, RC Snubber circuit, Lithium-ion battery, state of charge (SOC).**

I. INTRODUCTION

Wireless Power Transfer is an emerging technology all over the world throughout the century because it can make the power transmitting by the air gap, without the need of current-carrying wires. Therefore, the electronic devices like cellphones, laptop, mp3 players, rechargeable batteries, trimmers etc. are able to receive the power, only by putting them on the specific platforms of the system module. Single phase system has always been used in WPT system for recharging devices, controlling robots, moving fuel-free vehicles. In this paper, the secondary of the three-phase system has been used in the circuit instead of the single-phase and the primary system has remained as single connecting with the other components of the design. Moreover, the star-delta connection of a three-phase transformer has been implemented here to obtain the desired output. As three-phase works following Faraday's Law, it is used for power generation and electrical distribution network operation and as a result, they are likely to be found in hi-power industrial loads as rectifiers, motor drives' equipment. So far most of the researches have been associated with three-phase WPT, performing as dynamic EV systems [1].

So far, most of the experiments have been conducted with the supply voltage fed into the primary side of a transformer and the secondary side remain as single phase or connected with the load [2]. But in this desired design, the secondary side of the transformer has been connected to act as the three-phase system. Moreover, the AC voltage that is rectified into DC voltage which then generated and get smoother by RC circuits. The secondary system of the three-phase transformer enables that rectified and converted smooth voltages to be balanced easily. As a result, the smooth capacitance gets reduced before the primary system may work to contribute a balanced output. The magnetic coupling creates a mutual inductance that may vary on the position of the primary with respect to the secondary. Some researchers have stated that the adjusting the impact of the inter-phase mutual inductance is possible.[3] The designed model that includes the three-phase transformer, itself creates a mutual inductance. Addition to this, RC snubber circuits are added to this model for reducing spike voltage that occurs at a switch node. Mainly, an internal diode is added with the MOSFET that makes it act as a resistance when the gate signal is applied.

The universal diode bridges here acts as to allow the simulation of diodes. The diodes of this model have internal resistance and internal inductance when these are in on-state [4]. The switches must be bi-directional in this case.

II. CONCEPT

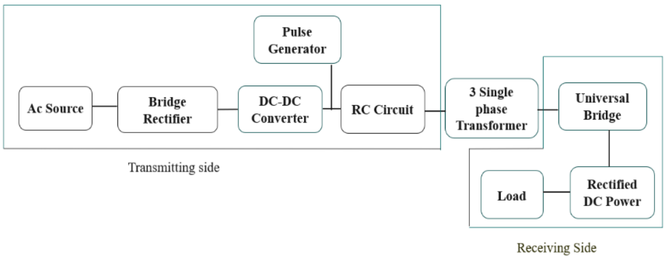
Three-phase transformer can distribute huge power to the needed load. The efficiency of energy transfer depends on the alignment, coils, the spatial orientation of the magnetic field. Here, the transformer that is being used has 12 terminals that would reduce the magnetic interference or noise among multiple coils. The AC supply has been connected with universal bridge, then with MOSFET that acts as a switching device here has been connected and these rectifies the AC into DC before it has been fed to the secondary side of the three-phase transformer. Thus, it at first works as a step-down transformer that converts the high voltage and low current into low voltage and high current to the other side of the transformer. Since the goal is to get as much efficiency as possible so that this design can be useful to other applications apart from charging devices, controlling other devices or cooking induction purposes. Electric power can be transferred via air easily by means of coupling (capacitive, magnetic), LASER, microwave or ultrasound.

Generally, there are two types of wireless power transfer system that includes (i) near- fields and (ii)far fields. The proposed topology is based on a design that provides a comparative better output so that this model can be used for various purposes especially in vehicle charging areas. Previously there has been work on increasing the power transfer by increasing the frequency of transmitting signal. But most of that cases, DC voltage sources were used to convert into AC and then rectified and then again converted to DC before connecting with the rest of the load. But in this paper, we propose a design that does not require any direct DC voltage source in order to work enormously.

III. PROPOSED TOPOLOGY

This paper represents a model that would provide a reliable voltage to run a system without the need of charging cables, wires. The block diagram in figure 1 gives the general idea of how the circuit works.

