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Analysis and Design of Bi-Directional Power Regulator with wireless Power Transfer Technology for Electric Vehicles

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ABSTRACT:Wireless charging has the power to greatly increase the convenience and accessibility of electric vehicles for charging. Wireless charging involves transferring power from the electric grid to a battery without the use of wires, cords or plugs. Electric vehicles not only draw power from the grid but also can supply surplus energy to grid or home when power consumption peaks or power outage. This is done with the help of bi-directional wireless power transfer technology. A wireless electric vehicle charging system based on inductively coupled power transfer (ICPT) technology is presented in this project. A simulation system is built in the Simulink, and the feasibility of the system is proved by simulation results.

KEYWORDS: bi-directional wireless power transfer; energy feedback; electric vehicles; power regulation.

I. INTRODUCTION

Electric vehicles are used throughout the materials handling industry because they are low cost, reliable, inoffensive, and simple to control compared to alternative forms of motive power. The design focuses on the necessary approaches to ensure power transfer over the complete operating range of the system. As such,a new approach to the design of the primary resonant circuit is proposed, whereby deviations from design expectations due to phase or frequency shift are minimized. Vehicle–to-grid (V2G) or G2V systems essentially require an interface between the electric vehicle (EV) and the grid to facilitate the V2G concept. The proposed bi-directional wireless power interface is based on the Inductive Power Transfer (IPT) Technology, and comprises a high frequency IPT system and a low frequency bi-directional grid side inverter. A DQ controller is employed to regulate the power flow to and from the grid. Based on resonance soft switch, the authors have proposed a bi-directional power conversion topology with voltage type and high frequency in which it also establishes a double working mode: energy injection mode and autonomous running mode. The authors have presented an Inductive Power Transfer (IPT) technique for transferring power from one system to another with no physical contacts. Until now this technique has been widely used only for unidirectional power delivery in numerous applications over a wide power range. The authors have proposed a new feedback method for PR current control of LCL –filter based grid connected inverter. The weighted average value of the currents flowing through the two inductors of the LCL filter is used as the feedback to the current PR regulator. Based on the above analyses, this paper designs a wireless electric vehicle charging system with energy feedback mode on the occasion of large inductance existing in dc supply side, which can achieve electric vehicle and grid or home wireless energy exchange. The schematic diagram of system structure is as shown in fig. 1.

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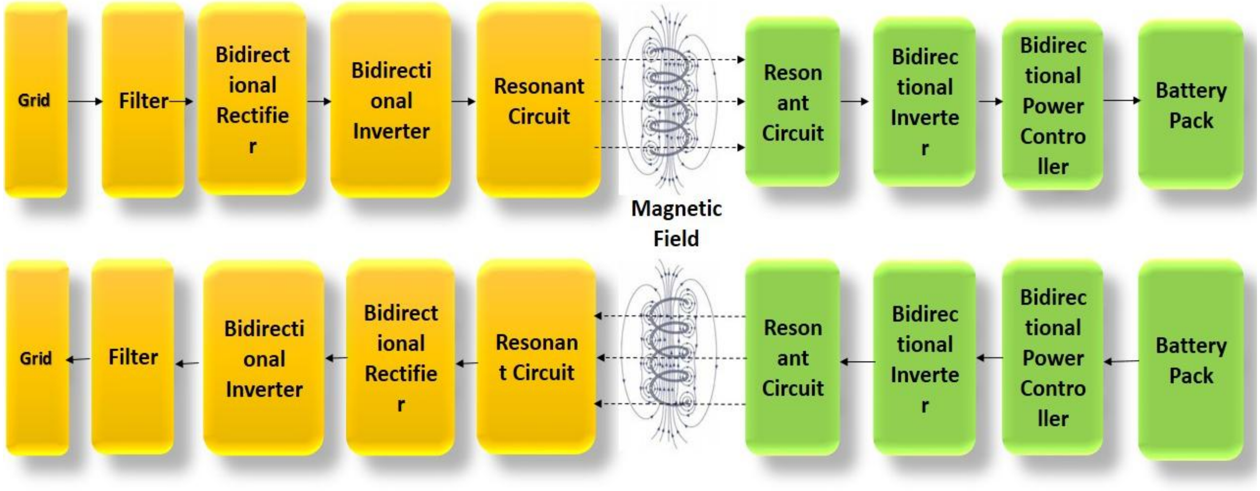

