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Solar Powered BLDC Motor Drive Train for Electric Vehicle

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ABSTRACT: As per studies, BLDC motor is found to be a suitable motive element for EV application based on its suitable torque speed characteristics. The system needs to implement with a suitable control mechanism that will help to operate the motor in an efficient manner. In MATLAB, the development of a PV(Photovoltaic) powered Electric Vehicle(EV) with a Brushless DC(BLDC) Motor Drive involves creating a comprehensive simulation environment to model the integration of solar energy harvesting, electric vehicle dynamics, and BLDC motor control. The system incorporates PV panels to convert sunlight into electrical energy, which is then utilized to charge the EV's battery pack. MATLAB allows for the implementation of algorithms to regulate the charging process efficiently and manage the power flow between the PV array, battery, and BLDC motor drive system. Through sophisticated control strategies and simulations, engineers can optimize the performance of the
PV- powered EV, considering factors such as vehicle speed profiles. The MATLAB platform facilitates the design, testing, and validation of various control algorithms and energy management strategies, ensuring the reliable and sustainable operation of PV-powered electric the reliable and sustainable operation of PV- powered electric vehicle equipped with BLDC motor drives.

I. INTRODUCTION

The increasing demand for sustainable energy solutions has led to growing interest in renewable energy integration with electric propulsion systems. Among these systems, Brushless DC (BLDC) motors have emerged as a preferred choice due to their high efficiency, reliability, and precise control capabilities. However, the intermittent nature of renewable energy sources poses a challenge for their integration with BLDC motor drives. To address this challenge, this paper proposes a novel approach that combines Photovoltaic (PV) panels with battery storage to power a BLDC motor drive system.

The integration of PV panels and batteries offers several advantages, including reduced dependency on conventional energy sources, lower operating costs, and minimized environmental impact. By harnessing solar energy through PV panels and storing excess energy in batteries, the proposed system ensures continuous operation and optimal utilization of renewable resources. Moreover, the adoption of a Proportional-Integral-Derivative (PID) controller enables precise speed control, allowing the BLDC motor to maintain desired performance characteristics under varying operating conditions.

This research aims to contribute to the advancement of sustainable transportation, renewable energy utilization, and environmental conservation. Through comprehensive simulation studies and experimental validations, the effectiveness and feasibility of the proposed PV-battery integrated BLDC motor drive system are evaluated. The findings of this study provide valuable insights into the design, optimization, and deployment of renewable energy-powered electric propulsion systems, paving the way for a greener and more sustainable future.

II. LITERATURE SURVEY

According to Mohammed Ismail, huge permanent magnets were employed for excitation in the earlier 19th century, but in the 20th century, more potent magnets like Alcomax and Alnico were discovered, producing more magnetic field lines and establishing strong coercive force in the machine, because they have greater benefits than traditional DC motors, Kamal claimed that "BLDC motors are commonly used in Servo motor applications [1]. To control BLDC motors, a simpler current controlled modulation technique is employed which is based on the creation of Quasi-square wave current, by employing only one current controller for three phases may control the motor,

Dubey recommended. The phase currents are maintained in balance, and the current is only controlled by one DC component, among other benefits of this method [2][3]. According to Alasayid, "Uses of BLDC motors have expanded in recent times as a result of evaluation in the field of magnetic materials and power electronics, as well as the availability of cheap and powerful processors." [4]. According to Suganthi, many electrical devices are developed with permanent magnets rather than electromagnets since it has more advantages and they have minimal excitation loss, are cost effective, and create high output torque [5]. According to P.S.Vikhe, BLDC motors offer good performance in both current and upcoming applications. These motors have a variety of uses, including spinning, drilling, elevators, locks, etc., and changing speed in BLDC motors is simple to implement [6]. According to Uma Gupta, BLDC motors

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are more efficient, consume less fuel, and have a higher power-to volume ratio than other types of motors [7]. R.G.Rajesh proposed that BLDC motors should have torque smoothness for high performance and efficiency. It is more crucial to obtain a precise and ripple-free instantaneous torque for good control performance [8]. Due to their attributes like great dependability, a simple frame, high efficiency, quick dynamic response, compact size, and very little maintenance, BLDC motors are also frequently utilised for domestic applications, according to Sathish Kumar [9]. According to Juhi Nishat Ansari, brushed DC motors have various drawbacks that are solved by BLDC motors. Additionally, the motor can be effectively regulated by employing hall effect sensors [10].

