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Wireless Charging Of Electric Vehicles

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Abstract
Electricvehicle(EVs)drivesofferanumberofadvantagesoverconventionalinternalcombustion engines, especially in terms of lower local emissions, higher energy efficiency, anddecreased dependency upon oil. Electric Vehicles are popular for their zero-pollution emission.WirelessPowerTransmission(WPT)ispopularandgainingtechnologyinEVthatcanovercomethelimitationsofplug-inmethod.Thepoweristransferredfromasourceto an electrical load without the need of interconnections. Sufficient power for the batterycanbetransferredtosecondarysection.Anon-boardreceivingpadinchasisofvehicleand an external charging pad is placed in the pavement of charging station constitute thewireless charging system. Wireless Power Transfer provides energy to the battery, increasing the driving range and overcoming 'range anxiety' depending on the transmission powerlevel.Thelossescanbereducedbyusingseries-seriescompensationtopology.Themaximumpower transfer can be obtained by using Resonant inductive power transfer method.TheWireless Electric Vehicle Charging System, solution for future automation can also reducetheproblemsassociatedwithrangeandcostofEVs

Keywords:*EV, WPT, RIPT, WCS, EMC, BMS, CWPT, IPT, RIPT*

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I. INTRODUCTION

A Wireless Power Transfer (WPT) is one of the promising technologies used to transferelectricenergyfromatransmittertoareceiverwirelessly.WPTisanattractivesolutionfor many industrial applications due to its enormous benefits over wired connections. Theadvantagesincludethenohassleofcarryingwires,easycharging,andsmootofpowertransmissioneveninunfavorableenvironmentalcircumstances. Theideaofwirelesspowertransfer(WPT) was first introduced at the end of the 19th century by Nicola Tesla. He manufacturedawirelesslightingbulbthatwasusedtoreceiveelectricalchargewireless[1].Teslausedtwometal plates that were closely placed to each other. A high-frequency Alternative Current(AC) potentials were passed between these two plates, and the bulb powered ON. WirelessChargingSystems(WCS)havebeenproposedinhigh-powerapplications,includingEVsandplug-inelectricvehicles (PEVs)instationaryapplications.Incomparisonwithplug-in charging systems, WCS can bring more advantages in the form of simplicity, reliability,anduserfriendliness.TheproblemorlimitationassociatedwithWCSisthattheycanonly be utilized when the car is parked or in stationary modes, such as in car parks, gar-ages, or at traffic signals. There are two main categories to the technology, which are staticanddynamiccharging.Asthenamesimply,staticchargingisavailablewhenthevehicleis stationary and dynamic charging is the process of supplying power to an EV while it ismoving. Early systems for WPT for EVs focused more on dynamic charging. The work isoneoftheearliestproposalsofRoadwayPoweredEVs(RPEVs).RPEVsareEVsthatderiveralltheirenergyfromaprimarysideinductorimplantedintothedrivingsurfacereceivedby a secondary inductor in the vehicle, thus limiting the journey range to the length of thepowereddrivingsurface.

Inaddition,stationaryWCShavesomechallenges,suchasElectro MagneticCompatibility (EMC) issues, limited power transfer, bulky structures, shorter range, and higher efficiency. In order to improve the two areas of range and sufficient volume of battery storage, dynamic mode of operation of the WCS for EVs has been researched. This method allows charging of battery storage devices while the vehicle is in motion. The vehicle requires less volume of expensive battery storage and the range of transportation is increased. However, Aligning the optimal driving position on the transmitter coil can be performed easily because the car is driven automatically in the dynamic mode. In addition, different compensation methods, such as series and parallel combinations, are employed on both the transmitting and receiving sides to reduce parasitic losses and improve system efficiency. The fundamental operation of WCS for EVs, including methods of power transfer, is analyzed and in addition, a variety of wireless transformer structures are explained in order to improve power transfer efficiency. The wireless power transfer (WPT) technology, which can eliminate all the charging troublesome, is desirable by the EV owners. By wirelessly transferring energy to the EV, the charging becomes the easiest task. For a stationary WPT system, the drivers just need to park their car and leave. For a dynamic WPT system, which means the EV could be powered while driving; the EV is possible to run forever without a stop. Also, the battery capacity of EVs with wireless charging could be reduced to 20 percentage or less compared to EVs with conductive charging.