Fig.1 Schematic diagram of wireless charging system with energy feedback mode for electric vehicles

As can be seen from Fig. 1, the flow of energy charging takes place from grid- rectifier of charging machine side-inverter of charging machine side-resonant circuit-rectifier of vehicle side-power regulator of vehicle side-vehicle battery. Energy flow with energy feedback takes place from vehicle battery-power regulator of vehicle side-inverter of vehicle side-resonance circuit-rectifier of charging machine side-inverter of charging machine side-line connected filter-grid.

II. LITERATURE SURVEY

[1] In the year 1994, A W Green and J T Boys has proposed “10 kHz Inductively Coupled Power Transfer Concept and Control”. Fifth International conference on Power Electronics and Variable Speed Drivers, 1994:694-699.Electric Vehicles are used throughout the materials handling industry because they are low cost, reliable, inoffensive and simple to control compared to alternative forms of motive power. [2] In the year 2005, Chwei-Sen Wang, Oskar H Stielay and Grant A Covic has proposed a “Design considerations for a Contactless Electric Vehicle Battery Charger”. IEEE Transactions on Industrial Electronics. 2005, 52(5): 1308-1314.The design focuses on the necessary approaches to ensure power transfer over the complete operating range of the system. As such, a new approach to the design of the primary resonant circuit is proposed, whereby deviations due to phase or frequency are minimized.[3] In the year 2010, Duleepa J. Thrimawithana and Udaya K. Madawala and Yu Shi has proposed “Design of a Bi-directional Inverter for a Wireless V2G System”.Vehicle-to-grid (V2G) or G2V systems essentially require an interface between the electric vehicle (EV) and the grid to facilitate the V2G concept. The proposed bi-directional wireless power interface is based on the Inductive Power Transfer (IPT) Technology, and comprises a high frequency IPT system and a low frequency bi-directional grid side inverter.[4] In the year 2010, Udaya K. Madawala has designed “A Two-way Inductive Power Interface for Single Loads”.Inductive Power Transfer (IPT) is a technique for transferring power from one system to another with no physical contacts. Until now this technique has been widely used only for unidirectional power delivery in numerous applications over a wide power range.[5] Guoqiao Shen, Xuancai Zhu, Jun Zhang, and Dehong Xu have proposed “A New Feedback method for PR Current Control of LCL-Filter-Based Grid-Connected Inverter”.For a grid-connected converter with an LCL filter, the harmonic compensators of a proportional–resonant (PR) controller are usually limited to several low-order current harmonics due to system instability when the compensated frequency is out of the bandwidth of the system control loop. A new current feedback method for PR current control is proposed.

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III. OPERATING PRINCIPLE

According to the schematic diagram, this project presents the main circuit topology of wireless electric vehicle charging system with energy feedback mode is as shown in Figure 2. Lg, Lc, Rd and Cf constitute line-connected filter.