Figure 1: Block diagram that represents the proposed circuit



An AC wireless power transfer system where a three phase transfer two winding transformer is being used shown in figure 7. At first the AC voltage is rectified into DC and then the DC voltage in converted to fed into the secondary side of the three phase linear transformer which is the Wireless Power link, 12 terminals transformer. The efficiency of Wireless Power Transfer depends on the load resistance and unlike other models, we have tested it by connecting the load on the primary side. RC circuits have been used on both sides of the transformer.
Both universal bridge blocks have following parameters :

TABLE 1: Parameters of Universal Bridge

Parameter	Value	Unit
R_{on}	1e-3	Ω
R_S	1e5	Ω
C_S	inf	

TABLE 2: Parameters for simulation work

Parameters	Value	Unit
V_{in}	220	V
f	50	Hz
C1, C2	5	F
C3	280	F
R1, R2	100	Ω
R3	1500	Ω

IV. SIMULATION OF THREE PHASE TWO WINDING TRANFORMER

To create a three-phase system, three single transformers are required. Here, a linear transformer has been used as this type of transformer is highly used as a power distribution networks [5]. In order to reduce the current on each transmission coil along with the iron loss, copper loss, three phase transformer has been used here. Besides, the coils will allow to reduce the radiation noise by canceling the noise using pairs of coils placed opposite to each other. This transformer is a two windings linear transformer that has equal number of turns which has an advantage as the voltage present at the secondary side is same as the voltage applied at the primary side [6] and there is no power loss while circulating current or applying voltage.

The following schematic of three phase two winding transformer in figure 2 is simulated in MATLAB Simulink:

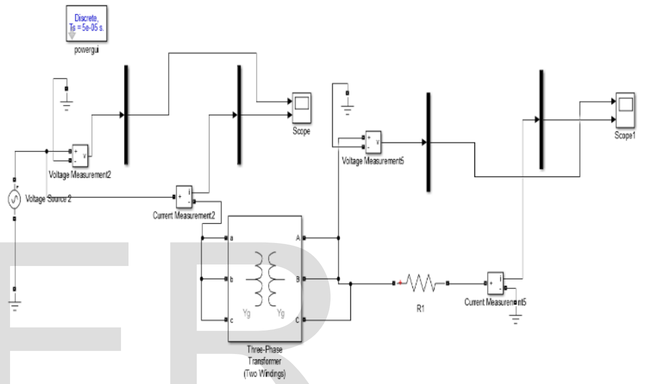


Figure 2: Single to three phase power conversion using three phase transformer rated as proposed diagram

TABLE 3: Parameter of Three Phase Two winding transformer

	Phase Voltage, (Vrms)	R (pu)	X (pu)
Winding 1	25e03	0.002	0.05
Winding 2	22e03	0.002	0.05

The magnetizing branch here is set as Rm= 400 pu; Xm= 400 pu

The primary & secondary side of the transformer have been connected as step down transformer. If we had to select ideal transformer, then the windings resistance would have been be zero.

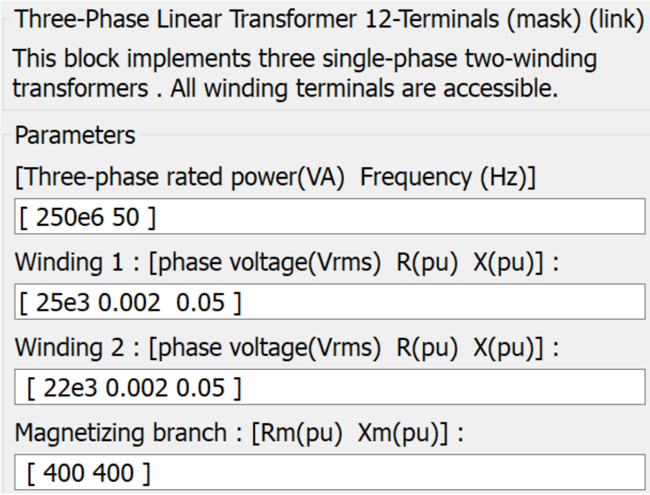


Fig 3: Dialog Box containing parameters

Rated power of three-phase transformer has been selected as 250e06 because three phase power can transmit more and efficient power than a single phase.