III. MATHEMATICAL MODELLING OF BLDC MOTOR

A 3 phases, 4 poles, Y connected trapezoidal back-EMF type BLDC is modeled. Trapezoidal back EMF is referring that mutual inductance between stator and rotor has trapezoidal shape. Therefore a b c phase variable model is more applicable than d-q axis. The following assumptions are made.i.e Magnetic circuit saturation is ignored, Stator resistance, self and mutual inductance of all phases are equal and constant, Hysteresis and eddy current losses are eliminated, All semiconductor switches are ideal.

The electrical and mechanical mathematical equations of BLDC are:
Phase voltage equations of BLDC motor

$$V_a = R\, i_a + (L - M)\frac{di_a}{dt} + E_a$$

$$V_b = R\, i_b + (L - M)\frac{di_b}{dt} + E_b$$

$$V_c = R\, i_c + (L - M)\frac{di_c}{dt} + E_c$$

Back emf equations of BLDC motor

$$E_a = K_e\, \omega_m\, F(\theta_e)$$

$$E_b = K_e\, \omega_m\, F\left(\theta_e - \frac{2\pi}{3}\right)$$

$$E_c = K_e\, \omega_m\, F\left(\theta_e - \frac{4\pi}{3}\right)$$

Torque equations are each phase of BLDC motor

$$T_a = K_t\, i_a\, F(\theta_e)$$

$$T_b = K_t\, i_b\, F\left(\theta_e - \frac{2\pi}{3}\right)$$

$$T_c = K_t\, i_c\, F\left(\theta_e - \frac{4\pi}{3}\right)$$

The electromagnetic torque is

$$T_e = T_a + T_b + T_c$$

$$T_e - T_l = J\frac{d^2\theta_m}{dt^2} + \beta\frac{d\theta_m}{dt}$$

$$\theta_m = \frac{p}{2}\,\theta_m$$

$$\omega_m = \frac{d\theta_m}{dt}$$

In the modeling equation K_e is back emf constant in volt/rad/sec and K_t=torque constant in N-m/Amp and ω_m is rotor angular speed.

IV. METHODOLOGY

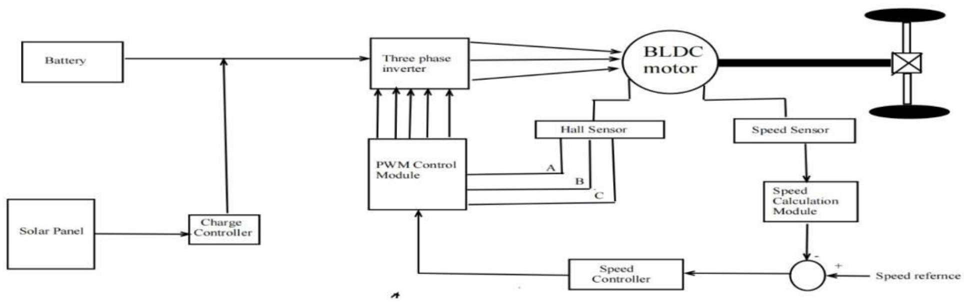
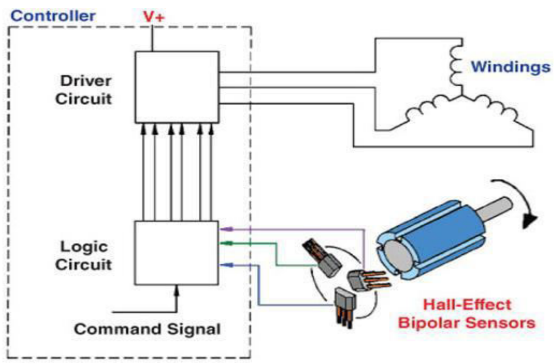


Fig: Block Diagram

For PMAC motors, a constant supply of position information is necessary; thus a position sensor with high resolution, such as a shaft encoder or a resolver, is typically used. For BLDC motors, only the knowledge of six phase-commutation instants per electrical cycle is needed; therefore, low-cost Hall-effect sensors are usually used. Also, electromagnetic variable reluctance (VR) sensors or accelerometers have been extensively applied to measure motor position and speed. The reality is that angular motion sensors based on magnetic field sensing principles stand out because of their many inherent advantages and sensing benefits .