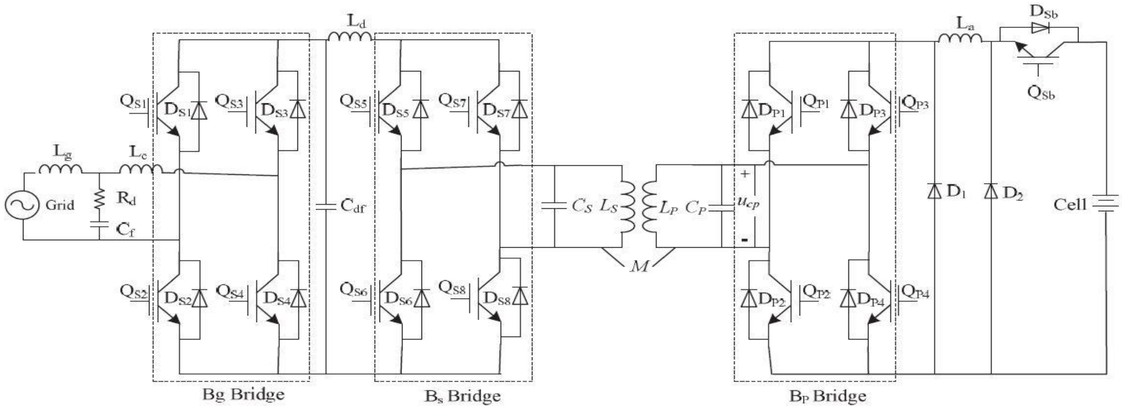

Fig. 2 Main circuit topology of system

Switch tubes Qs1-Qs4 form a bi-conventional rectifier-inverter bridge of AC network side, switch tubes Qs5-Qs8 form a bi-directional inverter rectifier bridge of charging machine side, and switch tubes Qp1-Qp4 build a bi-conventional rectifier-inverter bridge of vehicle side. Ls and Cs establish resonance tank of charging machine side, also Lp and Cp establish resonance tank of vehicle side. Ld and La are large DC inductance, Qsb is used to control the direction of energy transfer and buck regulation of energy feedback mode. D1 and D2 primarily play the role of freewheeling diode. For ease of description, Qs1-Qs4 is called as Bg Bridge, Qs5-Qs8 are referred to as Bs Bridge and Qp1-Qp4 are called as Bp Bridge.

By the principle of coupling, it is known that the mutual inductance between Ls and Lp is denoted as M where

$$M = k\sqrt{L_S L_P} \qquad (1)$$

Where, the coupling coefficient k between Ls and Lp is typically in the range of 0~0.2. The natural oscillation frequency of resonant rank ω0 can be given by

$$\omega_0 = 1/\sqrt{C_P L_P} = 1/\sqrt{C_S L_S} \qquad (2)$$

The circuit has two operating modes: charging and energy feedback mode.

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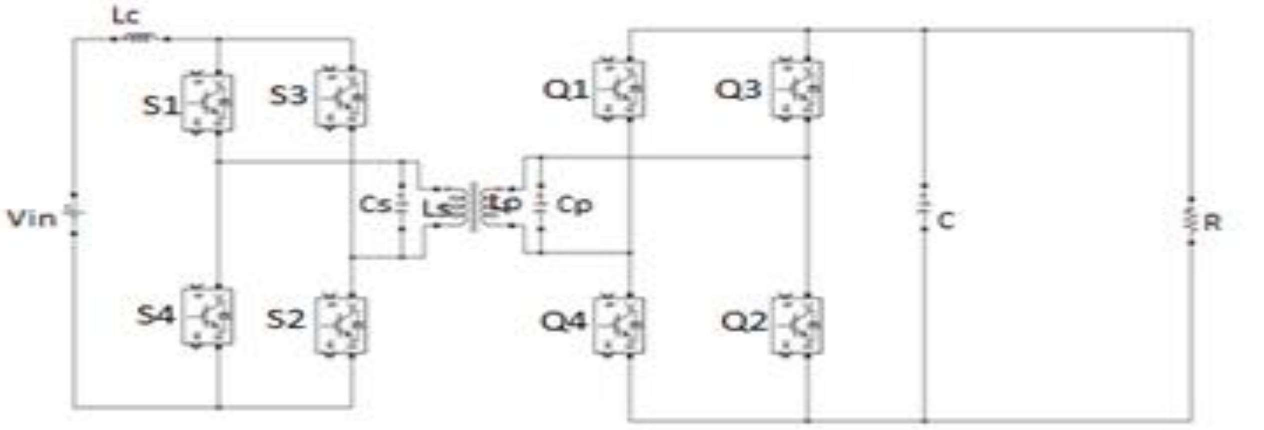