1.1Objective

TheobjectiveofthisprojectistostudybasicWPTtheoryandtogivebriefoverviewofthemainpartsinaWPTsystem. Italsoincludesthestudyanddesignofmagneticcoupler, compensation network, power electronics converter, and its control. The designshould be of fixed air gap and low losses. Efficiency can be improved by increasing thevalue of coupling coefficient.Also, to design an adaptive inductive resonant WPT chargingprototypeforchargingelectricvehicle

II. METHEDOLOGY

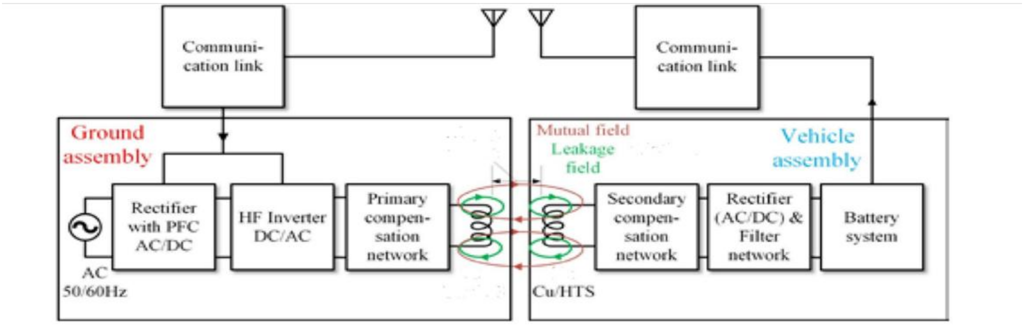

Figure 1: Basic block diagram of WPT system

Basic operating principle the basic block diagram of the static WCS for EVs is illustrated.ToenablepowertransferfromthetransmissioncoiltothereceivingcoiI,ACmainsfromthegrid is converted into high frequency (HF) AC through AC/DC and DC/AC converters. Inordertoimproveoverallsystemefficiency,seriescombinations-basedcompensationtopologyis included on both the transmitting and receiving sides.The receiving coil, typicallymountedunderneaththevehicle,convertstheoscillatingmagneticfluxfieldstoHFAC.TheHFACisthenconvertedtoastableDCsupply,whichisusedbytheon-boardbatteries.Thepowercontrol,communications,andbatterymanagementsystem(BMS)arealsoincludedto avoid any health and safety issues and to ensure stable operation. Magnetic planar ferriteplates can be employed at both transmitter and receiver sides, to reduce any harmful leakagefluxesandtoimprovemagneticfluxdistribution.Inwirelesschargingtherearetransmitter. andreceiver,220V50HzACsupplyisconvertedintoHighfrequencyalternatingcurrentandthis high frequency AC is supplied to transmitter coil, then it creates alternating magneticfieldthatcutsthereceivercoilandcausestheproductionofACpoweroutputinreceivercoil.Buttheimportantthingforefficientwirelesschargingistomaintaintheresonancefrequencybetween transmitter and receiver.To maintain the resonant frequencies,compensationnetworksareaddedatbothsides.Thenfinally,thisACpoweratreceiversiderectifiedto DC and fed to the battery through Battery Management System (BMS) and can bemonitoredthroughourphoneusingWi-Fimodule.

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III. WIRELESS POWER TRANSFER

Wireless charging consists in transferring energy from the source to the load without physical contact.This technology can be applied to EV battery charging for which daily recharge is mandatory. The tedious and inconvenient aspects of connecting the power cable hinder some users and may hinder the development of the EVs. A user-friendly solution consists in using a system of power transmission without contact. This solution provides ease of use and a good robustness to vandalism. With the introduction of Wire charging technology, no more waiting at charging stations for hours, now get your vehicle charged by just parking it on parking spot or by parking at your garage or even while driving you can charge your electric vehicle. As of now, we are very much familiar with wireless transmission of data, audio and video signals so why can't we transfer power over the Air. A general block diagram for the contactless charger for EV battery

3.1 Wireless Power Transfer Methods

A generic WPT consists of a transmitter supplied with high frequency alternating current (AC), which is generated by a high frequency power converter. The transmitter is coupledwith a receiver either through an electric, magnetic or electromagnetic field and induces a voltage in the receiver.[1] The voltage induced at the receiver is fed to the load through a power converter to match the voltage according to the load specifications.