An accelerometer is a electromechanical device that measures acceleration forces, which are related to the freefall effect. Several types are available to detect magnitude and direction of the acceleration as a vector quantity, and can be used to sense position, vibration and shock. The most common design is based on a combination of Newton"s law of mass acceleration and Hooke"s law of spring action. Then, conceptually, an accelerometer behaves as a damped mass on a spring, which is depicted. When the accelerometer experiences acceleration, the mass is displaced to the point that the spring is able to accelerate the mass at the same rate as the casing [12]. The displacement is then measured to give the acceleration. There is a wide variety of accelerometers depending on the requirements of natural frequency, damping, temperature, size, weight, hysteresis, and so on. Some of these types are piezoelectric, piezo-resistive, variable capacitance, linear variable differential transformers (LVDT), potentio-metric, among many others . The MEMS accelerometer is silicon micro-machined, and therefore, can be easily integrated with the signal processing circuits

These kinds of devices are based on Hall-effect theory, which states that if an electric current- carrying conductor is kept in a magnetic field, the magnetic field exerts a transverse force on the moving charge carriers that tends to push them to one side of the conductor. A build-up of charge at the sides of the conductors will balance this magnetic influence producing a measurable voltage between the two sides of the conductor. The presence of this measurable transverse voltage is called the Hall-effect.