Fig. 3 Circuit topology of charging mode

Fig. 3 shows the circuit topology of charging mode. The Bg works in rectifier mode, the Bs bridge works in inverter mode, the Bp bridge works in rectifier mode.The inverter circuit consists of four choppers. When the switches S1 andS4 are turned on simultaneously, the input voltage Vs appears across the load. If the switches S2 and S3 are turned on at the same time, the voltage across the load is reversed and is –Vs. The first four switches act as inverter and next four switches act as rectifier.

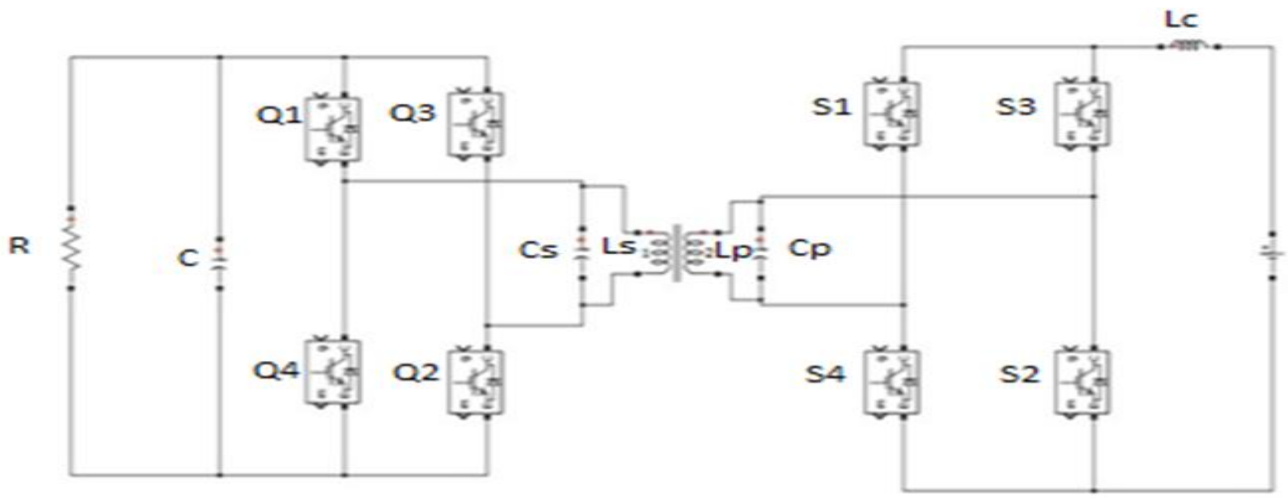

Fig. 4 Circuit topology of energy feedback mode

Figure 4 shows the circuit topology of energy feedback mode. The Bg works in inverter mode, the Bs bridge works in rectifier mode, the Bp bridge works in inverter mode. The inverter circuit consists of four choppers. When the switches S1 and S4 are turned on simultaneously, the input voltage Vs appears across the load. If the switches S2 and S3 are turned on at the same time, the voltage across the load is reversed and is –Vs. The first four switches act as rectifier and next four switches act as inverter.

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IV. SIMULATION ANALYSIS

In Fig.5 the first four switches act as inverter and next four switches act as rectifier. A 100v dc input is given, dc is converted to ac by inversion. Then ac is converted to dc by rectification, dc ouput of 250v is obtained.