3.1.1 Capacitive Wireless Power Transfer

The low cost and simplicity of CWPT technology, using advanced geometric and mechanical structures of the coupling capacitors, is very useful for low-power applications, such as portable electronics devices, cellular phone chargers and rotating machines. In the CWPT, coupling capacitors are utilized to transfer power from the source to the receiver instead of using coils or magnets. The main AC voltage is applied to an H-bridge converter though power factor correction circuitry. High-frequency AC generated by the H-bridge passes through coupling capacitors at the receiver side. The use the car's bumper bar as a receiver, to reduce the air gap between the two coupling plates. A stationary laboratory prototype >1 kW was demonstrated with approximately 83 % efficiency from the DC source to the battery bank at the 540 kHz operating frequency.in transmitter and receiver sides at the resonant arrangement, additional inductors are added in series with the coupling capacitors.

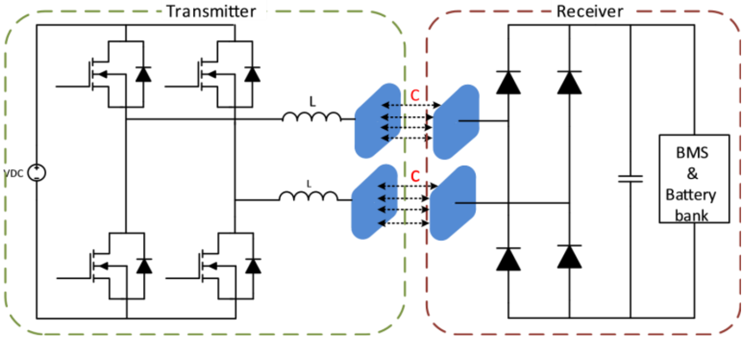

Figure 2: Capacitive Power Transfer

3.1.2Inductive Wireless Power Transfer

Traditional IPT was developed by Nikola Tesla in 1914 to transfer power wirelessly.ThebasicblockdiagramofthetraditionalIPTispresentedinFig.3.7.ItisbasedonseveralEV charging structures. IPT has been tested and utilized in a wide variety of areas rangingfrommilliwattstokilowattstotransfercontactlesspowerfromthesourcetothereceiver.In1996,GeneralMotors(GM)introducedtheChevroletS10EV,whichwaschargedbythe magnet-charge IPT (J1773) system to provide level 2 (6.6 kW) slow and level 3 (50 kW)fast charges [3].The primary coil, known as a charging paddle (inductive coupler) of themagnet-charge,wasinsertedintothevehiclechargingportwherethesecondarycoilreceivedpowerandallowedtochargethe EV