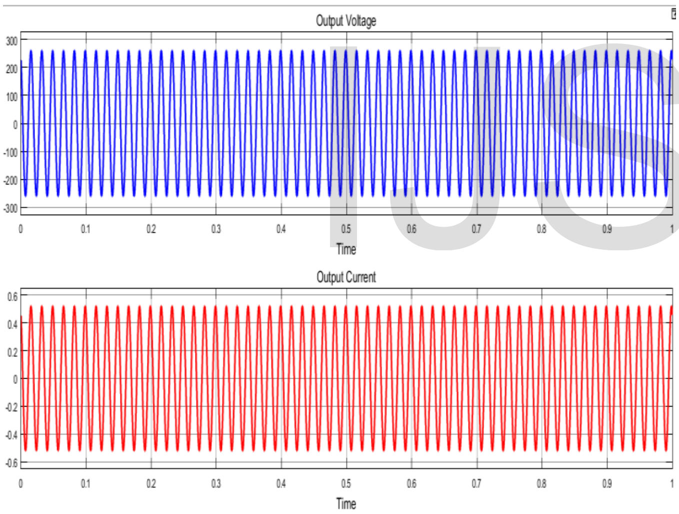


Figure 4: output voltage and output current of the single to three phase power conversion rated as the proposed design.

The output results are at single phase instead of three phase as we have connected the secondary side in single phase configuration while simulating.

V. BATTERY CHARGING MODE

The charging method of a battery effects the performance and life of a battery. The internal resistance of a battery increases if the battery operates in high charging current and as a result the battery gets damaged internally and battery life reduces exponentially. However, operating in low charging current might not be practical because battery can not be charged in low current.

TABLE 3: Specification of Battery

Battery	Lithium-ion
Nominal Voltage	12.8 V
Rated Capacity	12 Ah
Initial State of Charge %	90
Battery Response Time	15 seconds

Initially battery gets charged by the method of Current Controlled Mode and this process is continued till the nominal voltage and the voltage measured across the battery becomes equal. Apparently, Voltage control Mode turns on in which the voltage remains constant and the amount of current in a battery starts to get reduced. The whole process tends to be continued till a battery gets is charged fully [7].

VI. BIDIRECTIONAL DC-DC CONVERTER vs SINGLE TO THREE PHASE POWER CONVERSION

The proposed design is implemented using single to three phase power conversion. Previously, many model had been designed for battery charging and bidirectional dc-dc converter is one of them. In this paper, we have used the universal bidirectional DC-DC converter to compare with the result of proposed model using the following parameters.

TABLE 4: Parameters for converter

Parameters	Value	Unit
Vin	200	V
R1, R3	10	Ω
R2	100	Ω
L	0.0004	H
C	10e-9	nF

The above-mentioned parameters have been used to run the simulation for the same specified Lithium-ion battery in order to verify if this model is suitable or not. All these designs (figure: 2, 5, 6) are simulated and results are recorded with MATLAB Simulink software. As our desired model represents how fast a battery can be charged, we have converted the output into single power to observe the accuracy of result.