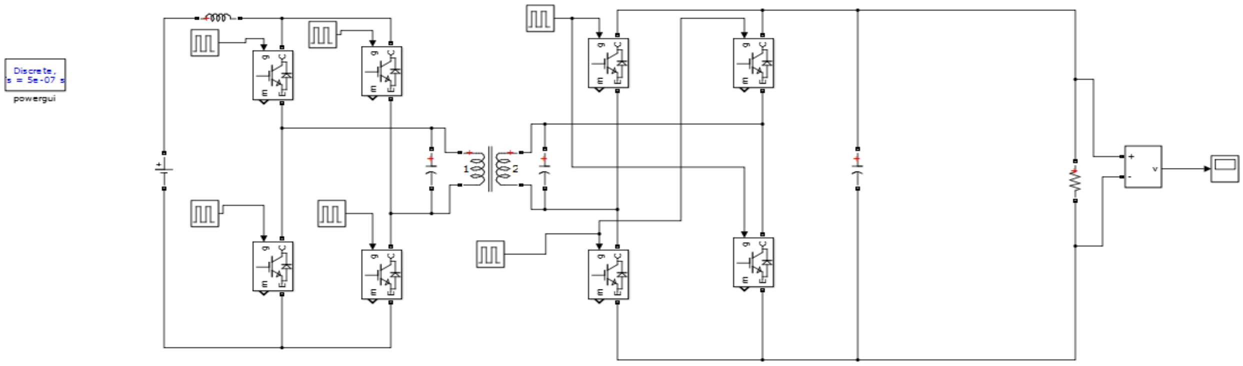

Fig. 5 Simulation circuit for charging mode

Fig 6 shows the simulation waveform under charging mode.it shows the waveform for voltage in volts versus time in seconds.A 100v dc input is given,the waveform shows how it is getting charged up to 250v

