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Wireless Energy Propagation for Three-Level Electric Mobility

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ABSTRACT-This paper explores the concept of wireless energy propagation for three-level electric mobility systems, presenting a novel approach to address energy transfer challenges in electric vehicles (EVs). With the burgeoning demand for sustainable transportation, efficient energy management is critical. Traditional EV charging methods face limitations such as plug compatibility, infrastructure constraints, and charging times, hindering widespread adoption. Wireless energy propagation offers a promising solution by enabling convenient, contactless charging for EVs.The proposed system employs three-level electric mobility infrastructure, integrating ground-based charging stations, mid-air energy transmitters, and onboard receivers within vehicles. Through electromagnetic induction and resonant coupling principles, energy is wirelessly transmitted from the infrastructure to the EVs, facilitating seamless charging while in motion or stationery. This innovative approach enhances EV usability, reduces dependency on physical charging points, and minimizes environmental impact by promoting renewable energy integration.Key aspects addressed include system design, energy transfer efficiency, safety considerations, and scalability. Through simulations and experimental validations, the feasibility and effectiveness of the proposed system are demonstrated. Furthermore, economic analyses highlight the potential cost-effectiveness and long-term sustainability of deploying wireless energy propagation for three-level electric mobility.

Keywords-Electric vehicles, Hybridelectricvehicle, Power quality, Harmonics distortion, Three-levelinverter, Wirelesspowertransfer.

I. INTRODUCTION

In the relentless pursuit of sustainable and efficient transportation solutions, the global focus has shifted towards revolutionizing electric mobility. As we navigate the challenges of environmental conservation and energy efficiency, one promising avenue that has garnered significant attention is the concept of Wireless Energy Propagation (WEP) in Three-Level Electric Mobility.Traditional electric vehicles (EVs) have made remarkable strides in reducing carbon emissions and dependence on fossil fuels. However, they are tethered to charging infrastructure, which poses limitations on their flexibility and range. The emergence of Wireless Energy Propagation introduces a paradigm shift by enabling the seamless transfer of energy to electric vehicles without the need for physical connections[1,4].The Three-Level Electric Mobility framework encapsulates the integration of WEP technology at various levels, addressing challenges at the individual, infrastructure, and societal scales. This multi-faceted approach aims to enhance the efficiency, accessibility, and overall viability of electric mobility on a global scale.Vehicle-Level Innovation: At the heart of this revolution lies the transformation of electric vehicles themselves. Three-level systems encompass advancements in on-board wireless charging capabilities, allowing EVs to efficiently receive energy from charging infrastructure or other compatible sources. This eliminates the need for traditional plug-in charging and significantly enhances the convenience of electric vehicle ownership[4].Infrastructure Integration: The second level involves the

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development and integration of robust charging infrastructure that supports Wireless Energy Propagation. Smart grids, wireless charging pads embedded in roadways, and strategically placed charging stations contribute to a comprehensive charging network. This not only extends the range of electric vehicles but also minimizes concerns related to charging accessibility[4].

Societal Adoption and Support: The third level recognizes the importance of societal acceptance and support for widespread adoption. Incentives, awareness campaigns, and collaborative efforts between governments, industries, and communities play a crucial role in fostering an environment conducive to the proliferation of Three-Level Electric Mobility.

II. WIRELESS POWER TRANSFER SYSTEM

Wireless Power Transfer (WPT) revolutionizes electric vehicle (EV) charging with cable-free energy transfer. It employs a discreet ground-integrated charging pad and a vehicle-embedded receiving coil using magnetic resonance coupling. The charging pad generates a changing magnetic field, captured by the receiving coil to convert alternating current (AC) into direct current (DC) for battery charging. Communication and control systems ensure optimal alignment and safe, efficient power transfer. WPT offers EV owners convenient, cable-free charging experiences, making it an innovative solution for the future of electric vehicle infrastructure[1].