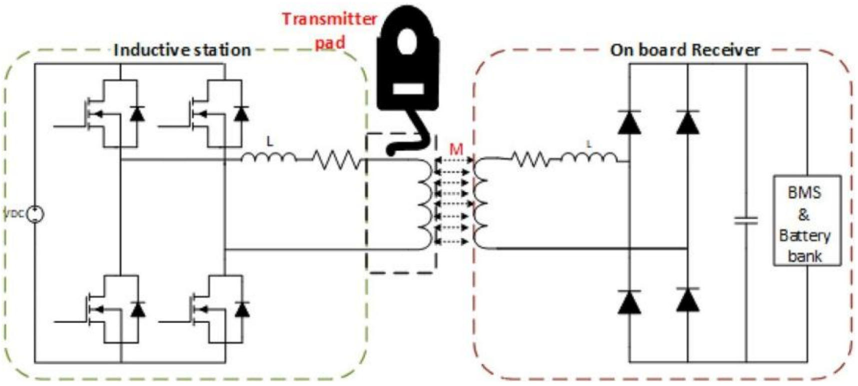

Figure 3: Inductive Power Transfer

3.1.3 Resonant Inductive Wireless Power Transfer

Resonant inductive power transfer(RIPT) is one of the most well-known and advanced versionsofthetraditionalIPT,intermsofdesigningpowerelectronicsandwirelesstransformercoils. Fig.3.8 shows the schematic diagram of the RIPT for EVs. Like other WPTs, the mainAC voltage is converted into the HF AC source and supplied to the transmitter or primarywinding.The receiver or secondary coil receives power via varying magnetic fields.Thereceived power is converted to DC for the battery bank of the EVs through additional powerelectronics and filter circuitry. In comparison to the traditional IPT, additional compensation networks in the series and/or parallel configurations are added to both the primary andsecondary windings. where fr is the resonant frequency of the primary and secondary coils,and L and C are the self-inductance and resonant capacitor values of the transmitter andreceiver coils, respectively.When the resonant frequencies of the primary and secondarycoils are matched together, efficient power transfer is possible. The operating frequency ofthe RIPT ranges from tens of kilohertz to several hundred kilohertz.The magnetic fluxgenerated at this frequency range, without any magnetic core, has a significantly adverseeffect on the mutual inductance and hence the reduction of the coupling coefficient (k). Thevalue of the coupling coefficient in the RIPT varies from 0.2 to 0.3 due to the minimumheight clearance requirement of the EVs, which is 150–300 mm can be applied to calculatethe coupling coefficient.Lp and Ls are the self-inductance of the transmitter and receivercoils, respectively. Lm is the mutual inductance between the two coils. If the primary andsecondary coils are strongly coupled, the mutual inductance value would be higher.Since maximum power transfer can be obtained in Resonant Inductive Power Transfer, thismethodisoptedforthisproject.

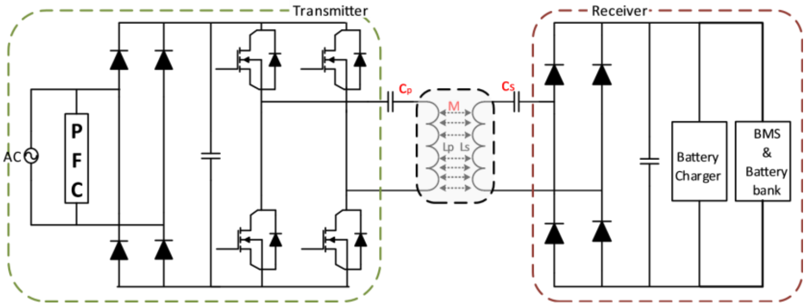

Figure 4: Resonant Inductive Power Transfer

3.2 Compensation Topologies

It is required to use a compensation network to reduce the VA rating in the coil and power supply. In early inductive charging designs, the compensation is set on primary or secondary side only. When the coupling coefficient is reduced to less than 0.3 in the EV WPT, compensation at both the primary and secondary side is recommended to have a more flexible and advanced characteristics.To compensate a leakage inductancethe simplestway is to add a capacitor at each side.Depending on how the capacitors are connected to the coils, there are four basic compensation topologies, which are Series-Series, Parallel-Series, Series-Series, Series-Parallel.
S-S compensation is selected as the value of the capacitor in the source and receiver sides is independent from the load conditions and mutual inductance. As a result, the resonant frequencies of the source and receiver sides are not reliant upon the mutual inductance and loads but depend on self-inductance of the primary and secondary coils. The second advantage is that such systems maintain a unity power factor by drawing active

power at the resonant frequency as the reflected impedance from the receiver coil does not add an imaginary part in the transmitter coil [2].ThisSStopologybasedWCScanofferabetterbatterychargingoptionbecauseitmayofferaconstantvoltageand currentforthebattery.

3.3Coil Geometry

ThecouplingcoefficientvalueKchangeswiththechangeinairgap. Efficiencyincreaseswithincreasedkvalue.Afteracertainpointitwillbeconstant.ThechangeinKalsodependsup on the coil alignment and its specification. The value of k will be maximum when the twocoilsarealignedaxiallywithsameairgapfortwoloops.

Mutual Inductance, $M=\frac{k}{\sqrt{L_1L_2}}$ (1)

Number of Primary turns (N_1)=100 (2)

Number of Secondary turns(N_2) =150 (3)

Primary Inductance, $L_1 = N_1^2\mu_0(\ln(\frac{8a}{r1} - 2))$ (4)

Secondary Inductance,$L_2 = N_2^2\mu_0(\ln(\frac{8a}{r2} - 2))$ (5)

$M = N_1N_2\mu_0\sqrt{ab}m^{\frac{3}{2}}$C(m) (6)

Table 1: Coil parameter and specifications

Primary Turns	100
Secondary Turns	150
Primary Inductance	10.43 μH
Secondary Inductance	60.86 μH
Resistance	0.121 ohm
Mutual Inductance	10.43 μH
Coupling Coefficient	0.48

IV. SIMULATION

The simulation was carried out using the MATLAB. The variousparameters used for simulation are given. The input is given by a constant dc supply.Theoutputwaveformistakenacrosstheloadresisterconnectedinreceivercircuit.