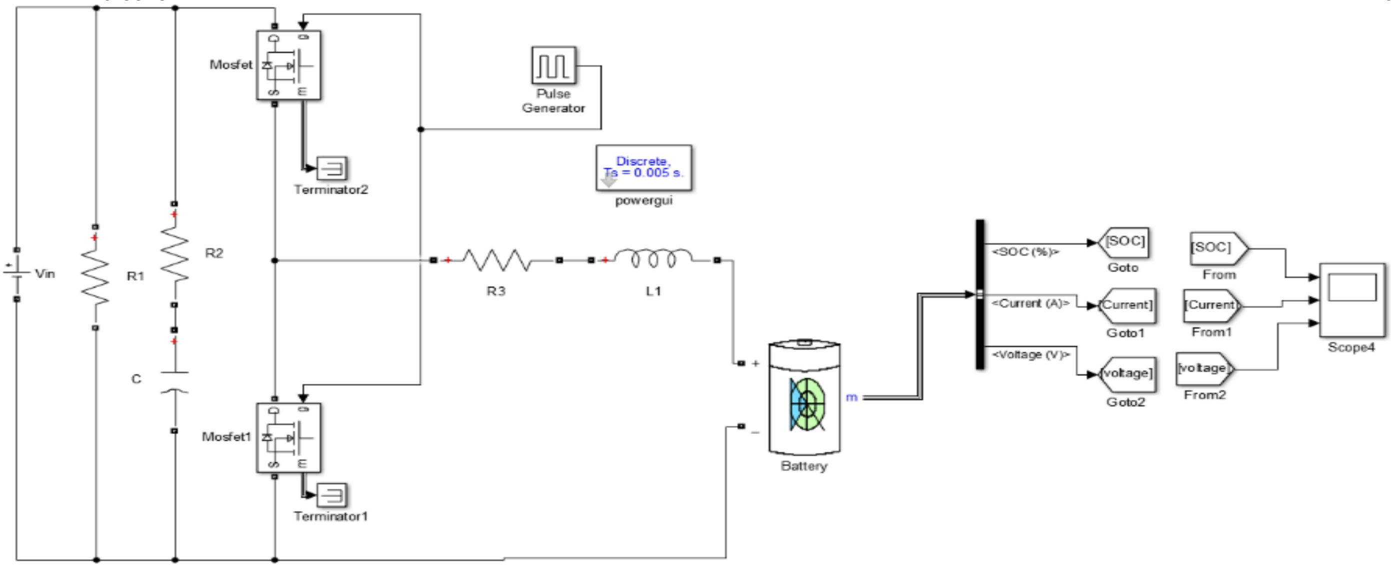


Figure 5: Bidirectional DC-DC Converter for charging battery

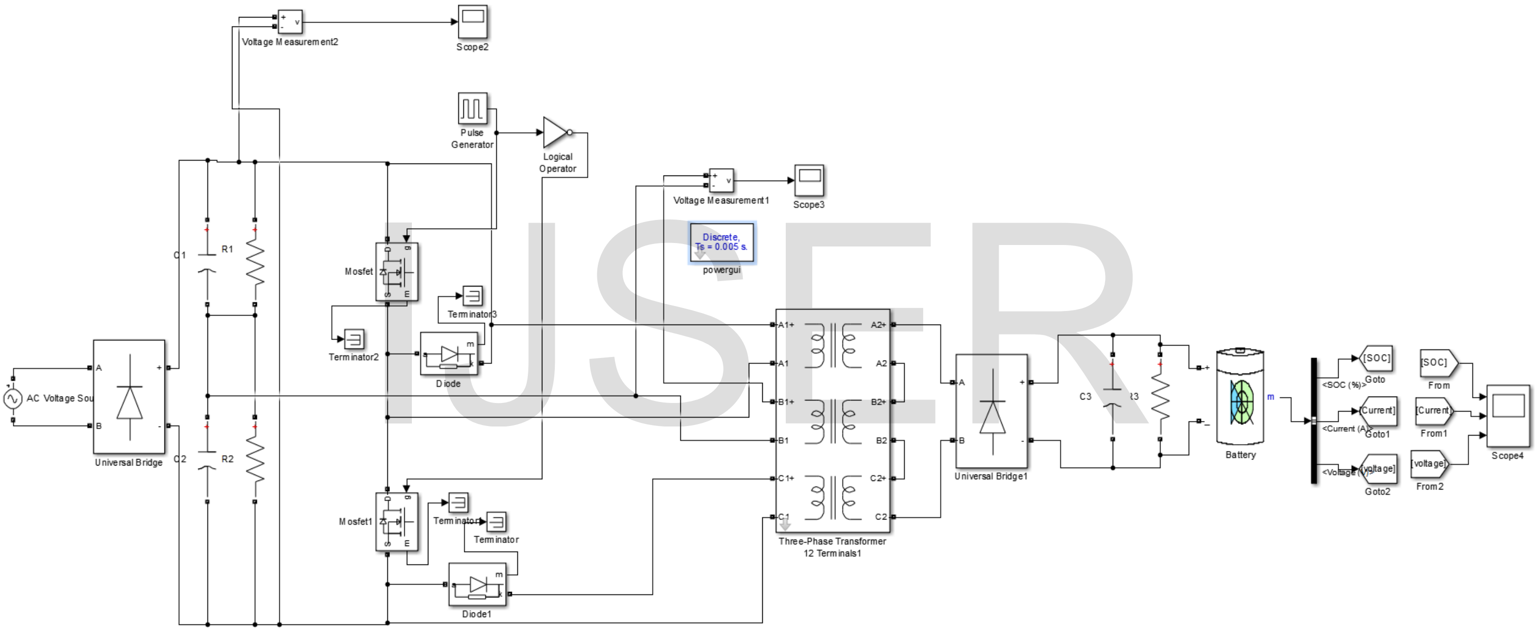


Figure 6: Proposed design of single to three phase power conversion for battery using three single phase transformer

We know, Battery capacity= Charging Current * Charging time

Now, mAh which stands for the milliampere-hour is the technical term. It refers how much electrical charge a battery can hold. The formula of battery mAh is, (A)*(h)*1000 = (mAh)