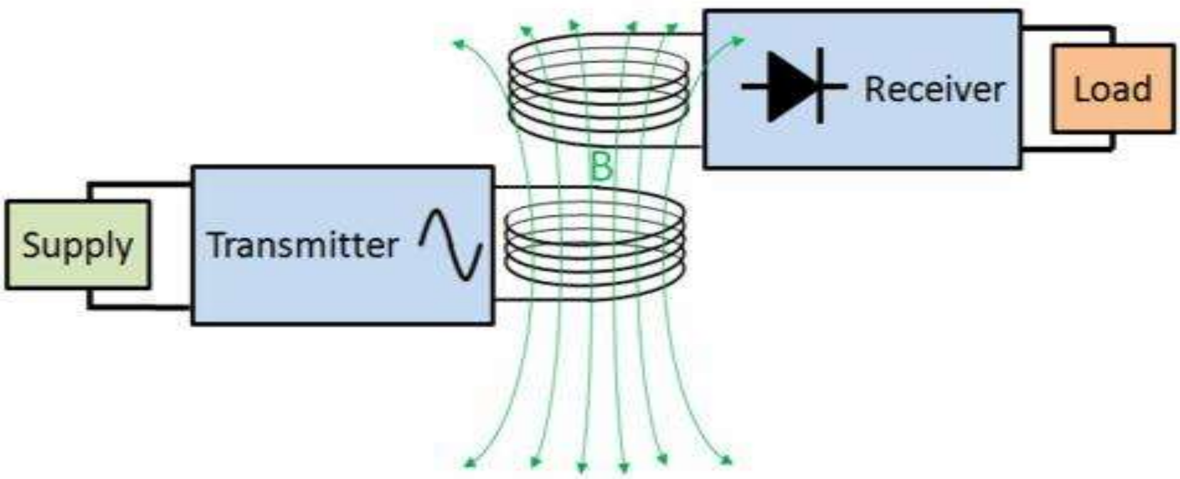

Figure 1- Wireless Power Transfer System

A. 3-LEVEL RECTIFIER

A 3-level rectifier is an advanced power electronics circuit utilized in wireless electric vehicle (EV) applications. It outperforms 2-level rectifiers by generating three distinct voltage levels, reducing harmonic distortion for smoother AC waveforms and improved power quality. This leads to lower electromagnetic interference (EMI), making it suitable for wireless charging[3,5].

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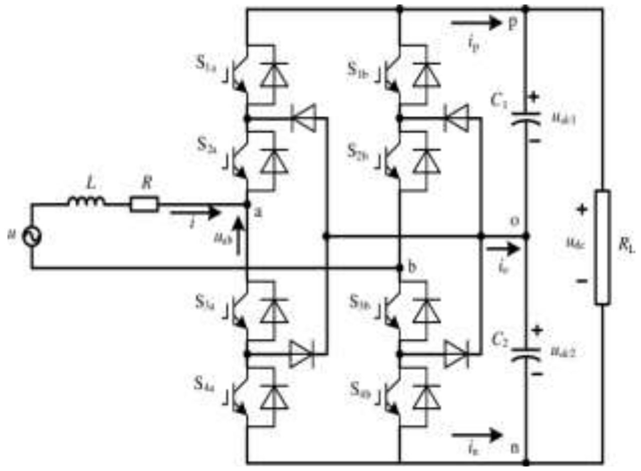

Figure 2.1- 3-Level Rectifier

The added voltage level in a 3-level rectifier distributes stress more evenly, enhancing component reliability and longevity while improving overall efficiency by reducing losses from harmonic distortion. However, the increased complexity and cost should be considered when choosing a rectifier topology for wireless EV charging systems. The 3-level rectifier operates by converting DC power from the vehicle's battery into AC power through controlled switching of power semiconductor devices, achieving improved waveform quality and reduced EMI. It involves additional devices and control circuitry for precise voltage waveform generation, continuously adjusting switching signals based on voltage and current conditions for safe and efficient operation. The resulting AC output drives the electric motor or wirelessly charges the EV's battery, highlighting the 3-level rectifier's role in enhancing power quality in wireless EV applications.

