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Grid and Renewable Powered Electric Vehicle Charging Stations Using Hybrid Honey Badger Algorithm (HBA) and the Cat and Mouse-Based Optimizer

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Abstract- The rapid adoption of electric vehicles (EVs) necessitates the development of efficient and sustainable charging infrastructure, particularly in regions like India, where energy demand and environmental concerns are rising. This study presents a techno-economic assessment of grid and renewable-powered electric vehicle charging stations, optimized using a hybrid metaheuristic technique that combines the Honey Badger Algorithm (HBA) and the Cat and Mouse-Based Optimizer (CMBO). By leveraging the strengths of both algorithms, this hybrid approach ensures efficient resource allocation, minimizes operational costs, and maximizes the use of renewable energy sources such as solar and wind power.The proposed model evaluates multiple objectives, including minimizing the total cost of energy consumption, optimizing the charging station's placement, and reducing carbon emissions by integrating renewable energy into the charging infrastructure. A comprehensive analysis of capital and operational expenditures is conducted, with a focus on the Indian market, considering grid constraints, dynamic electricity tariffs, and government incentives. The study also assesses the impact of energy storage systems and grid stability, ensuring a robust and scalable solution for urban and rural areas.

Simulation results demonstrate that the hybrid HBA-CMBO algorithm significantly improves the overall performance of charging stations by enhancing energy efficiency and reducing reliance on grid electricity during peak demand hours. This novel approach provides a promising framework for policymakers and stakeholders aiming to establish environmentally sustainable EV charging networks in developing countries.

Introduction

Aggressive marketing and major aid from the government have been instrumental in accelerating recent technological advancements in the areas of electric power trains and batteries. There has been a significant decrease in the costs associated with the production of batteries over the course of the last three years. Experts predict that EVs will become more important to the car industry in the years to come. As a result of the electric vehicle (EV) conversion scenario and the roll-out timeframe that was specified in 2015, the number of electric vehicles (EVs) surpassed one million in October of 2018, as shown by the evidence. Through the implementation of several legislation, the government of the United States of America has created an incentive for the public sector to provide infrastructure for charging electric vehicles [1].According to the Canadian Ministry of Transportation, the province of Ontario spent twenty thousand dollars in 2017 to install five hundred charging stations for electric vehicles in around two hundred and fifty different sites. It is anticipated by the German National Platform for Electric Mobility that there will be one million electric vehicles (EVs) by the year 2020. Additionally, it is anticipated that the demand for charging stations, particularly road charging stations, would exceed seventy thousand (CPs). [2] China developed a system that designates a certain quantity of solar-powered charging stations to address the constraints of renewable energy use and meet the increasing need for energy from electric cars. An international conference called the EV Initiative was scheduled to take place in May 2017 to promote the global development of electric automobiles. PHEVs and BEVs are two types of electric automobiles (EVs) that cost less than internal combustion engine vehicles (ICEVs). Recently, car manufacturers in several nations have been trying to meet client demand by launching new electric vehicle models. [Hansen, K., 2019] Utility and power companies have collaborated with many stakeholders to expand and improve the market for electric car charging infrastructure. Several countries lack the required infrastructure for charging electric vehicles, even if the legislation and regulations mentioned above are crucial.

Hybrid Electric Vehicle (HEV)

A combination of an electric power train and an ICE is what propels a hybrid electric car. As we'll see in a little, these two components may take several forms. When electricity demand is minimal, a hybrid vehicle's electric propulsion system kicks in. In low-speed settings, like urban areas, it's great since it cuts fuel usage by turning the engine off entirely when it's not in use, as when there's traffic. Reduced emissions of greenhouse gases are another benefit of this feature. If the hybrid electric car needs extra speed, it switches to the internal combustion engine. The two power trains may work together to boost efficiency. A common method for reducing or eliminating turbo lag in turbocharged cars like the Acura NSX is to install a hybrid power system. By providing speed boosts when required and bridging the gaps between gear changes, it increases performance. Regenerative braking is an additional energy recovery mechanism that certain hybrid electric vehicles (HEVs) use, while internal combustion engines (ICEs) are able to recharge the batteries.