VII. SIMULATION RESULTS AND DISCUSSION

The simulation results for both of the circuit (Figure 5,6) are shown in this section. Figure 7.1-7.2 are the result after simulating bidirectional DC-DC converter (figure 5) & figure 8.1-8.3 are results of our proposed model (figure 6). The running simulation time is set to 150 units.

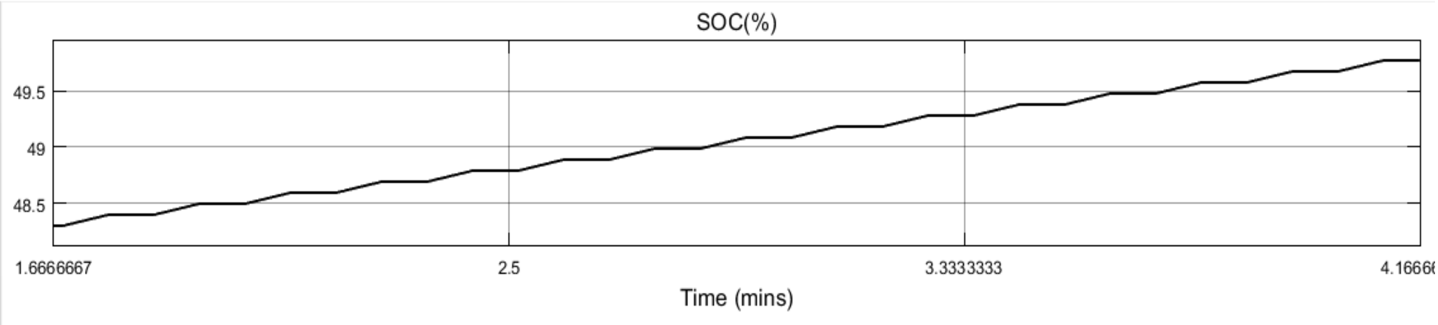


Figure 7.1: State of Charge of Battery (SOC) vs Time for DC-DC Bidirectional Converter