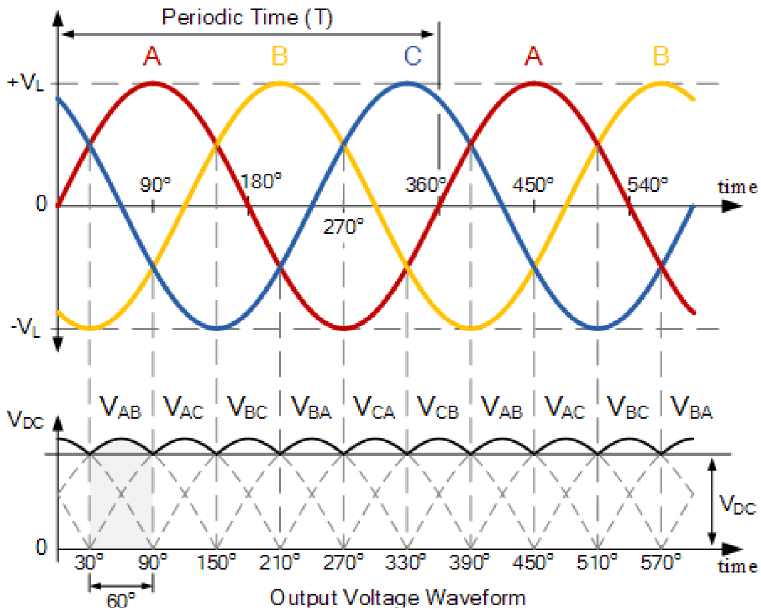

Figure 2.2- Waveforms of Rectifier

B. 3-LEVELINVERTER

A three-level inverter is a power electronic device converting DC to AC with distinct positive, negative, and zero voltage levels. Controlled by PWM, it minimizes switching losses, lowers harmonics for improved power quality, and reduces interference[3].

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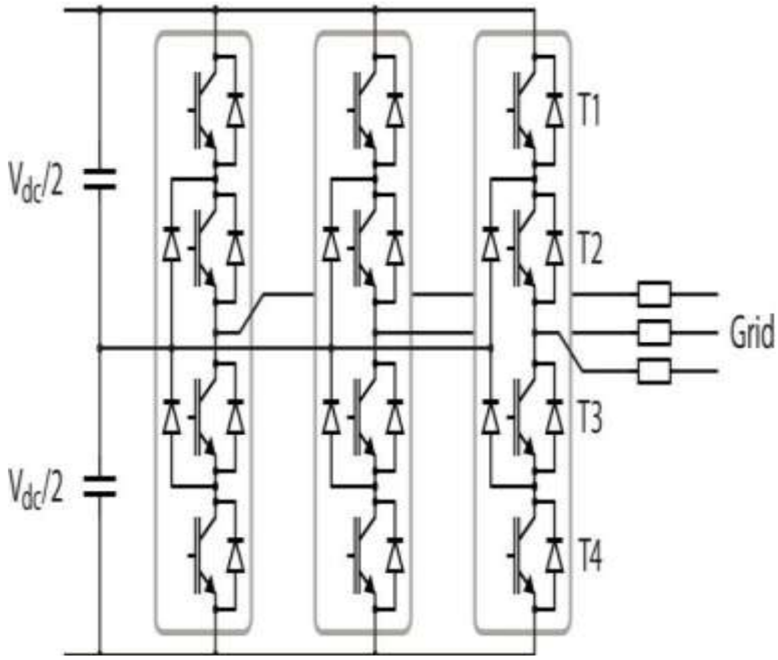

Figure 2.3- 3-Level Inverter

Offering higher voltage output, it enhances efficiency in high-power applications, ensures smoother motor control with less torque ripple, and reduces electromagnetic interference. This results in lower stress on components, enhancing system reliability. Overall, three-level inverters are preferred for their efficiency, improved power quality, and reliability in diverse applications requiring effective power conversion.

