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Regenerative Braking System: Why is Energy Regeneration System Required?

Suyash Tripathi[2], Avanish Kumar Tiwari[3], Samyak Jain[4], Priyanshu Tomar[5]

I. INTRODUCTION

Our vehicle's Fundamental objective revolves around the incorporation of the Energy RegenerationSystem (ERS)designedtoenhance energy efficiency. The ERSfunctionsby capturing kinetic energy generated during braking and deceleration, effectively storing this energy in a high-capacity battery. Subsequently, the vehicle's powertrain converts this stored energy into electricalpowertorechargethebatterythroughthe ERS.Thisinnovativeapproachnotonlyconverges energy but also exemplifies the efficient transformationofenergyfromonestatetoanother.

Indeed, the ERS system plays a crucial role in preventing energy wastage. The ERS minimizes reliance on external energy by converting braking kinetic energy into electrical energy, enhancing efficiency and sustainability while reducing the need for external energy. Thissystem helpsmake the vehicle more environmentally friendly.

II. CONCEPT AND TECHNICAL FEATURES

The heart of electric vehicles lies in the Brushless DC (BLDC) motor, which serves as the main control of the inverter. Regenerative braking, a mechanical innovation in electric vehicles, tackles the challenge of energy recovery during braking, excelling in stop-and-go scenarios. Distinguished from traditional braking systems reliant on friction, it captures, converts, and stores a significant portion of kinetic energy in batteries or supercapacitors, marking a significant leap in energy efficiency and sustainability.

In theworking principleof BLDCmotors,the rotor, representing the rotating part, is a permanent magnet, while the stator, the fixed part, generates a stationary magneticfield. Controlled byadjusting current direction and magnitude, BLDC motors offer higher efficiency and durability,making them ideal for electric vehicles.

During acceleration, the current from the motor battery is reversed, and directed into the supply battery,enablingregenerativebraking.PulseWidth Modulation (PWM) in independent switching is employed for effective brake control, maximizing energy recovery during the regenerative braking phase. The application of a PI controller in the current control mechanism ensures constant torque, and the entire setup facilitates regenerative braking through PWM control.

In conclusion, integrating BLDC motors and regenerative braking enhances the efficiency of electric vehicles and contributes significantly to sustainable transportation. This innovative approach, employing advanced motor control and regenerative braking systems, aligns with the evolving landscape of eco-friendly mobility solutions.

Fig.1 Represents Operational phase working of Electric Vehicle propulsion

A. Operational Phases of Electric Vehicle Propulsion

1) Acceleration

In the initial phase of operation, the electric vehicle undergoes acceleration, gradually reaching a steady speed determined by the applied torque. As the motor initiatesitswork,theremightbebriefcurrentspikesthat subsequentlydecrease.Positivecurrent,conformingto standard conventions, is supplied from the battery to themotorduringthisphase,facilitatingforwardmotion.

2) Braking

During forward motion, when the accelerator pedal is released,themotorgeneratesreversetorque,inducing aslowingeffectonthevehicle.Thismarkstheactivation of theregenerative braking system, where theenergy producedduringbrakingchargesthebattery.Duetothe reversal in direction, the current flows back to the battery (acting like a generator) but with a negative sign. The motor initially accelerates under external input, and when braking is required, the regenerative system engages. Precise control of the braking operation is managed by a controller, in coordination with hall effect sensors for effective switching of the inverter/motor controller.

Electric vehicle dynamics encompass acceleration,with a positive current from the battery propelling themotor forward. Upon releasing the accelerator,regenerative braking engages, causing the motor togenerate reverse torque.

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This system, managed by acontroller and hall effect sensors, converts brakingenergy into a charge for the battery. The intricateinterplay of acceleration and regenerativebraking optimizesefficiency,markingasustainable approach toelectric vehicle performanceandenergymanagement.

Components Specifications:-

- Battery:-It'sforStoringtheenergyrecovered During the regenerative braking.