V. SIMULATIONS RESULTS

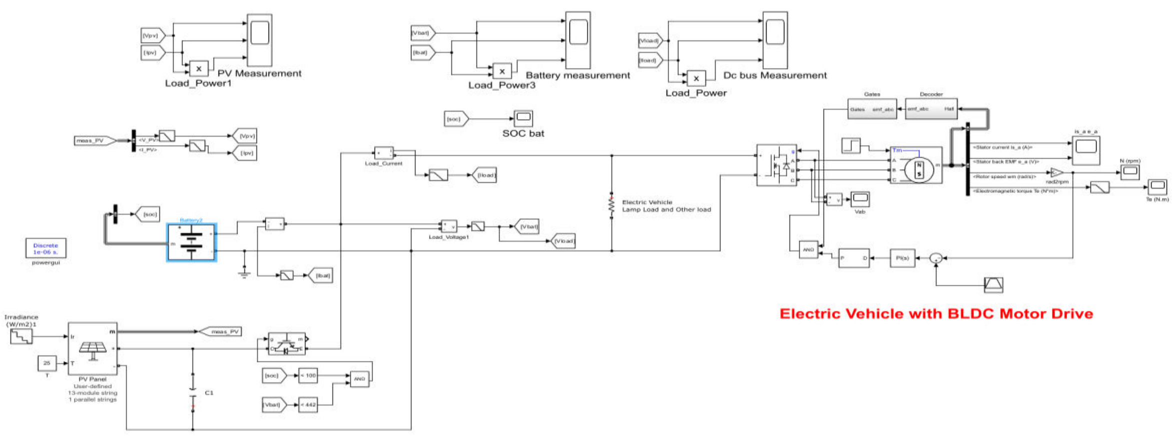


Fig: Simulation Circuit Diagram

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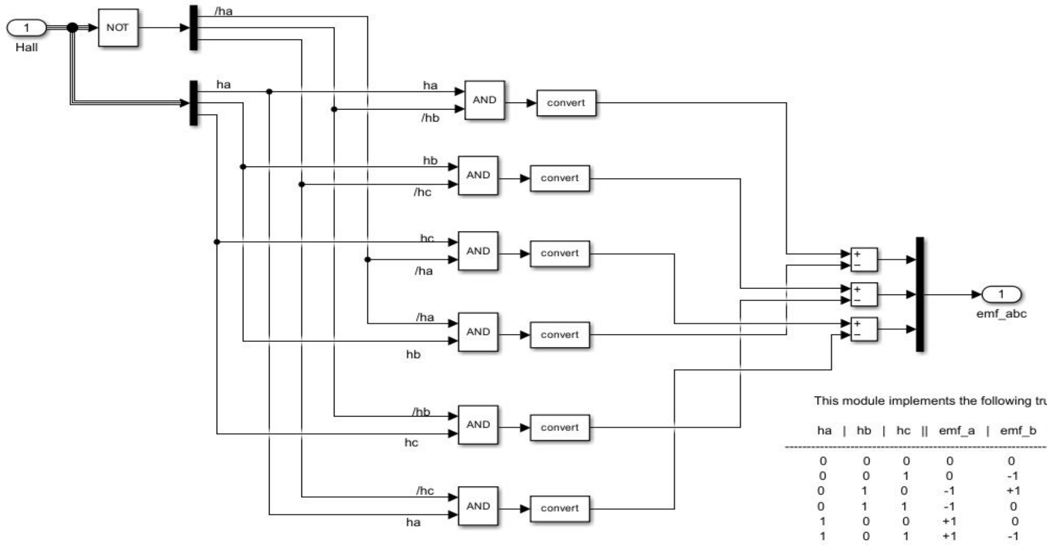
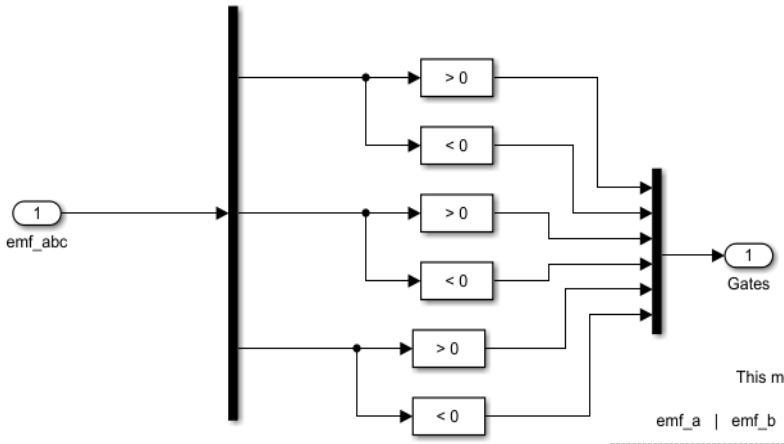


ha	hb	hc	emf_a	emf_b	emf_c
0	0	0	0	0	0
0	0	1	0	-1	+1
0	1	0	-1	+1	0
0	1	1	-1	0	+1
1	0	0	+1	0	-1
1	0	1	+1	-1	0
1	1	0	0	+1	-1
1	1	1	0	0	0

Fig: Decoder Subsystem



emf_a	emf_b	emf_c	Q1	Q2	Q3	Q4	Q5	Q6
0	0	0	0	0	0	0	0	0
0	-1	+1	0	0	0	1	1	0
-1	+1	0	0	1	1	0	0	0
-1	0	+1	0	1	0	0	1	0
+1	0	-1	1	0	0	0	0	1
+1	-1	0	1	0	0	1	0	0
0	+1	-1	0	0	1	0	0	1
0	0	0	0	0	0	0	0	0