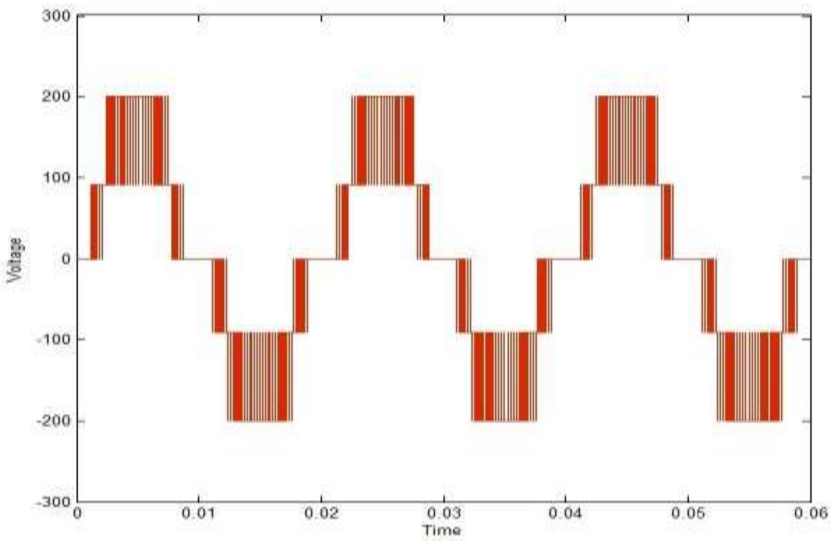

Figure 2.4- Waveforms of Inverter

C. BUCK CONVERTER

The buck converter is a crucial component in wireless electric vehicle (EV) systems, ensuring efficient power transfer from charging infrastructure to the EV battery. By lowering voltage and increasing current, it regulates power effectively[3,6,15].

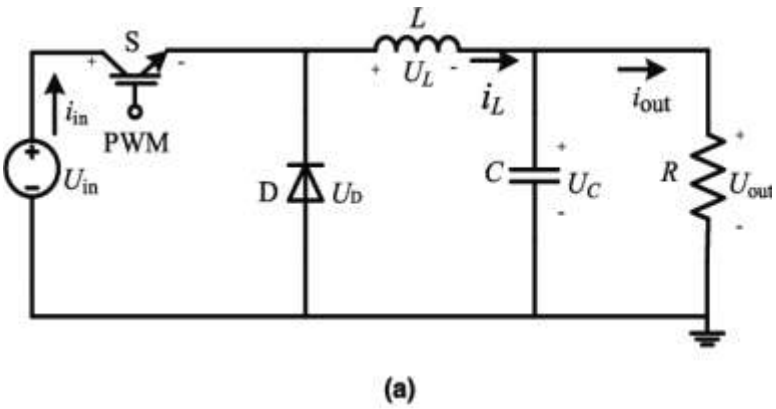

Figure 2.5- Buck Converter

It comprises a power switch, inductor, diode, and capacitor. The closed switch stores energy in the inductor, released upon opening, causing a voltage drop. The diode directs current to the output capacitor and battery. Precise control of the switch's duty cycleregulates voltage. In wireless EV charging, the buck converter optimizes power transfer, adjusting voltage for battery charging, enhancing efficiency, and improving EV charging performance.

III. PROPOSED SYSTEM

Wireless energy propagation for three-level electric mobility involves a sophisticated system to transmit electrical power without physical contact. The operation of this technology can be summarized as follows:

A. Power Generation:

The process begins with power generation, typically in the form of direct current (DC) stored in the electric vehicle's battery.The DC power is converted into alternating current (AC) through a three-level rectifier. This rectifier produces three distinct voltage levels: positive, neutral, and negative.

B. Wireless Transmission:

The AC power is then wirelessly transmitted from a power source to the electric vehicle. This wireless transmission is usually achieved using resonant inductive coupling or other wireless power transfer technologies.