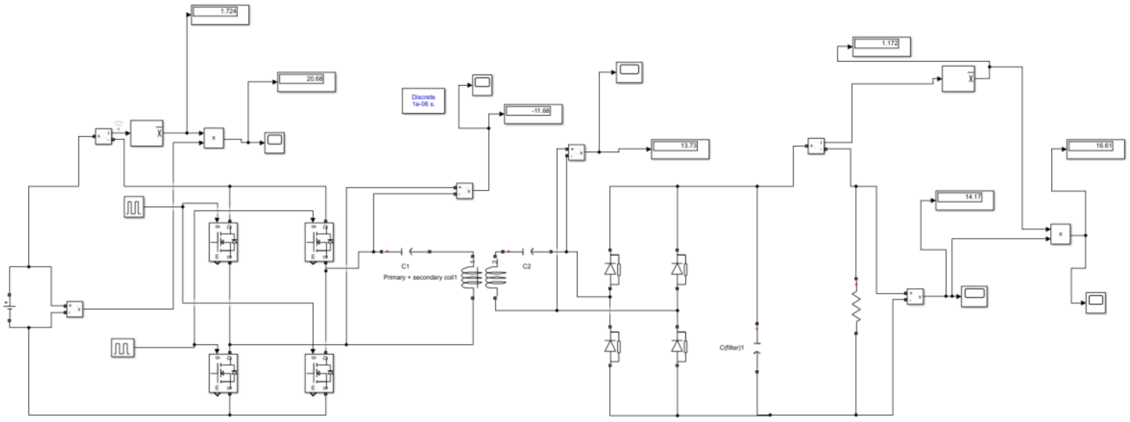

Figure 5: Simulink Model

Table 2: Simulink parameter and specifications

Input Voltage	12V
Input Power	20.71 W
Output Power	16.87 W
Filter Capacitor	1000μF
Resistor	10 Ohm

Theinputpowerofthesimulationisgivenbyfig6 and the outputparameterfromgraphisgivenbyfig.7 Fromthegraphitisclearthat

Efficiency=Outputpower∗100/Input power (7)