Hybrid electric vehicles (HEVs) are ICE cars that supplement their ICE's performance and fuel economy with an electric power train. In order to get these traits. The use of HEV configurations is widespread among automakers.

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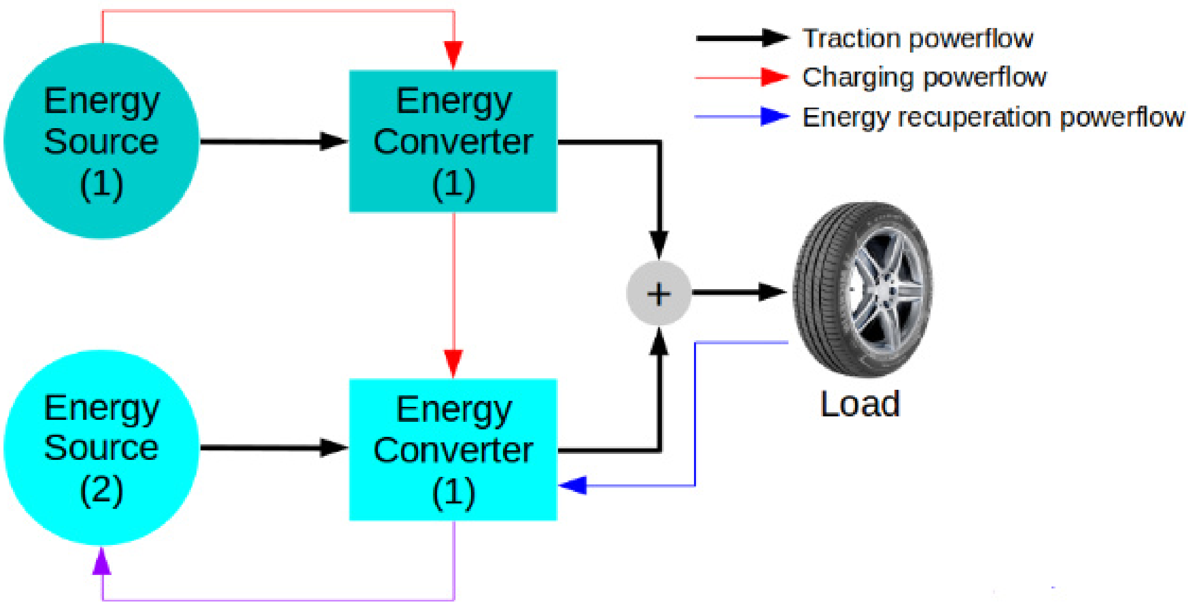

Figure 1. HEV basic operating principle

Simulation Model-

The proposed system in this article focuses on addressing the challenges and optimizing the fast-charging technique of electric vehicles (EVs) using the Vienna T-type converter and Partial Power Processing (PPP) technique. Firstly, the article aims to explore the use of the Vienna T-type converter, a grid-facing AC/DC converter known for its high-power quality on both the AC and DC sides. This converter interface between the grid and a regulated DC bus, with attributes including negligible input current harmonics and nearly unity power factor. Despite its high efficiency, the Vienna T-type converter requires many devices, which can pose challenges in terms of complexity and cost.