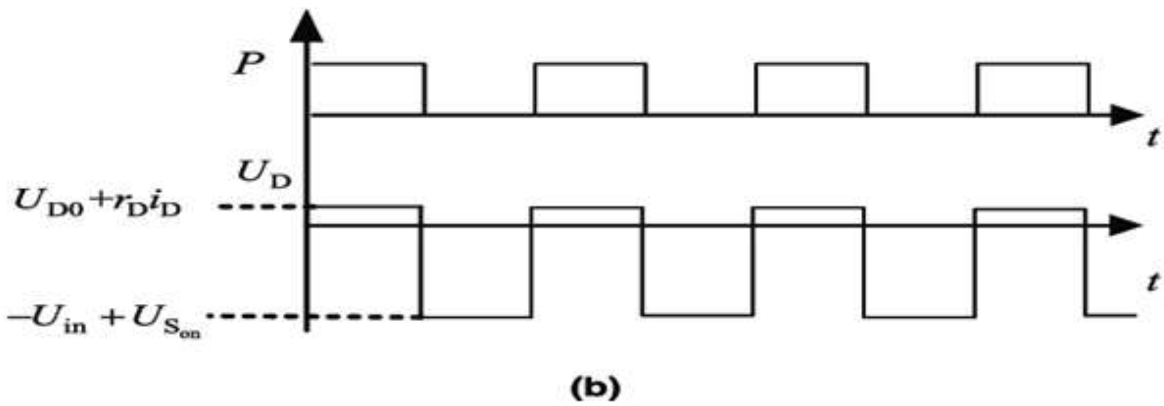

Figure 2.6- Waveforms of Buck Converter

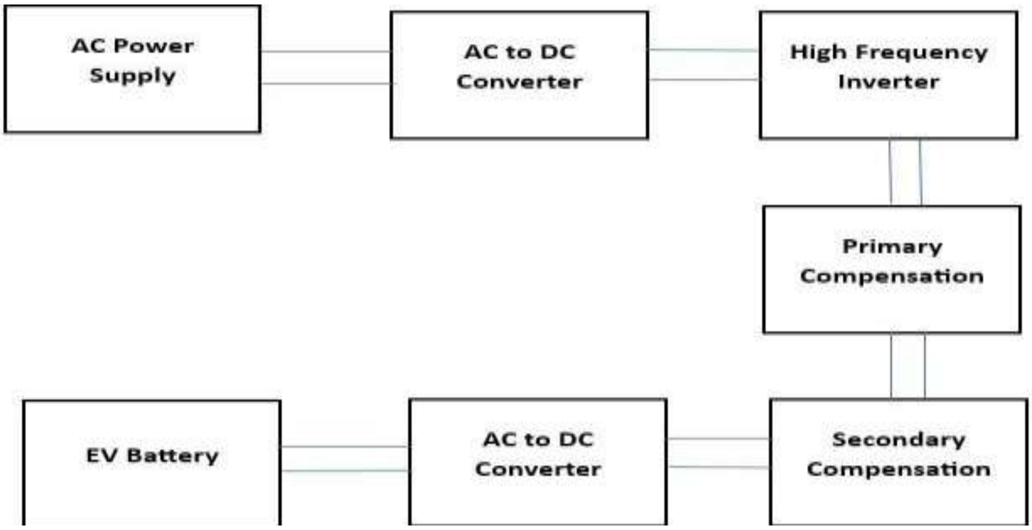

Figure 3- Block diagram of WPT

C. Reception by Vehicle:

The electric vehicle is equipped with a receiver system that is tuned to resonate at the frequency of the transmitted AC power.The receiver captures the wirelessly transmitted AC power and converts it back into DC power suitable for charging the vehicle's battery.

D. Control and Regulation:

Control circuitry in both the transmitter and receiver systems ensures efficient power transfer. This involves adjusting the frequency, amplitude, and phase of the transmitted power to maximize efficiency and align with the receiver's resonance frequency.