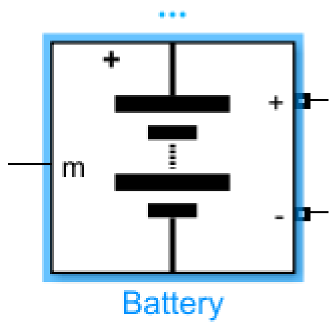

Fig1.1Battery Block

- NominalVoltage=48V
- InitialSoC%=100%
- Ratedcapacity=50Ah

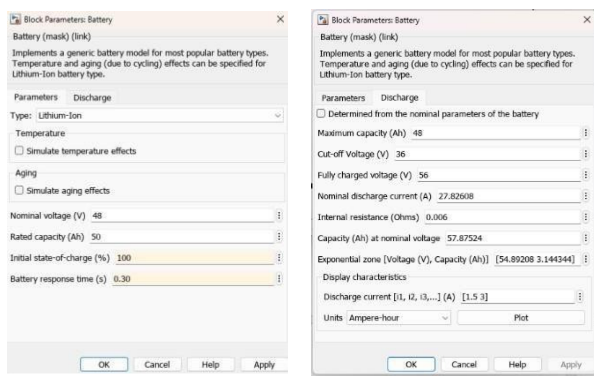

Fig1.2ParametersoverBattery

- Universal Bridge Block:-It is used for the fast switching.

Basicallythisblocksconsistsoftwobasicvoltage boosting states such as

- Energizing
- Storingphase.

Currenthasbeenturneduptothebatterybybothof the diodes.

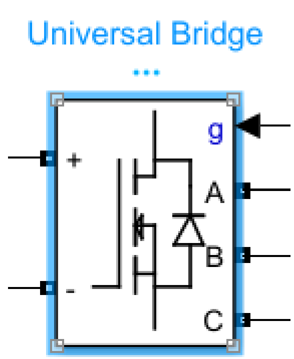

Fig1.3UniversalBridgeBlock

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a) Motor:-

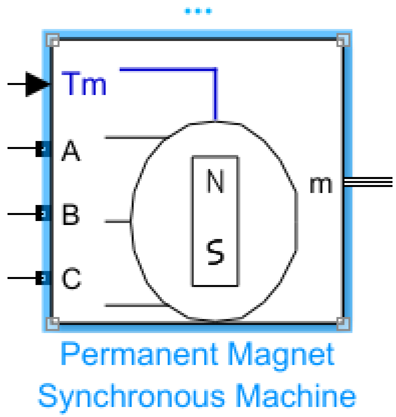


Fig1.4PMSMBlock

- InthisSystemthePMSMblockhasbeen used as a BLDC Motor.
- FortheFunctionthetworequiredinputsas Torque and angular Velocity.
- TheMechanicaltorqueasaninputisgivenin the PMSM Block.
- TheMotorwillbeconnectedtothebus selectors.

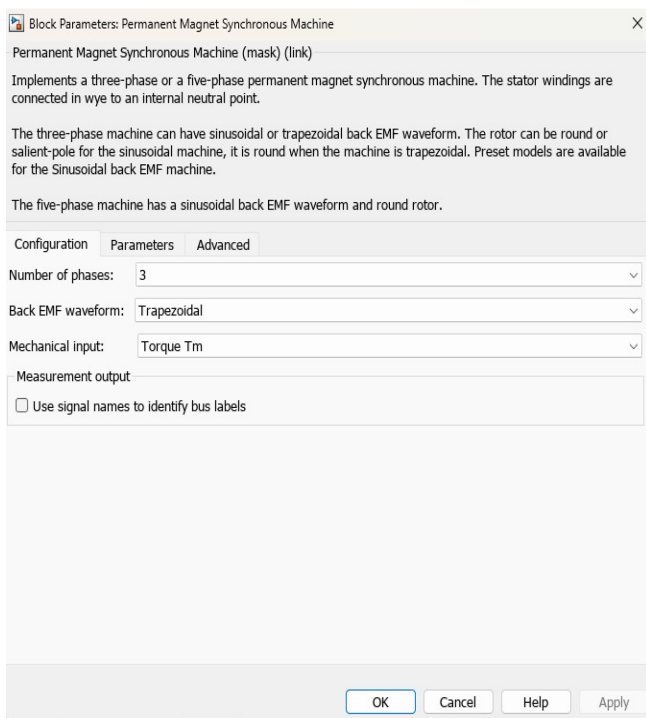


Fig1.5ParametersofPMSM

b) Controller:-

Thisisthecontrollerwhichwillbeusedinthesystem consisting of a hall sensor, rated speed,etc.