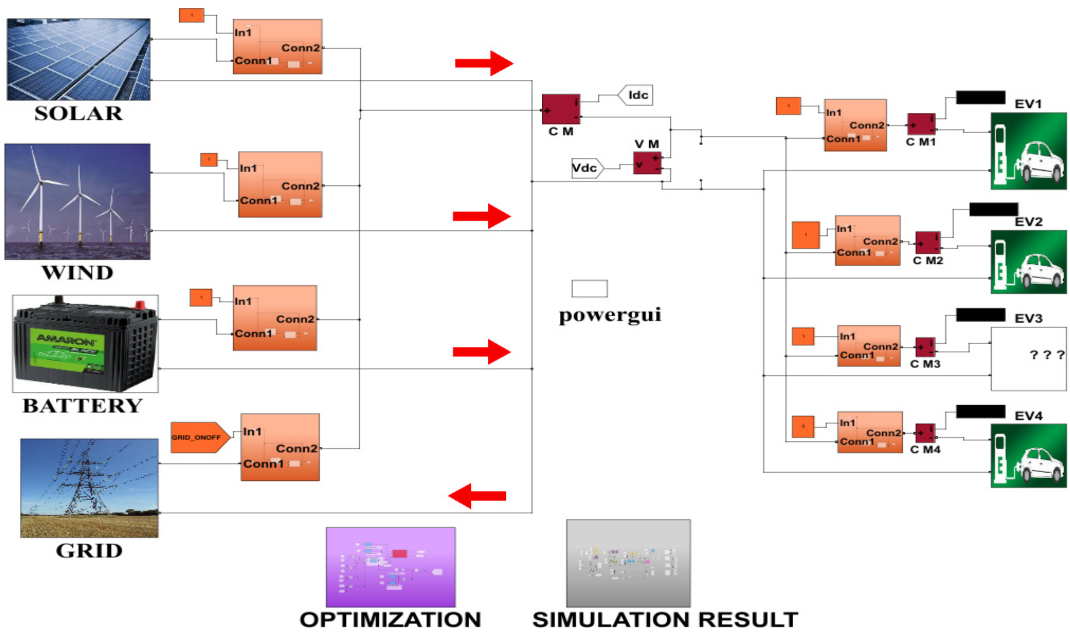

Figure 2: MATLAB Simulink model

Results-

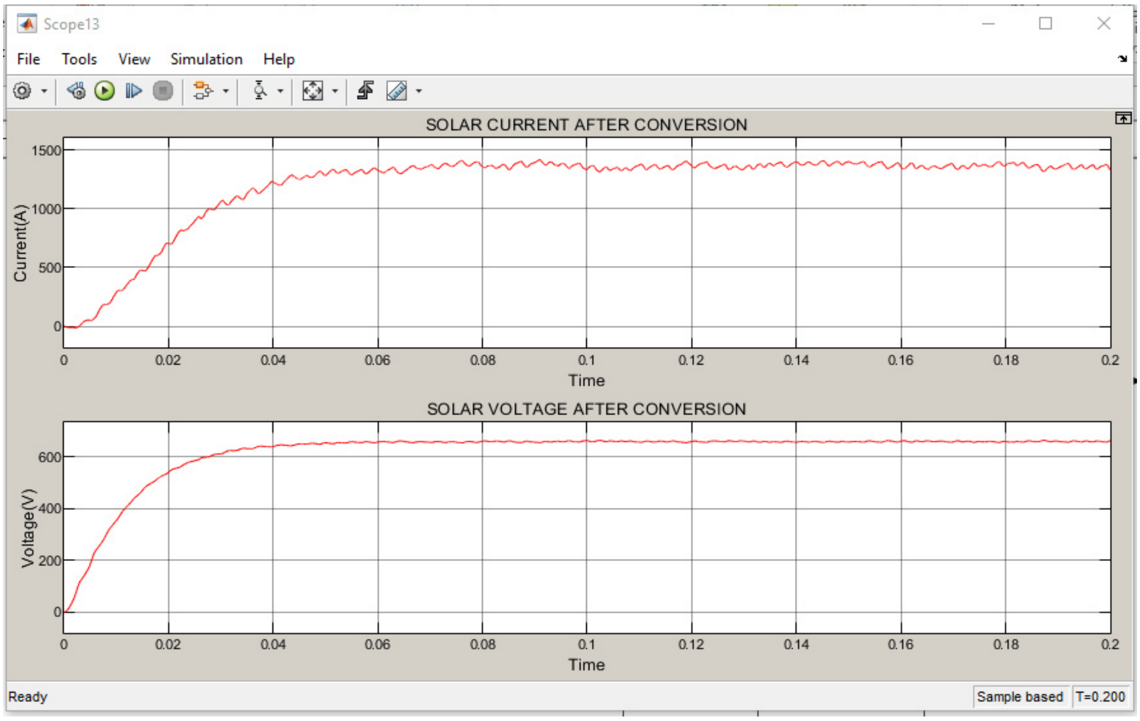

Figure 3. Solar voltage and current waveform

Figure3 showing the solar voltage and current waveform after the converter, the current generated 1470 A, Where Voltage generated 650V from the solar