E. Three-Level Rectifier Functionality:

The three-level rectifier in the electric vehicle plays a crucial role. It ensures the conversion of received AC power into a stable DC output.By utilizing three distinct voltage levels, the rectifier reduces harmonic distortion, resulting in smoother AC waveforms. This enhances power quality and minimizes electromagnetic interference[5].

F. Optimization and Safety:

The system continuously monitors voltage and current conditions to optimize power transfer efficiency.Safety mechanisms are in place to shut down or adjust the system in case of irregularities, ensuring the protection of both the charging system and the electric vehicle.

G. Charging:

The converted DC power is then used either for charging the electric vehicle's battery or directly powering the electric motor for propulsion.

H. Efficiency and Reliability:

The three-level rectifier's additional voltage level aids in distributing stress evenly, enhancing the reliability and longevity of system components. The reduction in harmonic distortion contributes to overall system efficiency. While wireless energy propagation for three-level electric mobility presents advantages such as convenience and reduced physical wear, the technology's successful operation requires careful design, control, and safety considerations. Additionally, factors like system efficiency, alignment, and compatibility between the transmitter and receiver systems play crucial roles in its effective implementation.

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IV. EXECUTION OF SIMULINK DIAGRAM

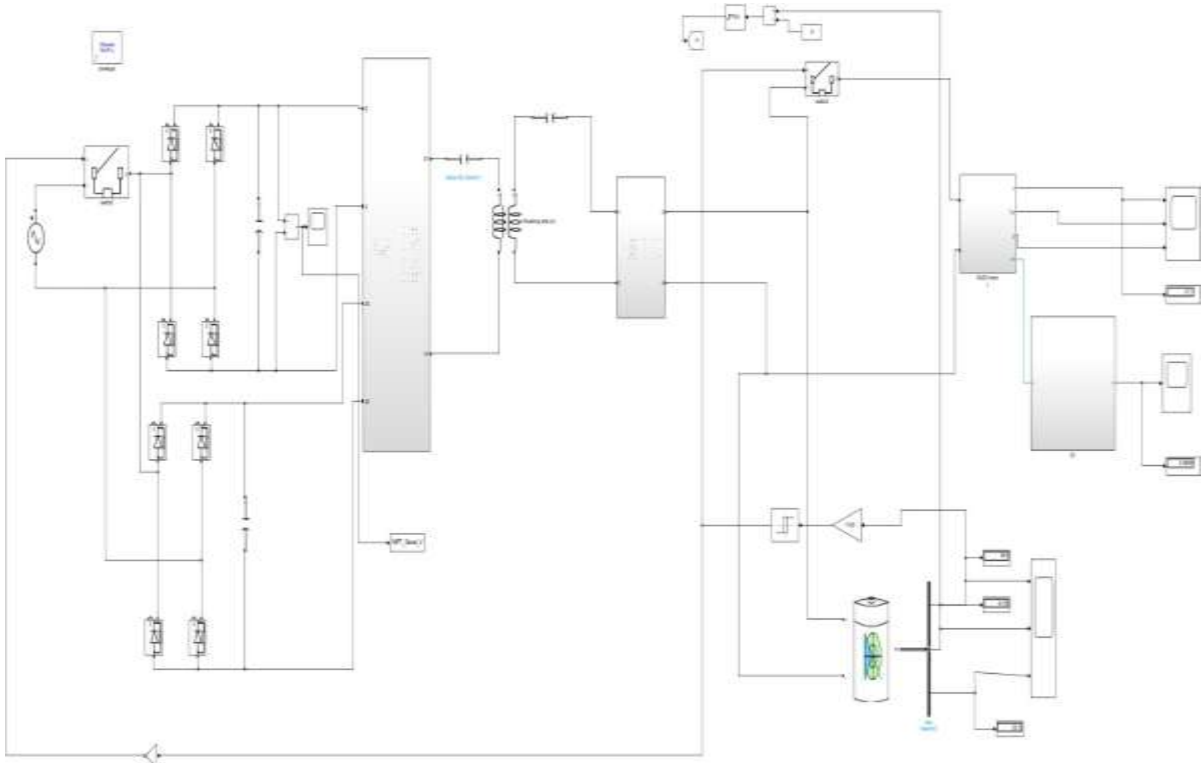

Figure 4- Simulation diagram of wireless power transfer for 3-level based electric vehicle

