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Wireless Electric Vehicle Battery Charging System using PV Array

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***Abstract:** The rapid emergence and evolution of wireless power transfer technology (WPT) have led to the development of various electrical vehicle applications. One of these is the exploitation of the power from a photovoltaic (PV) array. This paper proposes a system that can extract the power from the PV array and recharge the electric vehicle's battery using a Series-Series compensated network.*

The use of the resonance phenomenon in transferring power efficiently has been widely acknowledged. Due to the presence of various reactive components, a frequency analysis of a series-series compensator is performed.

A proposed system for analyzing the frequency of a wireless power transmission system is simulated in MATLAB Simulink software. The results of the study and the simulation are presented in this paper, which helps in validating the proposed system. The proposed system can be used in various climatic conditions to recharge an electric vehicle. In addition, the proposed system can be developed with closed-loop controllers to improve its performance.

***Keywords:** PV array, H-bridge inverter, Rectifier, wireless power transfer, series-series compensation, photovoltaic, Battery, Transmitter, Receiver.*

I. INTRODUCTION

The use of wireless power transfer technology, which is known as WPT, can eliminate the charging problems of electrical vehicles [1][2][3]. It can be done by parking the vehicle at a charging station. Recently, the technology was widely used in electrical vehicles. This type of power transfer involves the use of an inductor and a large air gap between the two components [4]. The inductor windings are connected to a magnetic core, which means that the entire flux produced by one component gets linked with the other.

This phenomenon allows the tightly coupled network to transfer the power efficiently. However, if the secondary coils do not share the same magnetic core, the power transfer through the system will be reduced [5].

In order to overcome the low efficiency of the system, the inductors can be maintained at a resonance frequency. This is done through the addition of a capacitor on both the sides of the inductor. Resonant frequencies can be generated by various reactive components in the system.A frequency analysis of a Series-series compensator is carried out to determine the optimal frequency for the wireless power transfer. In addition, a PV array can be used to provide an eco-friendly alternative to the traditional method of charging vehicles. Through the use of PV cells, the electricity generated by the solar energy can be used to recharge the vehicle [7][8][9].

Since the solar energy can be used to recharge the vehicle, the PV array can be utilized as the primary source of power for the WPT system. In order to convert the electricity generated by the solar energy into a high-frequency AC voltage, a power conversion device is proposed. This device can be used to transfer the power to the charging circuit of the battery.

The main components required:

1) PV Array
2) H Bridge Inverter
3) Magnetic coupled network
4) Full bridge diode rectifier

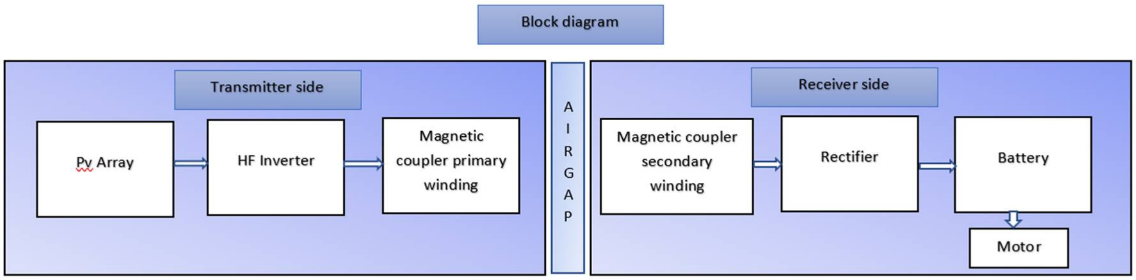

Fig. 1 Block diagram

II. PV ARRAY

PV array is the assembly of PV cells [11]. A photovoltaic cell is an electrical device that uses the energy of light to generate electricity. This technology, which is commonly referred to as a solid-state electrical device, is capable of storing electrical energy in the form of photons. Electrons then flow from the electrical field to the other side. The assembly of solar cells is a process that involves making multiple modules that are designed to capture the energy from sunlight. These are usually assembled together in one plane. When multiple modules are combined, the resulting system is referred to as a solar panel. The electrical energy that is generated by solar modules is an example of solar energy. This technology is commonly referred to as photovoltaics. Although it is focused on the practical application of solar cells, it also studies the theoretical and technological aspects of this technology.

Unlike other types of electrical devices, photovoltaic cells are not always able to receive sunlight. They are therefore used for various applications, such as detecting light and other electromagnetic radiation.