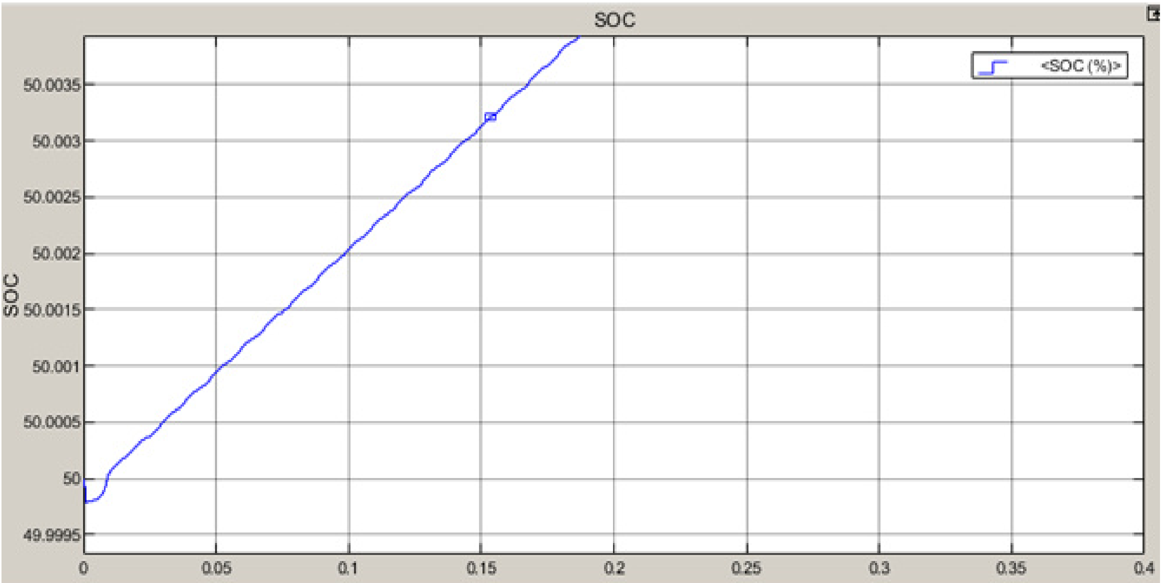

Figure 4. SOC charging at 50%

In the third case If soc between 50% to 90%, it will charge showing in fig. 4.