whichisapproximatelyabout82%

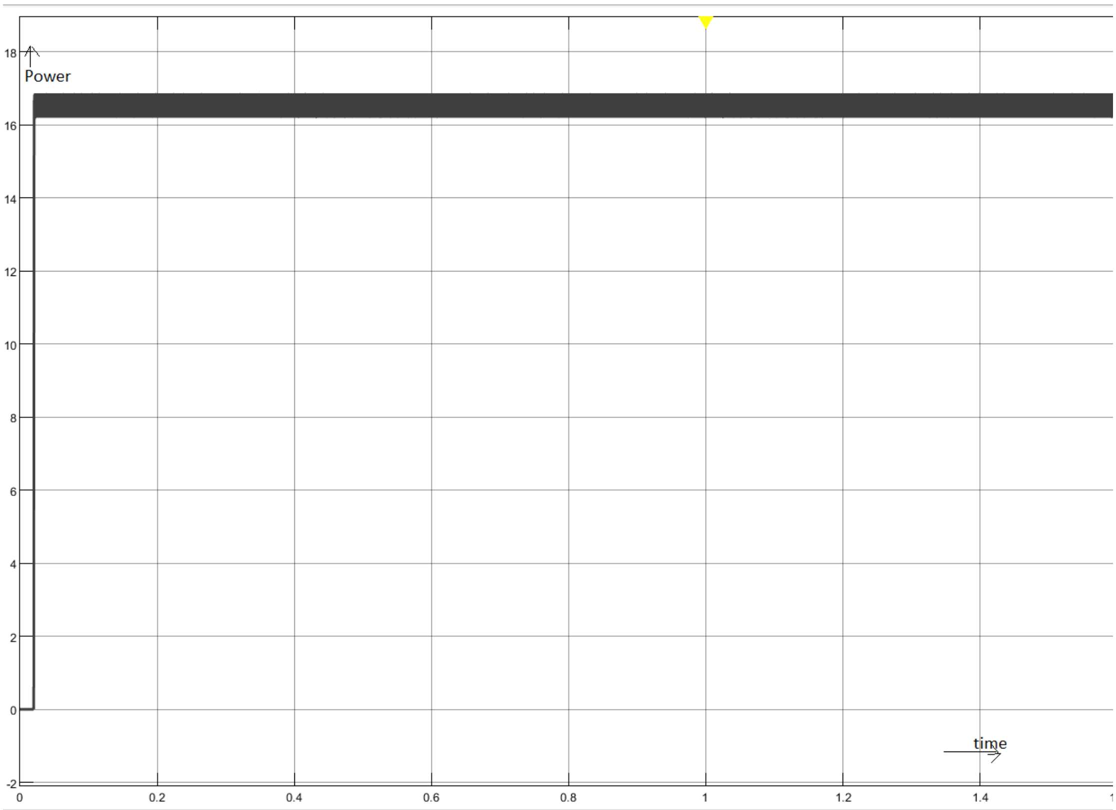

Figure 6: Input Power Graph

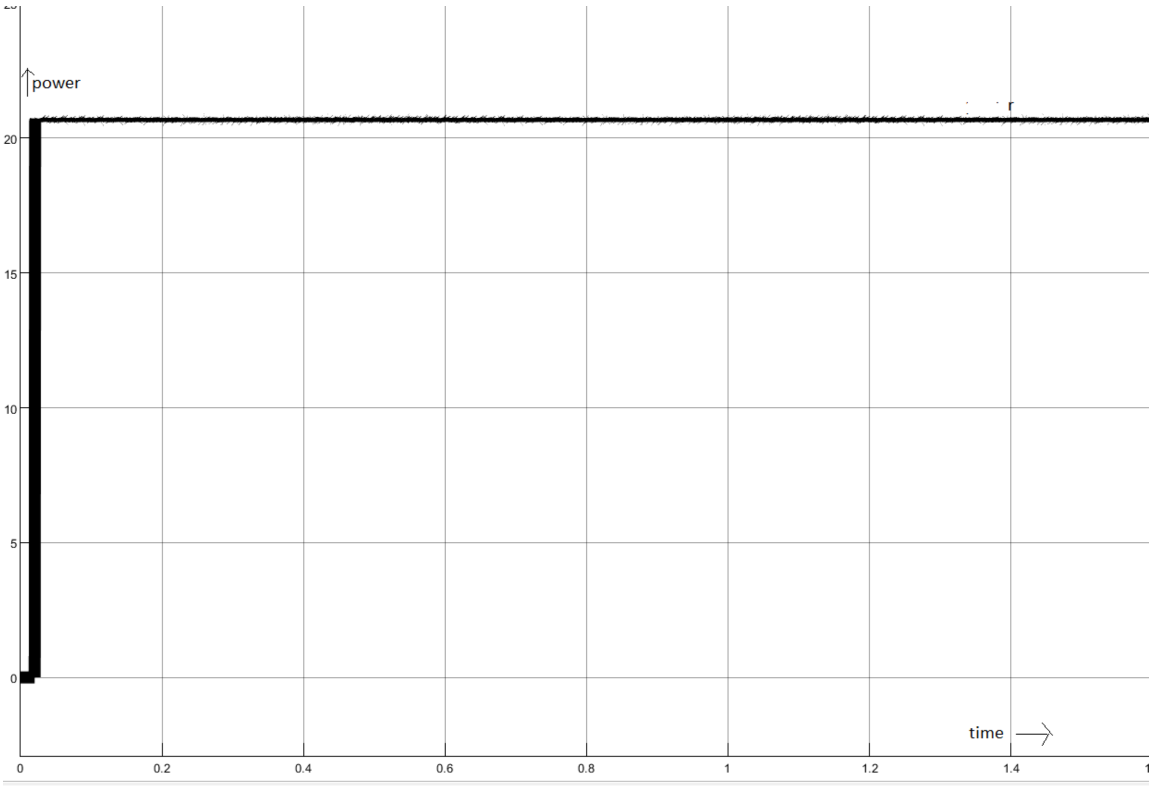

Figure 7:Output Power Graph

V. HARDWARE IMPLEMENTATION

Transmittersection in fig 8 consistsofArduinoUNOascontroller,RFIDmoduletoreadvehicletag, IR transmitting and receiving sensor to sense the presence of charging vehicles,DC/AC converter to convert input DC to AC for producing magnetic flux in primary coil,motor to control the working of gate, and lcd display to display real time status of prototype