A. Some Important Advantages of Photovoltaic -PV- Systems

1) Through the use of solar energy, we can provide a renewable energy source that can replace the electricity that comes from fossil fuels. This energy can be used to meet our energy needs and reduce our greenhouse gas emissions. As more people adopt PV panels, the more we can help reduce our emissions
2) The industrially-matured PV panels are a reliable and green technology for the production of solar energy. They are capable of providing long-term durability and efficiency levels. PV companies provide warranties on the longevity of their products, as well as their efficiency levels. Some of the most common types of PV panels can last up to 25 years, while others have a maximum efficiency loss of 18%
3) They operate completely autonomously, and they do not generate noise. In some cases, they can be mounted on a fixed pole and have an adjustable rotating mechanism that allows them to follow the sun. Even with this type of system, the movements are relatively minimal, and they do not generate any disturbances
4) Unlike other sources of energy, such as hydro or thermal energy, photovoltaic panels require minimal maintenance and operating costs. They are also more efficient when they are regularly cleaned. This is because regular cleaning of the panels' surface can help maintain their high efficiency.

B. Disadvantages of Photovoltaic (PV) Panels

1) One of the disadvantages of photovoltaic panels is their low efficiency levels. Unlike other renewable energy sources such as solar thermal, such as wind turbines, PV systems have a range of efficiency levels between 12 to 20%. Despite the continuous technological advancements that have been made in the field of PV materials, these systems are still limited due to their limitations.
2) Another main disadvantage of photovoltaic panels is that they require to convert their DC to AC before they can be used for consumption. This process can be very expensive, as it involves the use of various electronic equipment and multiple technological limitations. Besides these, the cost of implementing PV panels also increases due to their size.
3) Although solar energy is usually used during peak energy demand times, it can't store excess energy for later use. This is because solar panels only receive sunlight once and they can't benefit from the sunlight's energy production when there is no sunlight. This is especially important during times of night when there is no sunlight and weather conditions are variable. The reduction in the efficiency of solar panels will result in a lower output, which will affect the financial performance of your PV project.

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III. H-BRIDGE INVERTER

An H-bridge is commonly used as an inverter, which generates a square wave voltage across a load. The output of this type of circuit is then controlled by a DC supply. In a pure inductive load, the current generated by the H-bridge would be a triangle wave. Here the circuit is connected with 4 IGBT's which represents the alphabet H. So, it's called H-bridge Inverter.

An H-bridge is an electronic switch that senses the current applied to a load and then switches the polarity of the load. This type of circuit is commonly used in various applications, such as motors that can run backwards or forwards. The four switching elements in this diagram are arranged as the branches of a letter H, and the load is connected as the cross-bar of the diagram.

In this circuit we are using IGBT [12] for its fast-switching operation so the time delay for transition will be very less.

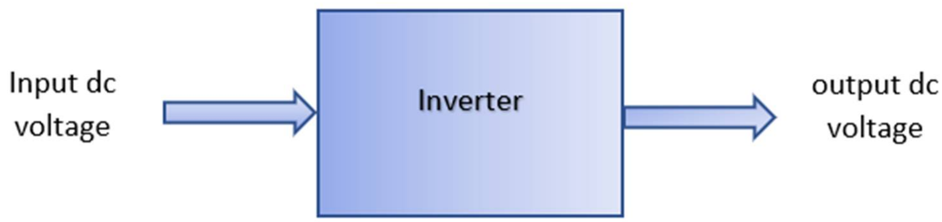

Fig.2 block diagram of inverter

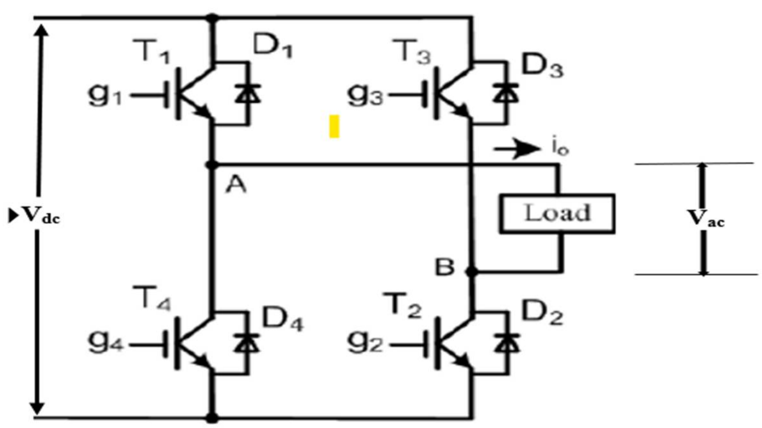

Fig. 3 H-Bridge

Operation [12] is as follows

Gate pulses are provided such that

(T1, T2)-ON (T3, T4)-OFF for positive half cycle.