Fig: Gate pulse Subsystem

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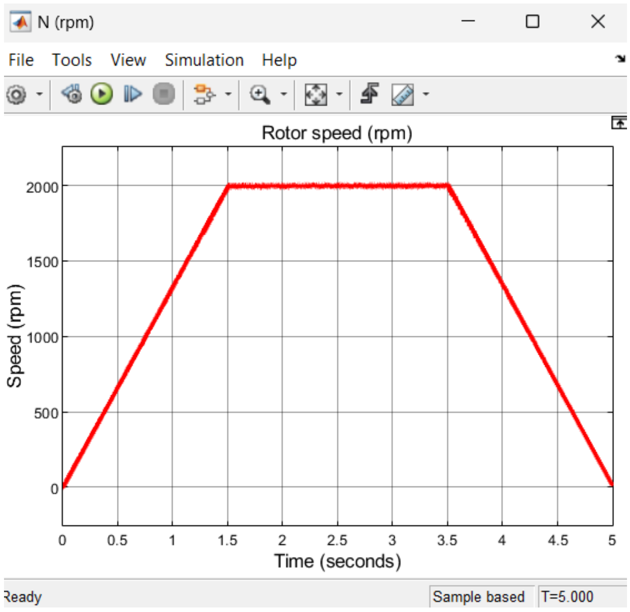
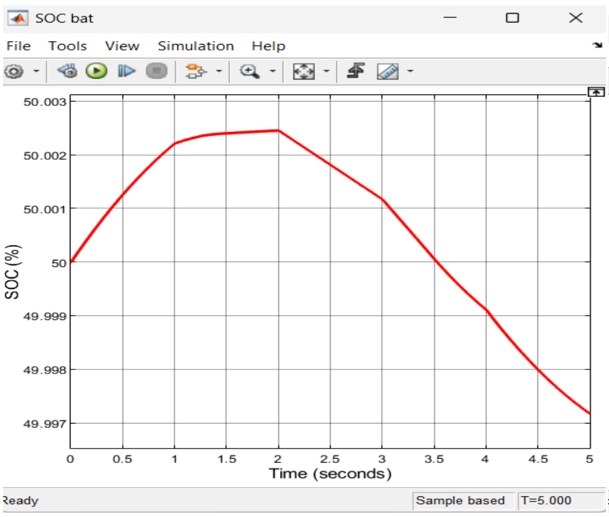
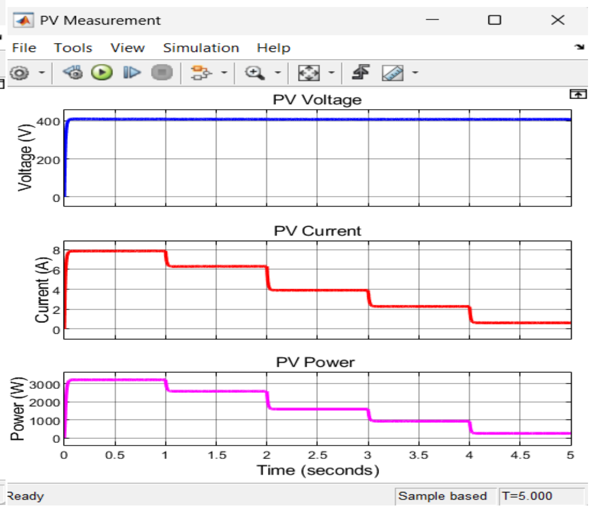
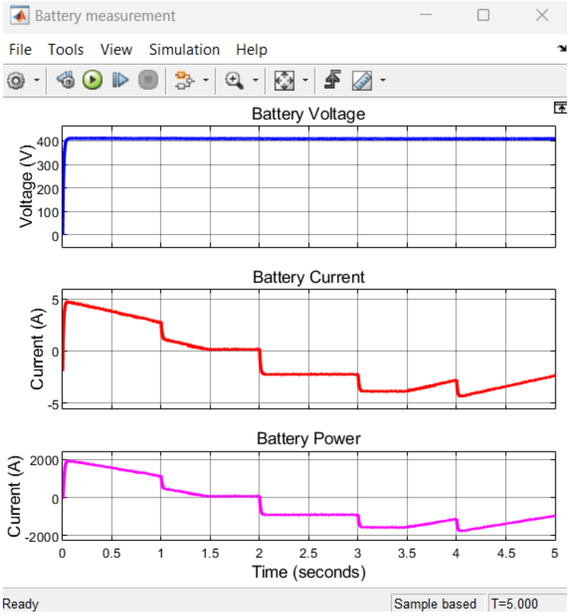
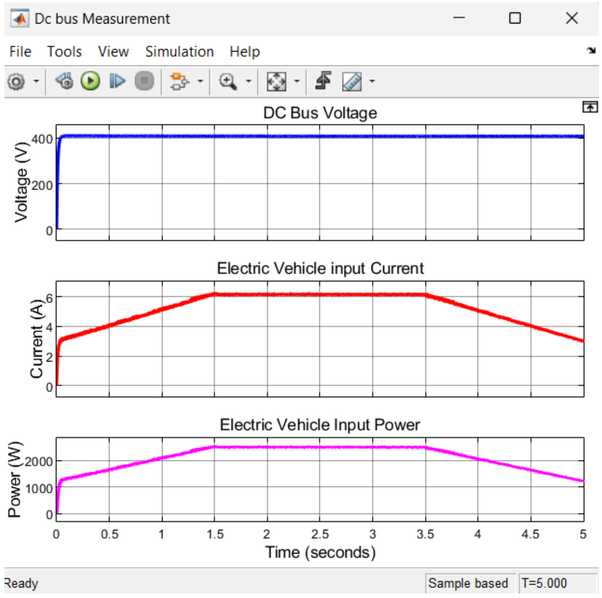