SpecifiedModelInsideController:- Inputs in the Controller:-

- 3Hallsensorpoints
- ASpeedController

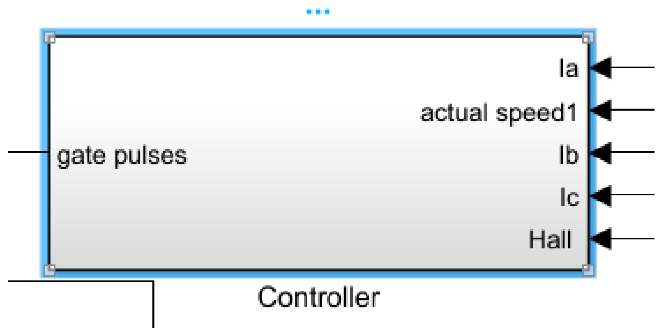


Fig1.6Controller

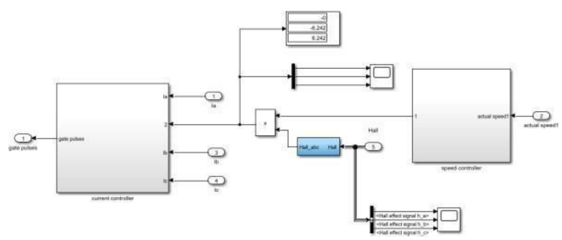


Fig1.7CircuitAnalysis

SpecifiedmodelunderspeedController:-

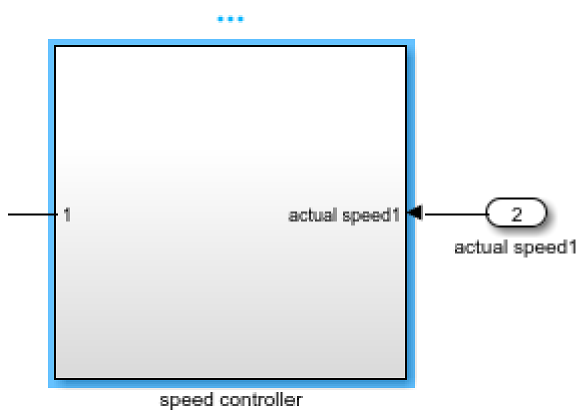
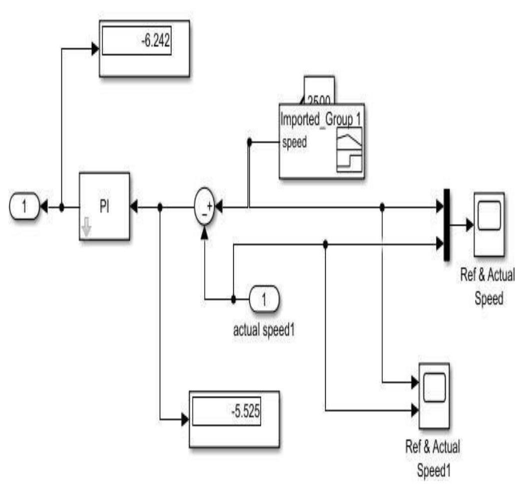


Fig1.8ControllerBox

It uses PI Controller that compares the Command setuppointandtheactualvaluebasedonfeedback.