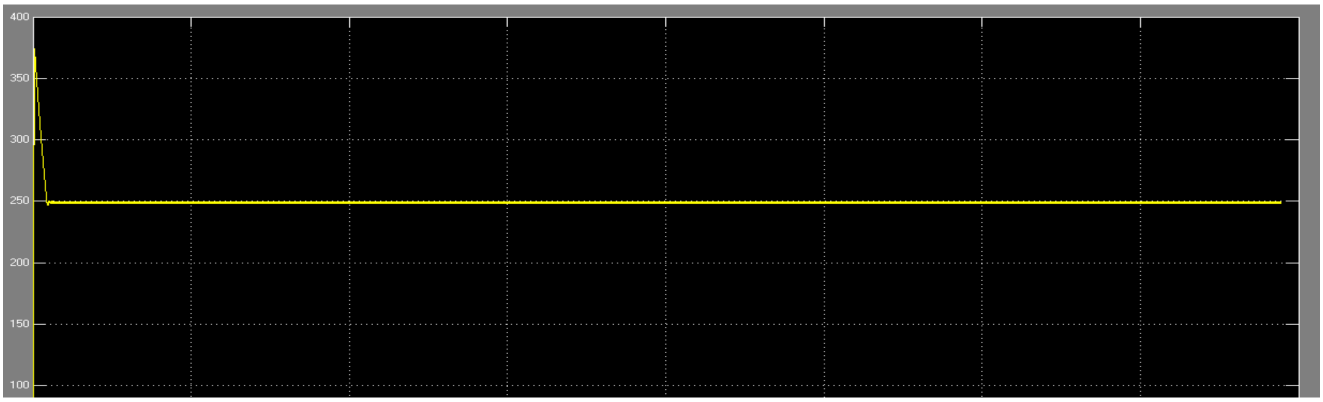

Fig. 6 Waveform under charging mode

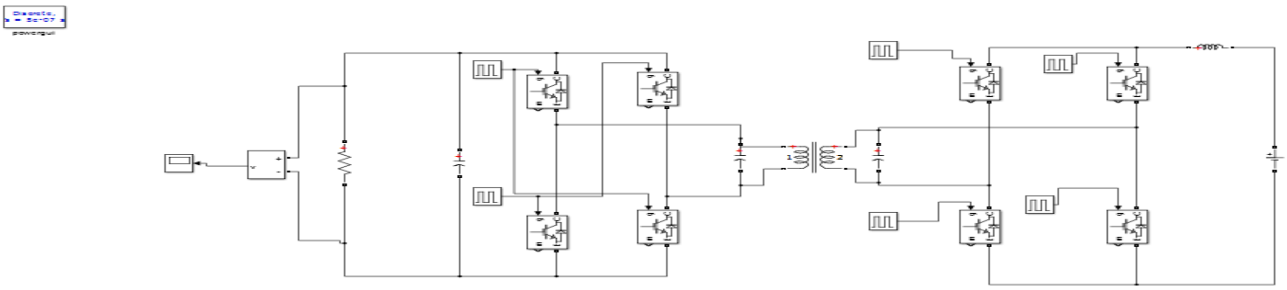

Fig. 7 Simulation circuit for Energy feedback mode

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Here the first four switches act as rectifier and next four switches act as inverter. A 250v dc is converted to ac by inversion, then ac is converted to dc by rectification, a feedback voltage of 120v is obtained.

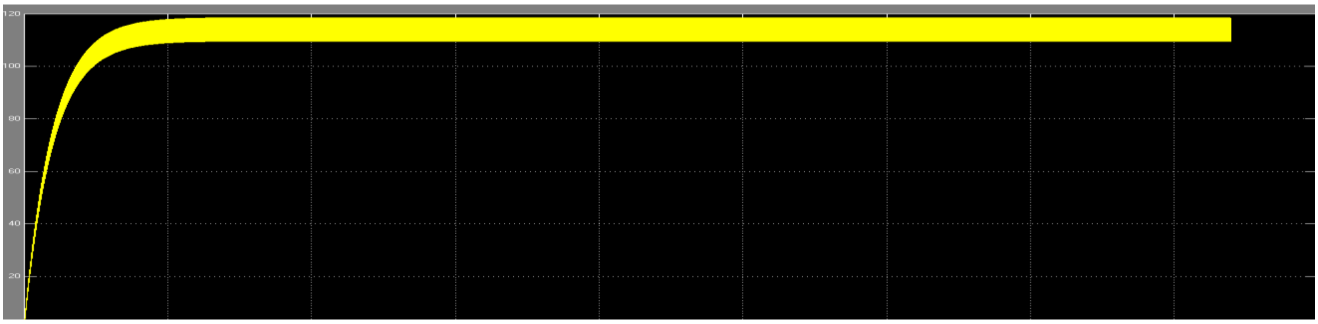

Fig. 8 Waveform under energy feedback mode

Fig 8 shows the simulation waveform under energy feedback mode.It shows the waveform for voltage in volts versus time in seconds.Input voltage given is 100v, charged up to 250v and the feedback voltage is 120v which can be observed from graph.

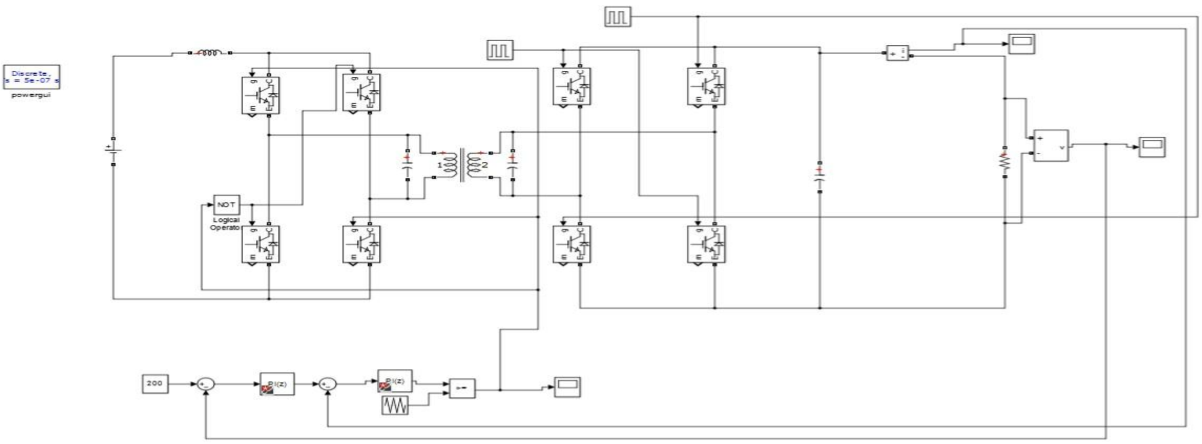

Fig. 9 Simulation circuit for charging mode closed loop

The inverter circuit consists of four choppers. The first four switches act as inverter and next four switches act as rectifier, 200v dc is taken as reference voltage. Here a sine wave is generated and compared with carrier signal, this is done to create pulse.