The above Simulink diagram for proposed system, for simulation first we give the AC supply to system and after passes to the 3-level rectifier it converts AC to DC and the outputs are shown in the below:

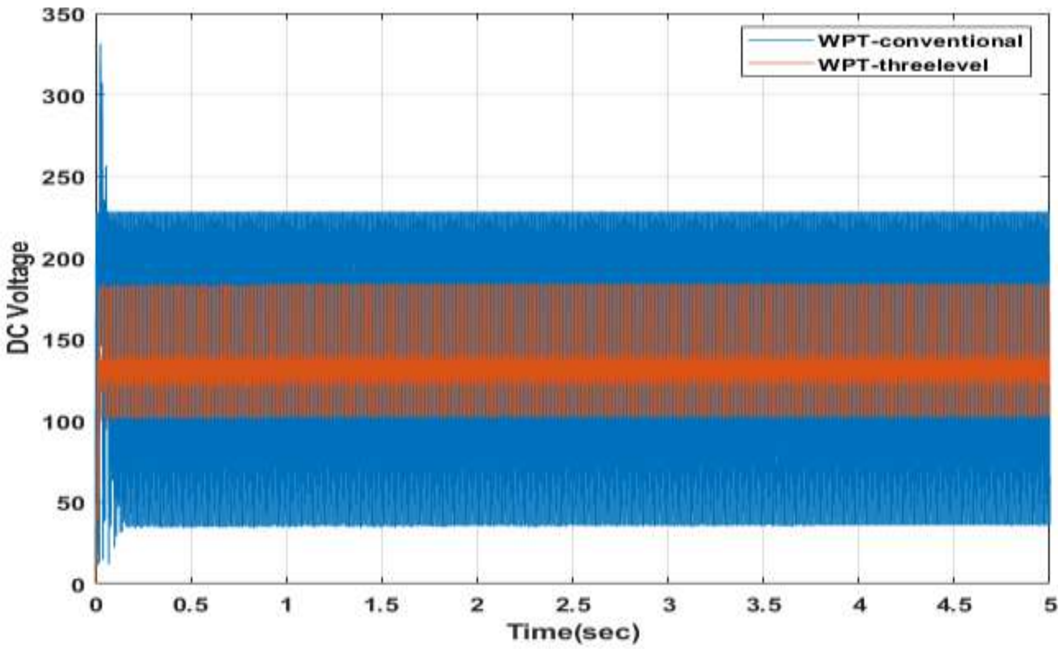

Figure 4.1- Output voltage wave form for 3-level rectifier

Then it passes to the high frequency inverter. The inverter will act as passes the DC voltage in high frequency for the required ranges of the battery. And then it passes to the buck converter

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connected with the rectifier and it act as reduces the high voltages to battery range voltages and rectifier will convert AC to DC.

V. RESULTS

The below figure depicts the waveform generated when utilizing a 3-level rectifier. The below one is the results of the FFT analysis of the proposed system.