(T1, T2)-OFF (T3, T4)-ON for negative half cycle.

In this way consecutive cycles occur time period depends on the frequency ($T=1/F_s$).

IV. MAGNETIC COUPLED NETWORK

An electric circuit is said to be coupled when there is a mutual inductance between the two components, which are referred to as inductors and coils. The term inductor and coil are sometimes interchangeably used. In the absence of a certain component, such as a resistor, the latter becomes inductor.

From the frequency analysis [6] there are 3 frequencies available as follows.

$$\omega_{01}=1/\sqrt{(L_1C_1)} \quad \text{-------(1)}$$

$$\omega_{02}= \omega_{01} /\sqrt{(1-k)} \quad \text{------(2)}$$

$$\omega_{03}=\omega_{01}/\sqrt{(1+k)} \quad \text{-----(3)}$$

Due to the presence of various inductors and capacitors in the compensation network, there are three different types of resonance frequencies. From the literature, it has been shown that the preferred resonance frequency is the self-inductance and capacitor frequency [13]-[20], while the other is the leakage inductance and capacitor frequency [21]-[24].

A total of three different resonance frequencies are studied. The first one is a self-inductance frequency, while the other two are leakage inductance and voltage gain. It has been shown that the voltage gain can change with the change in quality factor, but at other two frequencies, the voltage gain is always 1 regardless of the load variation.

The third resonant frequencies are determined by the coupling co-efficient(k). As voltage gain A_v is always 1 For power electronic applications, ω_{02} is preferred, while ω_{03} is preferred in other applications. The values of the series capacitors and the inductor are calculated using the first resonant frequency ω_{01}.The power transfer efficiency of an inverter can be improved by operating it at second resonance frequency.

The values of capacitors and inductors are computed according to the equations 1 and 2. They are expressed in terms of the first resonance frequency of the capacitors, which is 45 kHz. The designed values are shown below.

S.no	Name of the component	Value
1	Turns ratio	1:1
2	C1, C2	0.1uF
3	L1, L2	126.6uH
4	Mutual Inductance	25.3uH
5	Coupling Coefficient	0.2

Table. 1 Specifications of the coupled network

V. RECTIFIER

A rectifier is a device that uses one or more junction diodes to convert an alternating current to a direct current. This process is referred to as rectification. When the current flows in one direction, it's called a one-way valve. Rectifier components can be made from various materials, such as solid-state, vacuum tube, and mercury-arc valves. Some of the other types include silicon-controlled and single-phase devices. In the proposed project we have used full bridge rectifier [10].

VI. BATTERY

A battery is composed of several cells that react to chemical reactions to create a flow of electrons. These are referred to as batteries. The three basic components of a battery are an anode, a cathode, and an electrolyte. When two components of a battery are connected to a circuit, the chemical reaction between the anode and the cathode triggers an electron flow to the other side. This then causes the electrons to go back to the anode. However, if the materials in either the anode or the cathode are not used in the chemical reaction, the battery will no longer produce electricity. A battery that should be thrown away after it has been used is referred to as primary battery. On the other hand, secondary batteries can be charged. .In this project, we are using a Lithium-Ion battery [27] which is the most commonly used battery in EVs.

Along with the above components, some additional components are added such as a filter [25] and motor. Here filter gives the required output without any disturbances in the output waveforms. Motor [26] is added to check whether our model can physically work with real-time EVs.