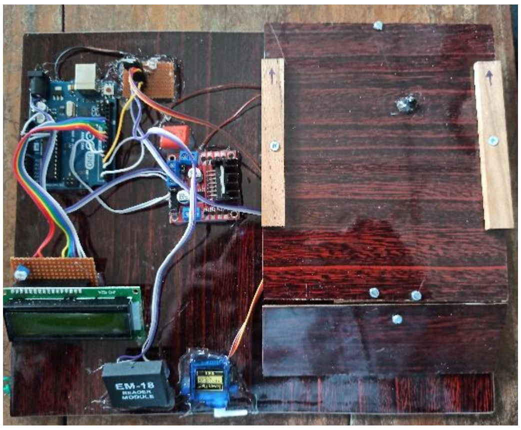

Figure 8:Transmitter Section

Receiver section in Fig 9 consists of receiving coil, AC/DC converter to convert inducedAC to DC to charge the battery. Voltage controller and BMS provides protection for batteryby control the voltage and current input for battery.Also, with the aid of Wi-Fi module[3]BMSprovidesrealtimechargingstatusofbatterythroughIoT

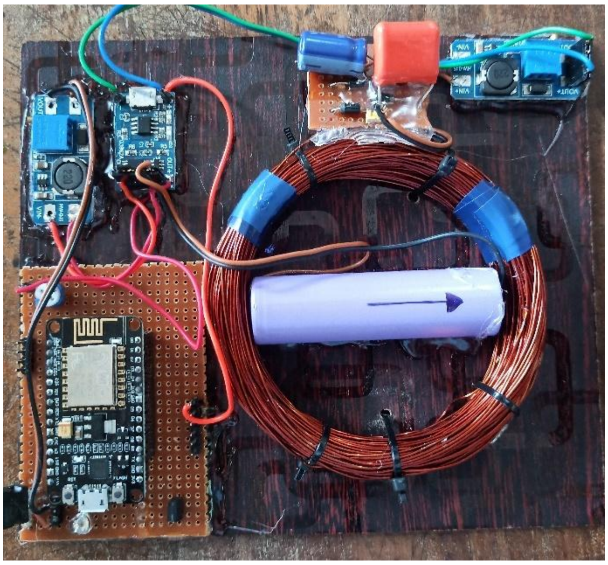

Figure 9:Receiver Section

Arduino UNO is supplied by 12V DC and which is used to run other components - RFID module, object sensor, H-Bridge inverter, servo motor and lcd display. The given 12V is step down to 5V by voltage regulator for the safe working of components. Arduino have in-built voltage step down converter which step down 12V input to 5V.

A DC voltage of 12V is converted to 12V AC through H-Bridge inverter. This 12V ACis transferred to the primary coil of 100 turns.A rotating magnetic flux is produced inprimary coil.RFID module is placed in order to check whether it is an authorized or anunauthorized user.Lcd displays "waiting for ID" until RFID reads a vehicle tag. WhenRFID read the vehicle tag, if the vehicle is registered then the gate opens for 5 sec otherwiseit remains closed.Lcd shows "authorised" when registered tag reads and "unauthorised"whennon-registeredtagreads.Thetimeperiodforgateopeningcanbeadjusted.
Whenthesecondarycoilisplacedontopoftheprimarycoilwithanairgapof3cm,and is aligned to have maximum power transfer.An emf is induced in the secondary coil of150 turns and an alternating current flows

through the secondary coil. This AC is convertedto DC with the help of a rectifier circuit. The DC output is boosted to 5V by voltage boostregulator. BMS input voltage must limited to 5V. From BMS, the voltage is controlled torecharge the battery. Battery draws 600mA current. Also, BMS output connect with Wi-Fimoduletomonitorrealtimechargingstatusofvehicleinuser'smobilephonethroughIoT.

Figure 10:Battey Status

VI. CONCLUSION

In this project, wireless charging of Electric Vehicles is proposed. The prototype developedis to charge a 2200 mAh battery through the wireless charging method with an air gap of 3cm.The battery draws 600 mA current and the discharge rate is 1.1A per hour. Registeredusers could access wireless charging technology to recharge their vehicle's battery whileparking and non-registered vehicles will be restricted from using this technology.Voltageregulators are used to regulate the output voltage amplitude to a safe and necessary level.Users can also monitor vehicle's real-time charging status through their mobile phones. Theproposedsystemcanbeestablishedcommerciallytodevelopfurtherbyincreasingtheratingof the components used. Even though it requires a huge investment, it is a better alternativetoovercomethelimitationsfacinginEVcharging. Thissystemalsohelpsustoovercometheproblemofdifferentprobshavingdifferentadaptershapes

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