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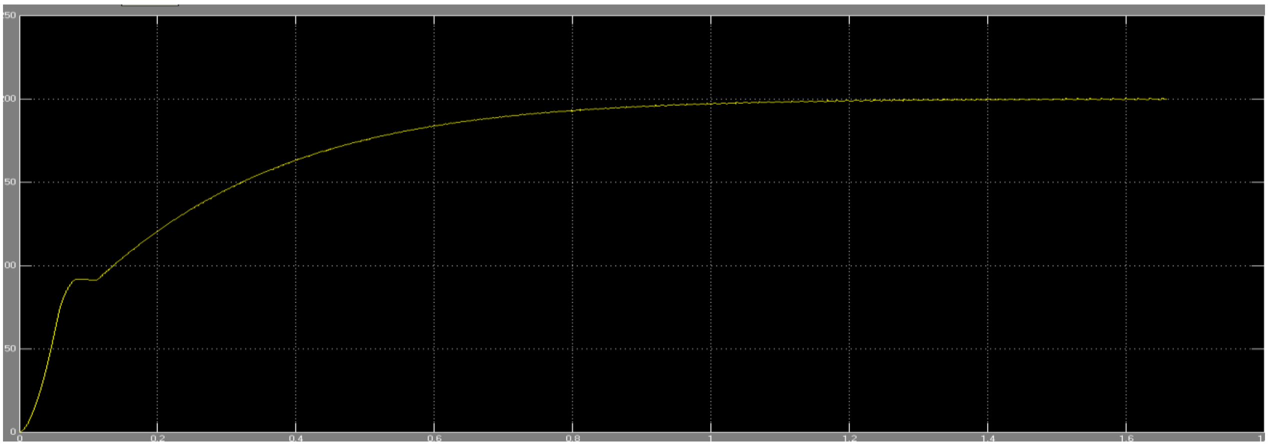

Fig. 10 closed loop output for charging mode

Fig 10shows the closed loop output for charging mode.Here 200v reference voltage is chosen, in closed loop circuit a sine wave is generated and compared with carrier signal so that pulse will be created.The above waveform shows 200v closed loop output.