When SOC of battery is 50%, than the PV drives the electric vechicle and charge the battery

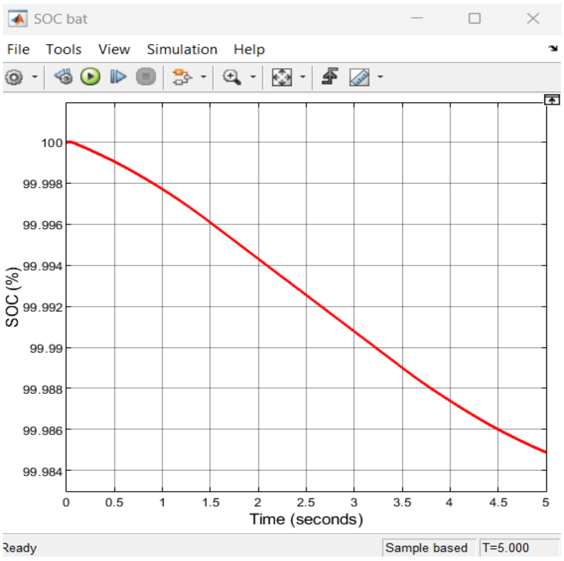


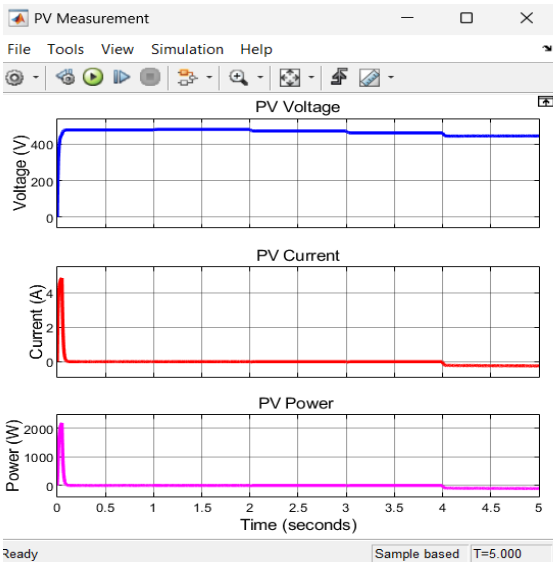






When SOC of battery is 100% , we doesn't require PV than battery drives the vehicle.





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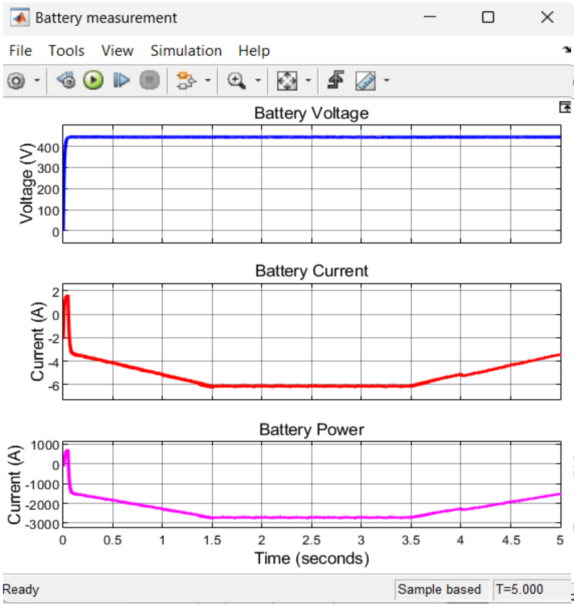