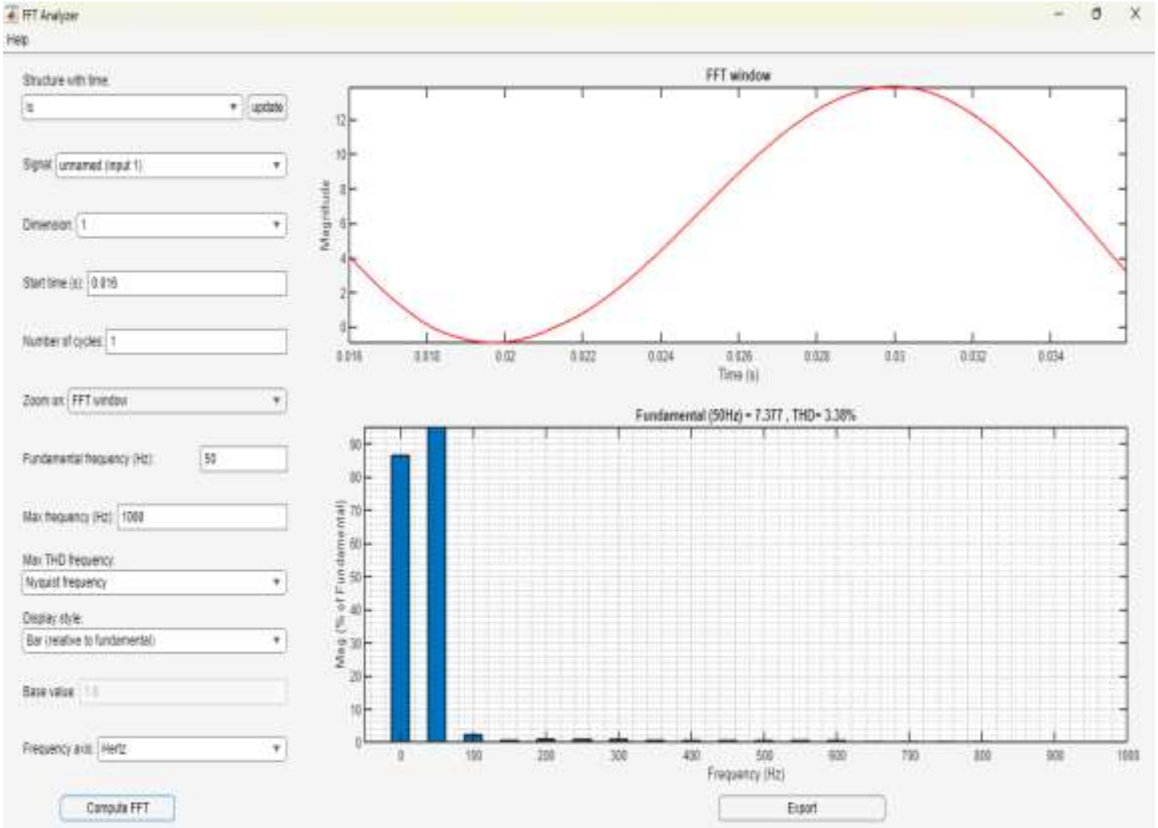

Figure 5- FFT outputs

By the above diagram we can see that the total harmonic distortion percentage is 3.38% and by this we can say that the harmonic distortion was reduced then the before system.

VI. CONCLUSION

In conclusion, the exploration of wireless energy propagation for three-level electric mobility presents a promising avenue for the advancement of sustainable transportation. The three-level electric mobility system, encompassing ground-based charging infrastructure, on-road wireless charging, and in-vehicle energy storage, offers a comprehensive solution to address the challenges associated with traditional electric vehicle charging. The wireless energy propagation technology not only enhances the convenience of charging by eliminating the need for physical connections but also promotes the widespread adoption of electric vehicles by addressing range anxiety and enabling continuous on-the-go charging. This innovation holds the potential to revolutionize the way we perceive and utilize electric vehicles, making them more accessible and practical for daily use. Moreover, the three-level electric mobility system contributes to the reduction of greenhouse gas emissions and dependence on fossil fuels, aligning with global efforts to combat climate change. The seamless integration of wireless energy propagation into the electric mobility infrastructure can significantly contribute to building a more sustainable and environmentally friendly transportation ecosystem. As we move forward, further research and development in wireless energy propagation technologies, coupled with the continuous improvement of energy storage systems, will be crucial for optimizing efficiency, increasing charging speeds, and expanding the range of electric vehicles. Collaborative efforts between industry stakeholders, policymakers, and researchers will play a pivotal role in realizing the full potential of this technology and ushering in a new era of cleaner and more efficient transportation.

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