VII. SIMULATION RESULTS

A. *Simulation Diagram*

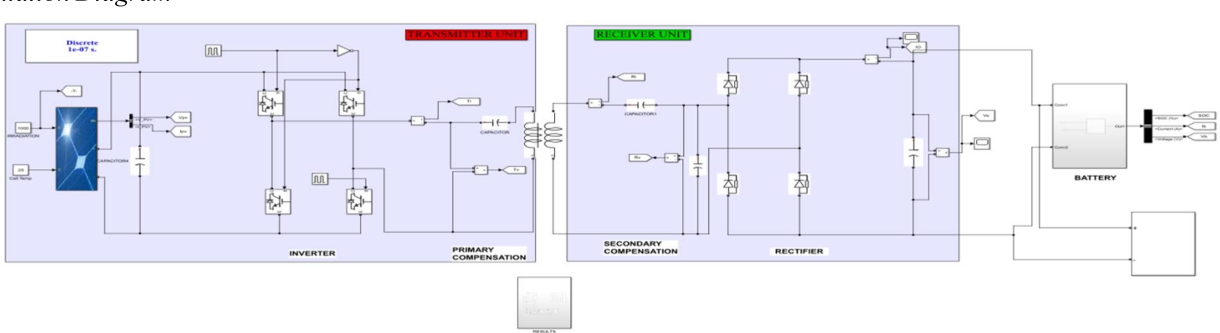

Fig. 4 Simulation Diagram

B. *PV array Voltage and Current*

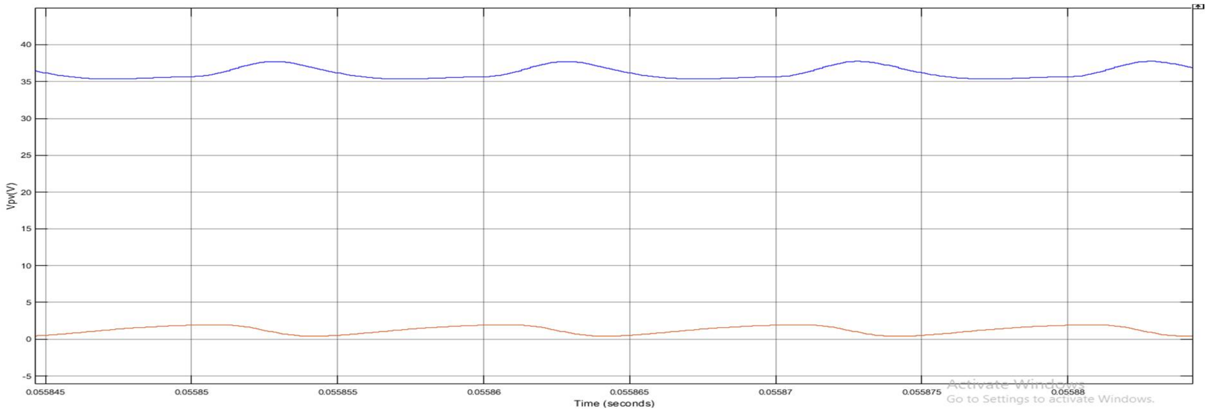

Fig. 5 PV array voltage and current outputs

C. *Transmission Side Voltage and Current*

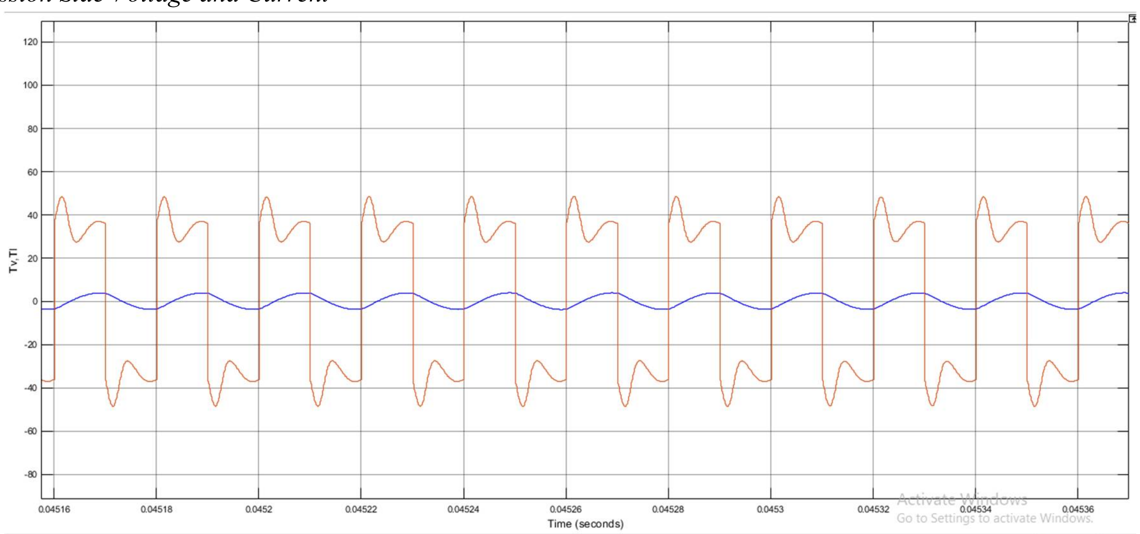

Fig. 6 Transmission side voltage and current output

D. *Receiver side voltage*

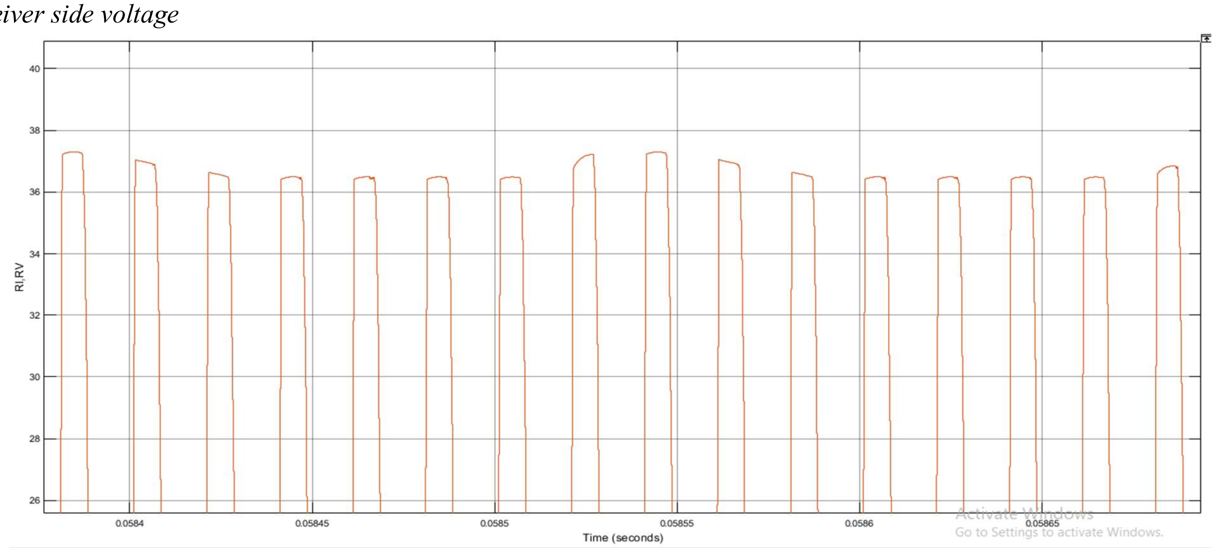