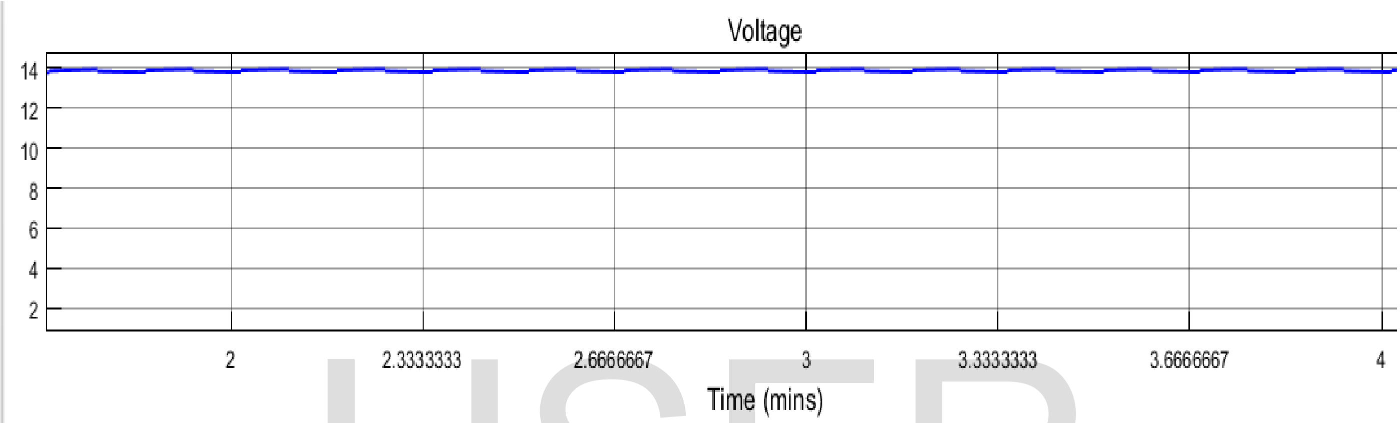


Figure 7.2: Battery Voltage Characteristics vs Time for DC-DC Bidirectional Converter