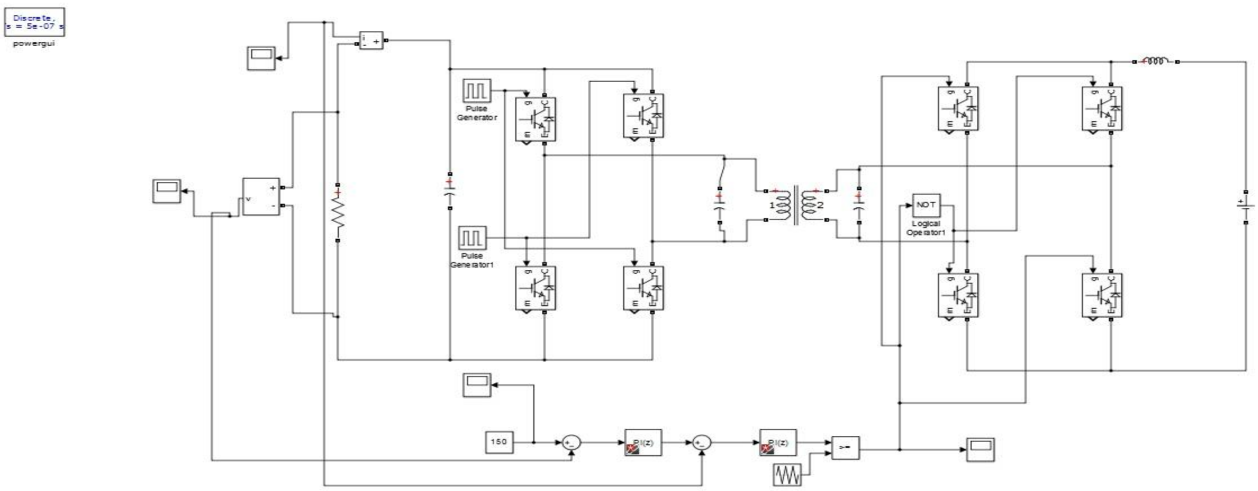

Fig. 11 Simulation circuit for energy feedback mode closed loop

The inverter circuit consists of four choppers. The first four switches act as rectifier and next four switches act as inverter 150 v dc is taken as reference voltage. Here a sine wave is generated and compared with carrier signal, this is done to create pulse.

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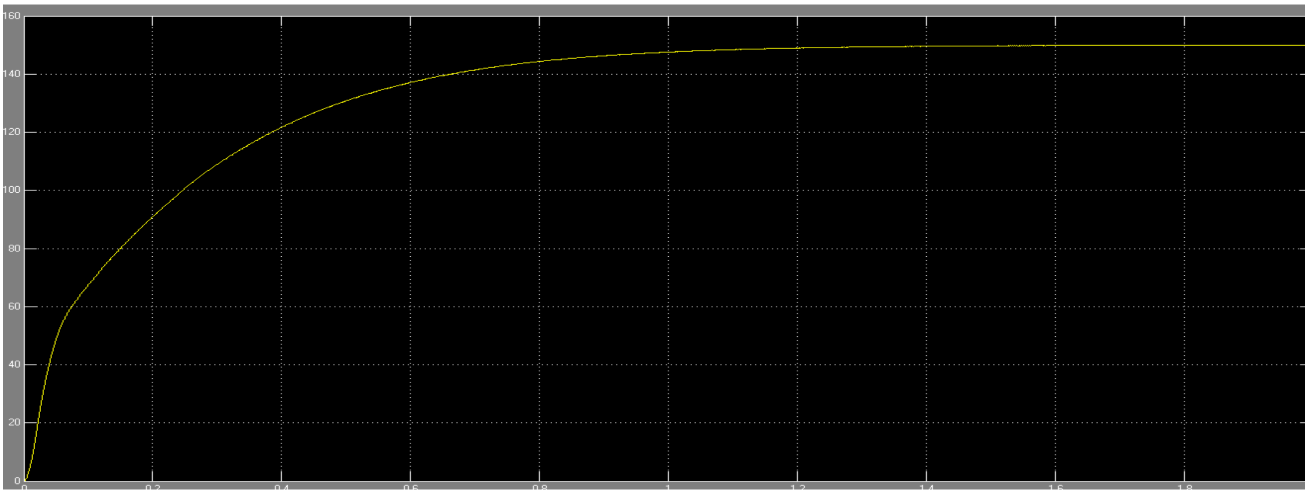

Fig. 12 closed loop output for energy feedback mode

Fig 12shows the closed loop output for energy feedback mode. Here 150v reference voltage s chosen,in closed loop circuit sine wave is generated and compared with carrier signal so that pulse will be created.The above waveform shows 150v closed loop output

V. CONCLUSION

The electric vehicles will be approved by people as the key issues of electric vehicles and power battery have become more and more mature. At the meantime, more attention will be transferred from the performance of electric vehicles themselves to the flexible and convenient charging method. This paper designed a wireless charging system with energy feedback mode for electric vehicles. With the help of such system, the electric vehicle can be charged without connector, meanwhile, it can provide the family or the grid with emergency power when power system fail occurs. The system has a bidirectional power adjustment capability, to some extent, expanding its scope of application.

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