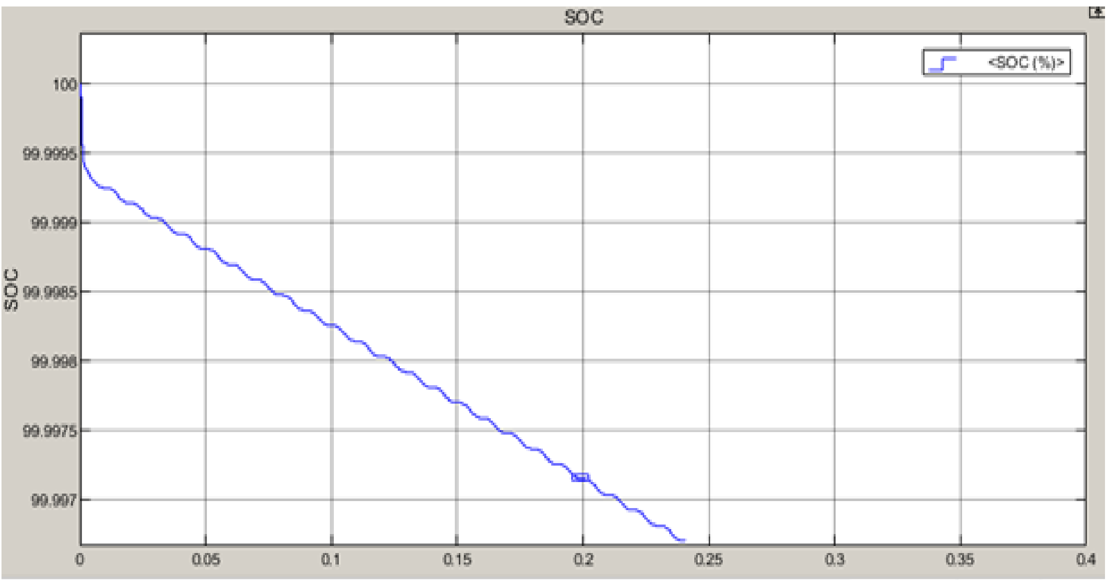

Figure 5. SOC discharging at 100%

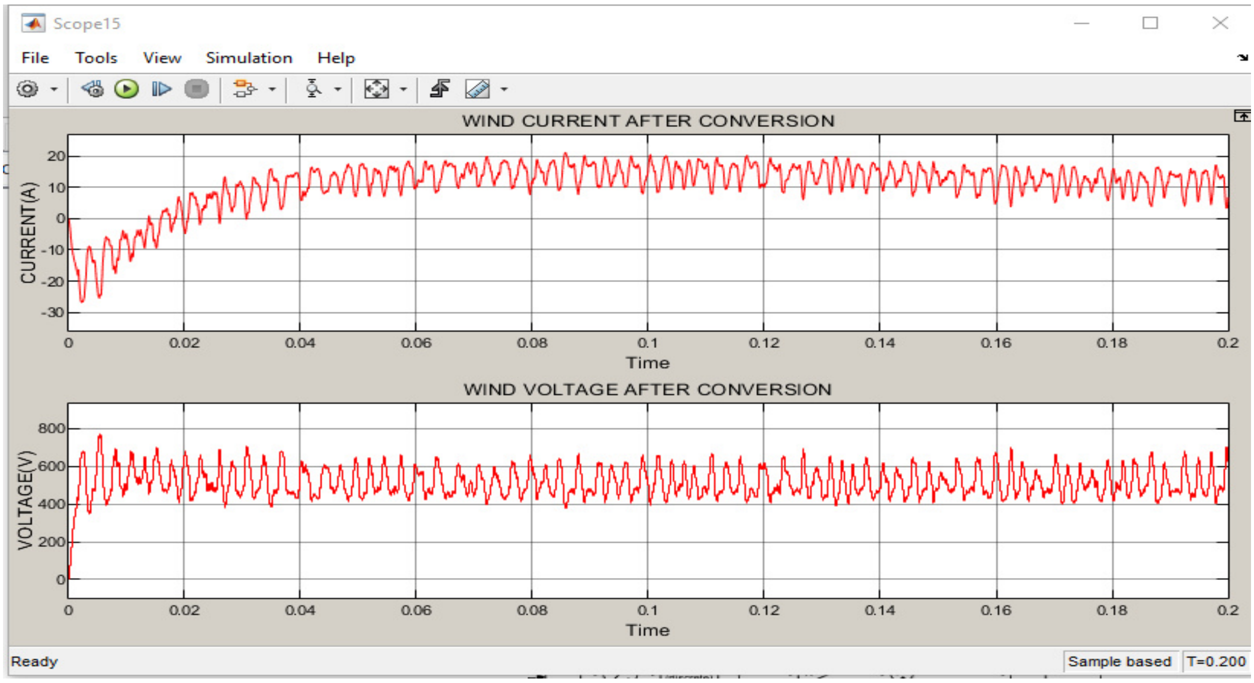

Figure 6. showing the wind voltage and current waveform after the converter ,the current generated 19 A, Where Voltage generated 640V from wind system