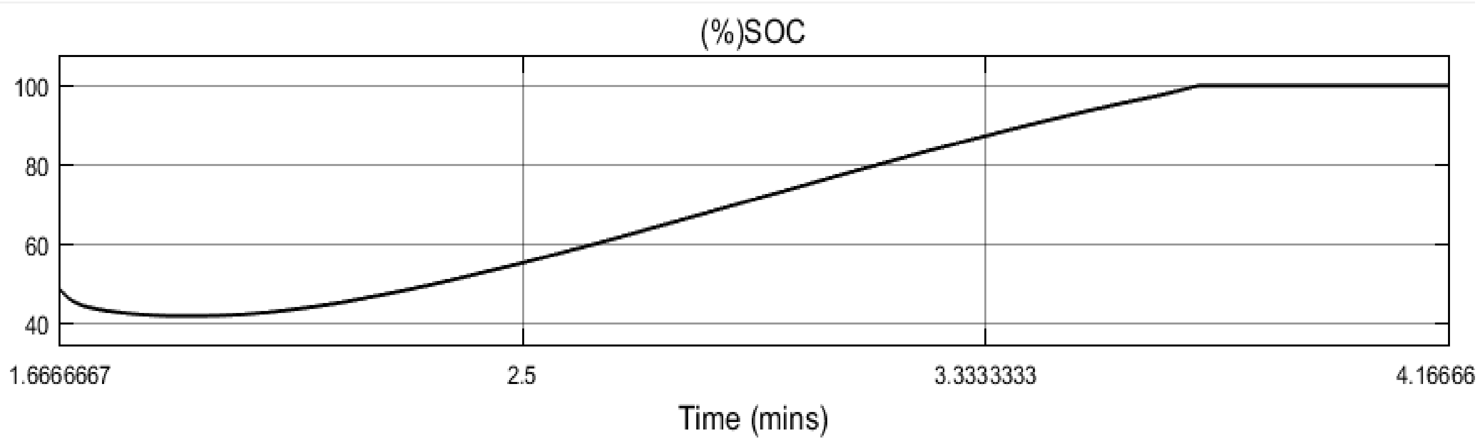


Figure 8.1: State of Charge of Battery (SOC) vs Time for proposed design

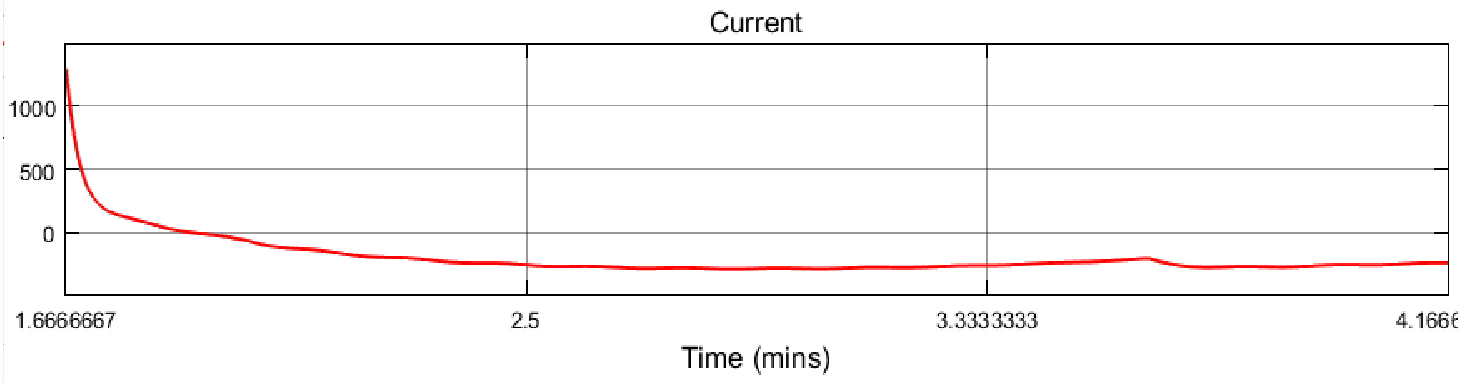


Figure 8.2: Battery Current Characteristics vs Time for proposed design

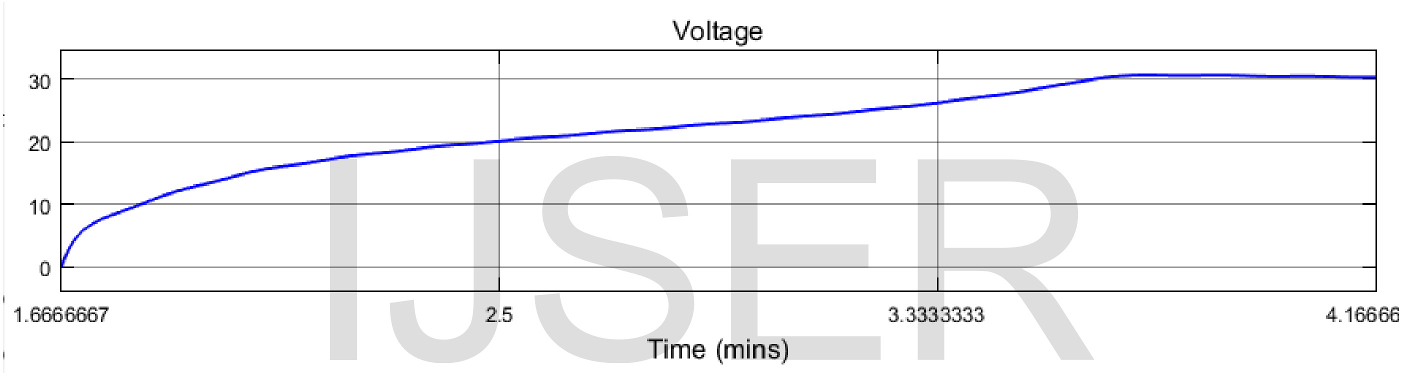


Figure 8.3 : Battery Voltage Characteristics vs Time for proposed design

The results from the graphs of our desired model clearly shows that the voltage is much more steady and stable throughout the whole simulation. We set the time here as 10 minutes (600 seconds) to analyze the differences of both models. The current and voltage are less likely to be rippled in our desired model. According to figure 8.1, we observe that the battery at it's initial charge is set 50% and even though it discharges with time, it starts to get charged within the time and reaches to 100%. From figure 8.3, we can also analyze that the voltage starts to increase with time and in respect to the discharging state of the battery and after a certain time it gets stable comparatively than the bi-directional converter system (figure 7.3). The acquired result and data show that using the single phase to three phase power conversion is a better topology for charging a powerful battery.

VIII. CONCLUSION

This paper presents a method of implementing a wireless power transfer module that is built up by a single AC power to three phase power conversion by using a three phase transformer. The main focus of the design is to provide efficient power or energy so that a higher capacitive battery can get charged comparatively fast. The proposed construction of circuit design can be used in many applications like motor drives, car vehicles, renewable energy, continuous power supply etc. Wireless Power Transmission system using three single phase transformers has been almost common so far. This paper presents such implementation that focuses on obtaining a comparatively better power. A MATLAB Simulink model is designed in order to implement this proposed model. From the result analysis, it can be stated that this design does not require any inductor to supply voltage or generate power. The output current contains little harmonic but the ripple is very less in proposed WPT system.

IX. REFERENCE

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