Fig. 7 Receiver side voltage

E. Battery Voltage

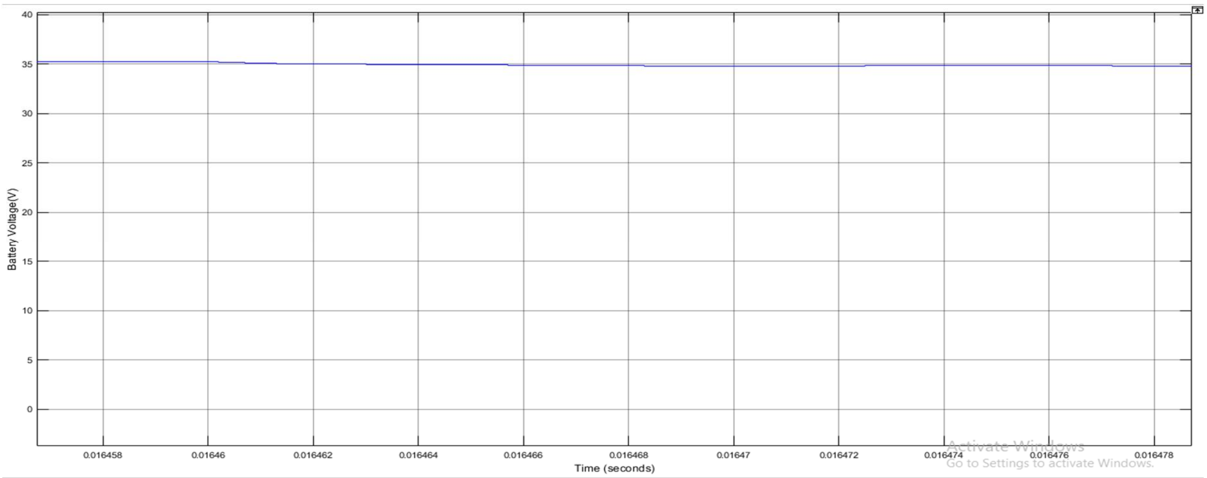

Fig. 8 Battery voltage

F. Output Voltage and Current

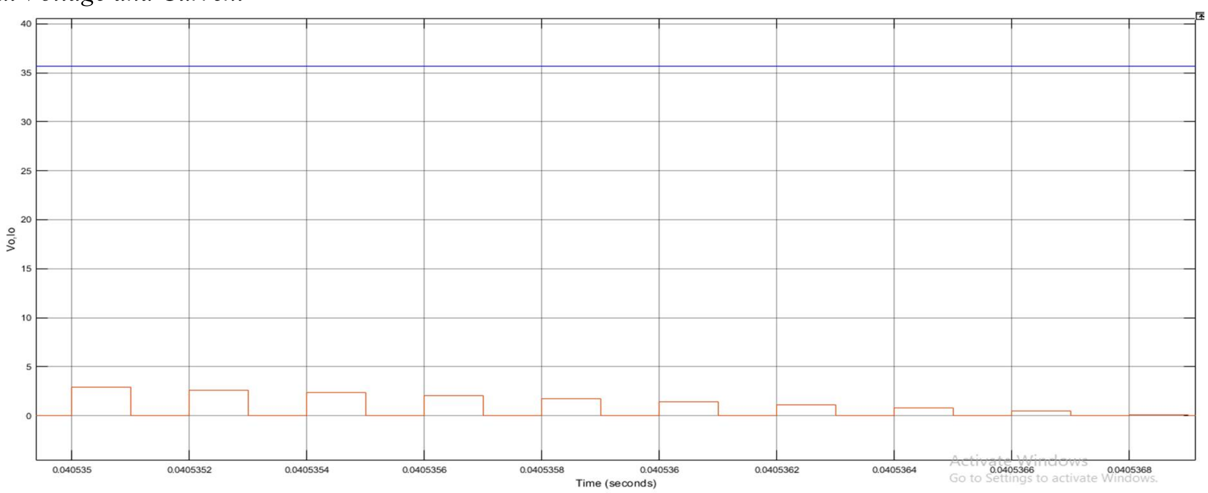

Fig. 9 Output voltage and current

G. Motor Parameters

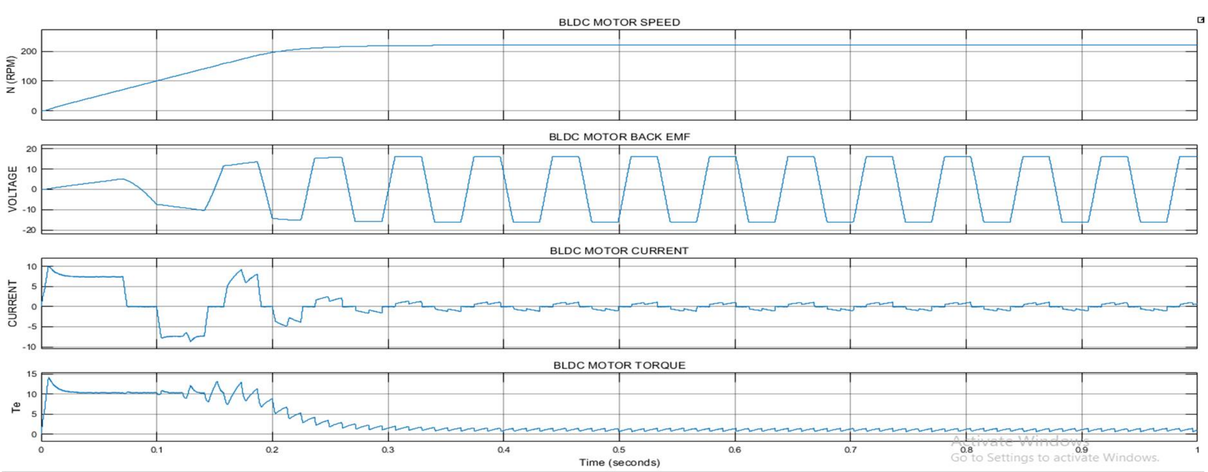

Fig. 10 Motor parameters

VIII. CONCLUSION

In this paper, a proposed system is presented that allows the charging of a battery from a PV array in the WPT mode. The system is performed through a detailed analysis of the frequency of the components and their corresponding compensation network. A laboratory prototype is being developed to test the results of the simulation. A physical model is also being created for experimental analysis. If the results of both the simulation and the experimental tests are satisfactorily valid then the proposed system can successfully operate.