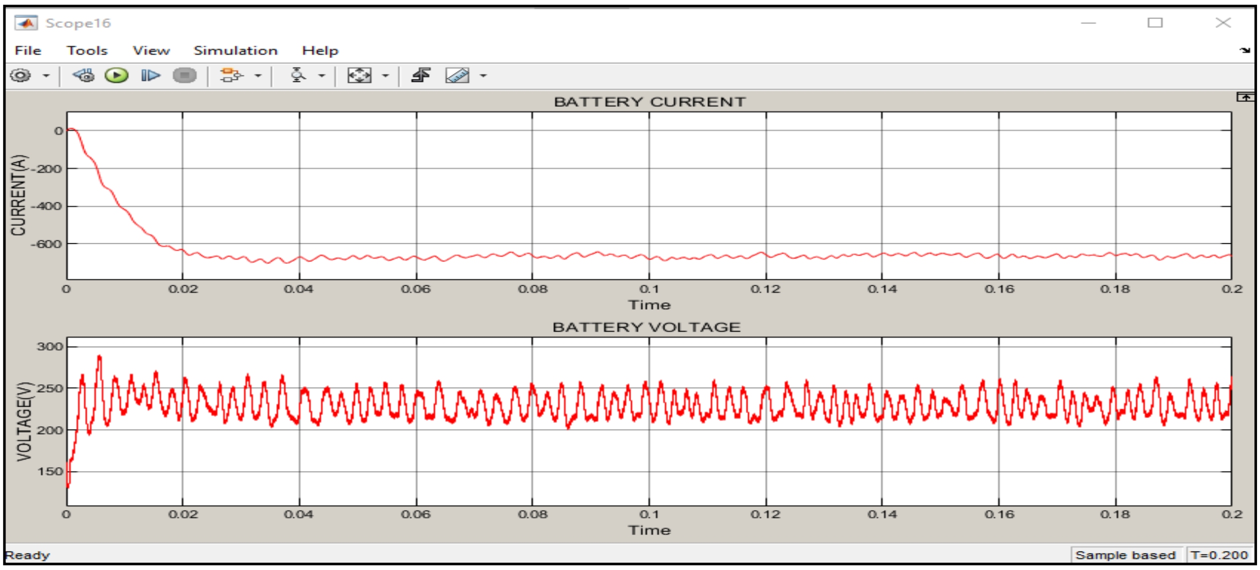

Figure 7. battery voltage and current of the system

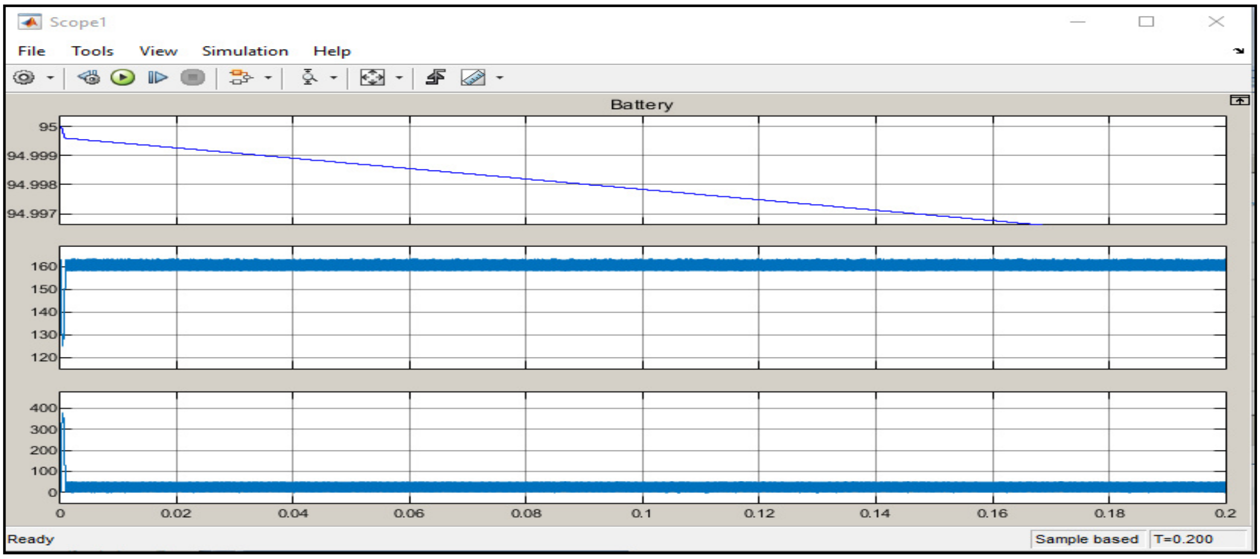

Figure 8. battery discharging condition voltage and current and SOC

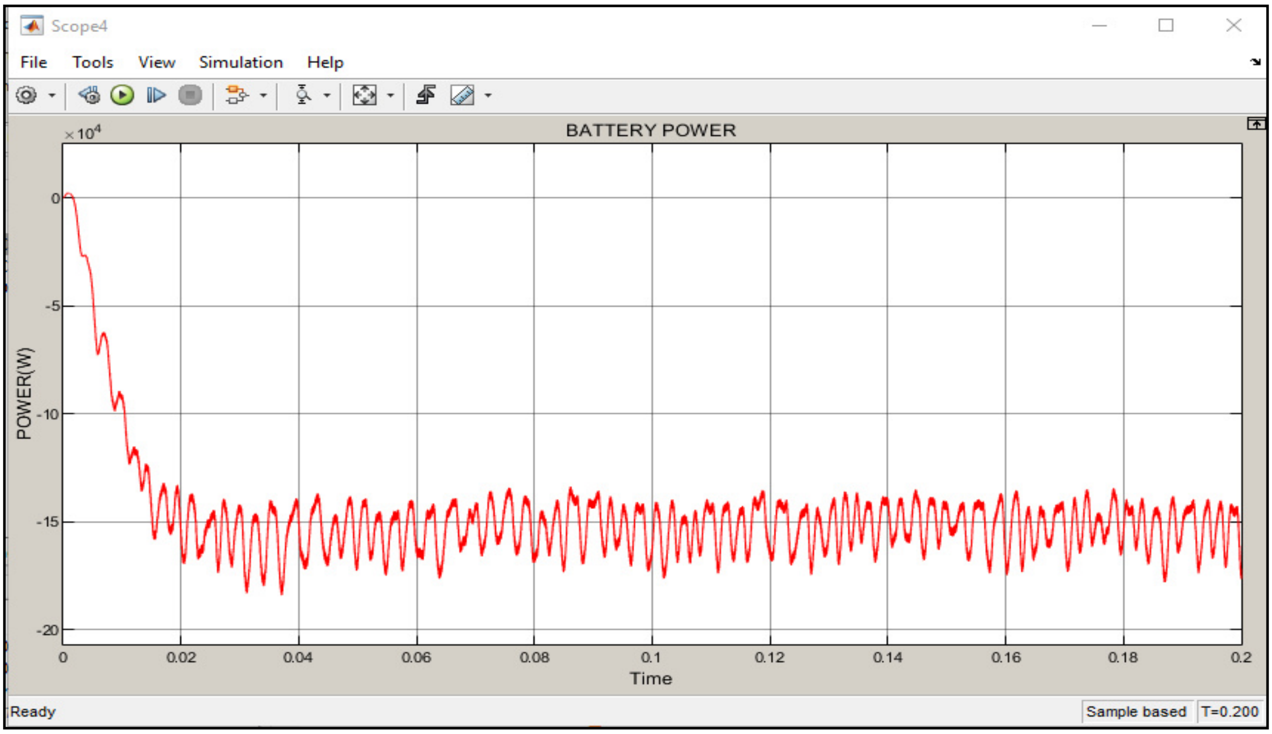

Figure 9. showing the battery power generate by the system

Conclusion

This article focuses on addressing the challenges and optimizing the fast charging technique of electric vehicles (EVs) by leveraging the Vienna T-type converter and Partial Power Processing (PPP) technique. The Vienna T-type converter offers high power quality on both the AC and DC sides, but its complexity and cost pose challenges. The PPP unit is designed to reduce power processed by the converter, minimizing losses and size. Integrating these techniques aims to optimize EV fast charging, achieving faster charging times while minimizing grid impact and maximizing overall system efficiency. The research explores design, implementation, and performance evaluation, focusing on voltage and current fluctuations, harmonics, and efficiency. Ultimately, this work contributes to advancing EV charging infrastructure, promoting widespread EV adoption, and reducing greenhouse gas emissions in the transportation sector.

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