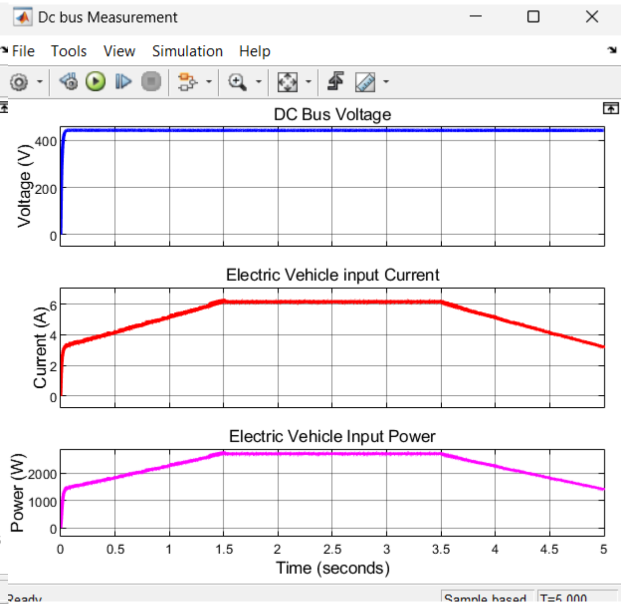

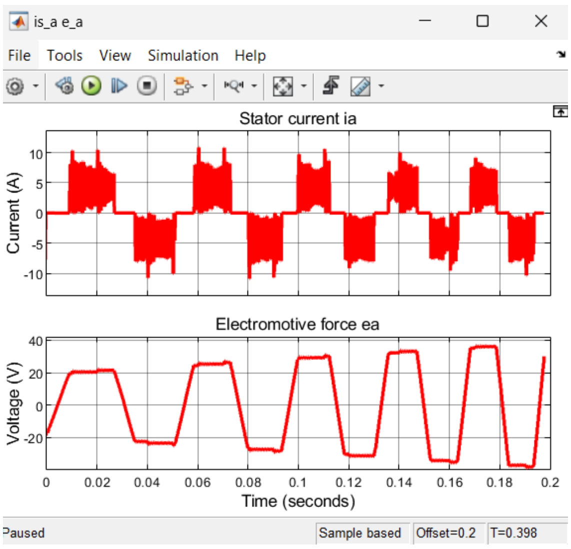

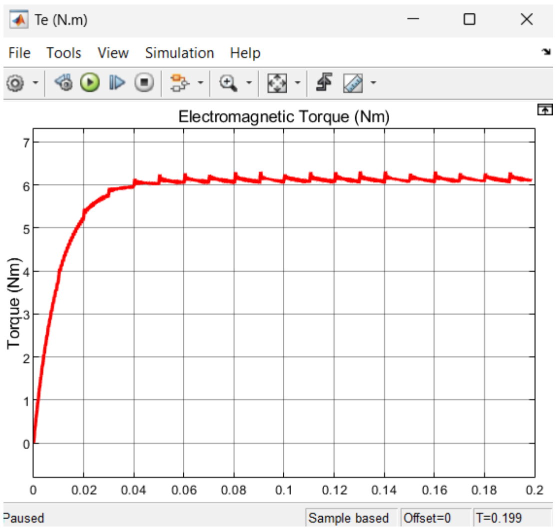

VI. CONCLUSION

This study presents Solar powered Brushless DC (BLDC) electric drive system using Simulink. The BLDC motor control system comprises several key components, including the decoder block, gate pulse generation, and universal bridge. These components work together to interpret rotor position feedback, generate PWM signals, and drive the motor phases, enabling precise control over motor speed and torque.Throughout the study, we gained insights into the intricate control algorithms and power electronic circuitry required to efficiently operate a BLDC motor. By leveraging the capabilities of Simulink, we were able to model, simulate, and optimize the performance of our BLDC motor control system in a virtual environment before implementation.

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