IX. ACKNOWLEDGEMENT

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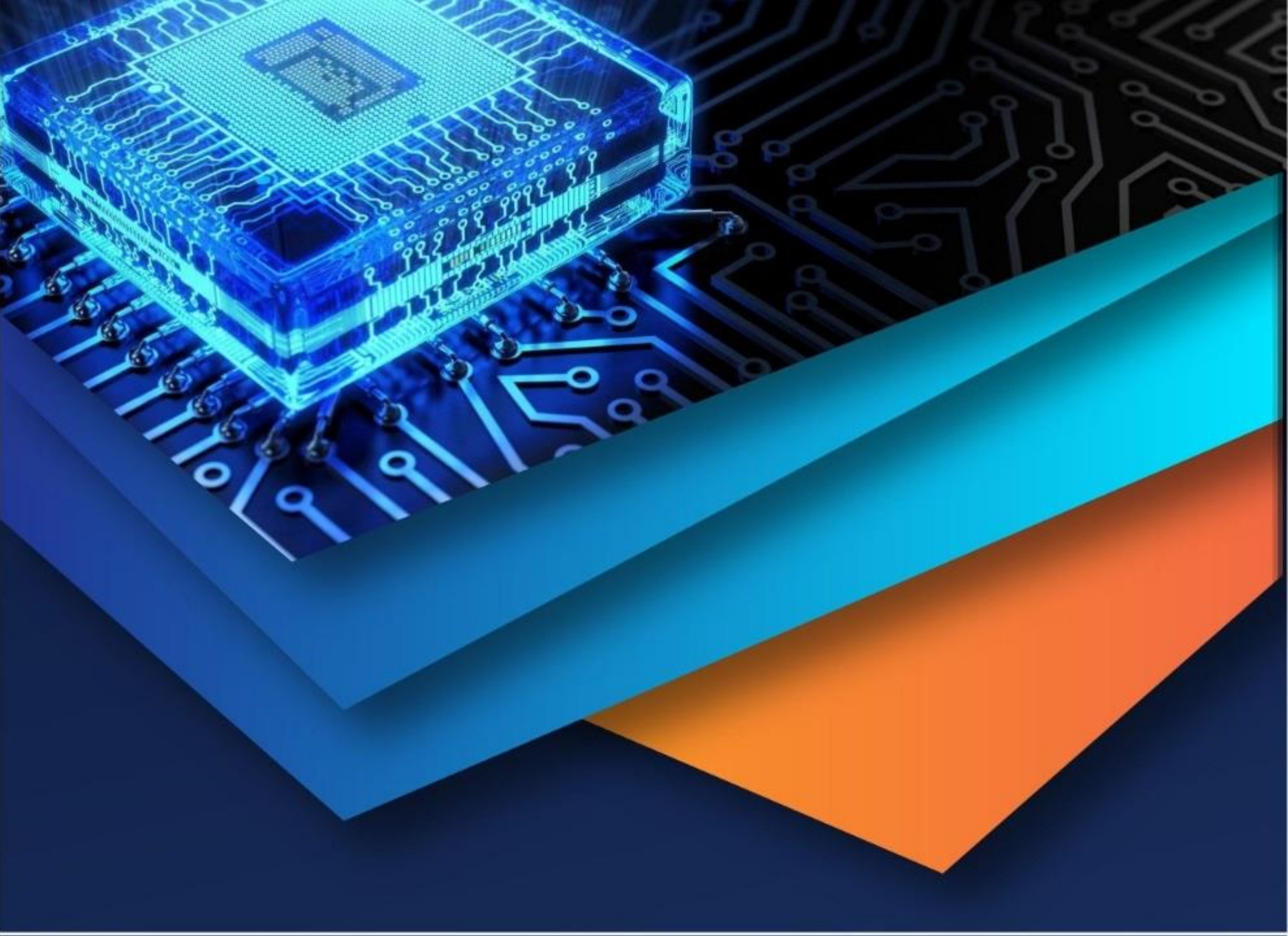

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