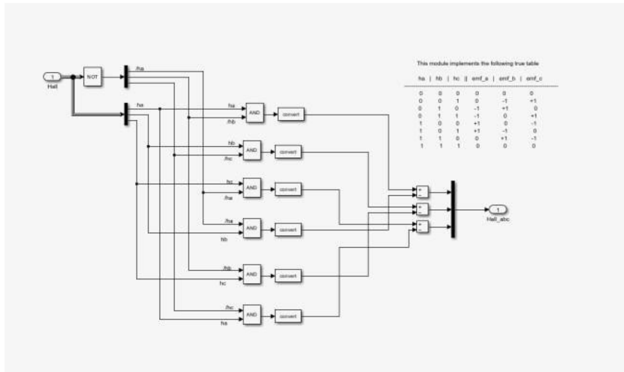


Fig1.9HallSensor Circuit

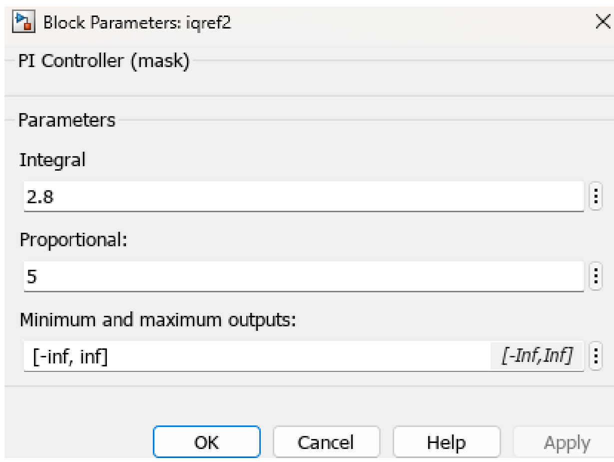


Fig1.10ParametersofPIController

The purpose of the hall sensor is to determine the rotorpositiontodetecttheenergizedwindingafterthe energizing sequence.

c) CurrentController:-

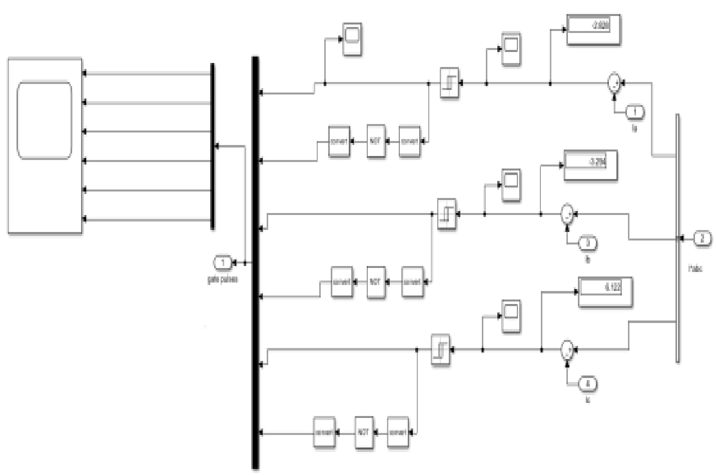


Fig1.11CurrentControllerCircuitDiagram

Theoutputofthecurrentcontrollerwillbetheoutput ofthewholecontrollerblockanditwillbeconnected to the switching element MOSFET: the universal bridge block.

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Concerning the torque of the brake pedal, a Simulinkfunctioncalledsignalbuilderwasused to generate torque values.

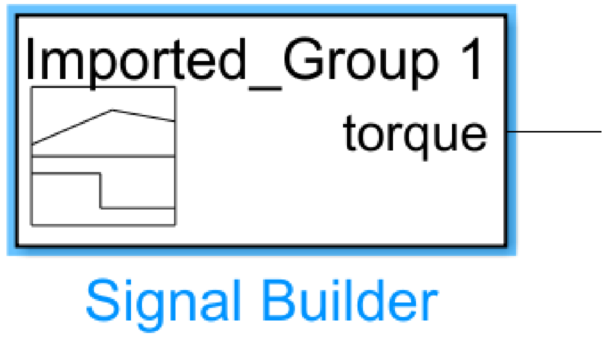

Fig1.12SignalBuilderBox

III. CALCULATION AND ANALYSIS TARGET

1) Specifications:-

Parameters	Estimates
Weight	220kg
Initialvelocity	35km/hr.
brakingForce	1100N
stoppingdistance	4m
Regenerationefficiency	56%
Energyconversion efficiency	80%

2) Calculations:-

Efficiency

- KineticEnergy:-

Vin=35km/hr.
=9.72m/sec
KineticEnergy(initial)=1/2*m*V2(initial)
=1/2*220*(9.72)2
=10392.624J

- WorkDoneDuringBraking:-

W=BrakingForce*StoppingDistance
=1100*4
=4400J

- EnergyRegenerated:-

EnergyRegenerated=WorkDoneDuring Braking*Regeneration Efficiency
=4400*0.56
=2464J

- EnergyConvertedtoBattery: -

Energytobattery=EnergyRegenerated*Energy Conversion Efficiency
3696*0.80
1379.8J

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- StateofchargeChange:-

Stateofchargechange=Energyofbattery/Battery Capacity

BatteryCapacity=50Ah

SOCchange=1379.8/50

=27.59

- Deceleration

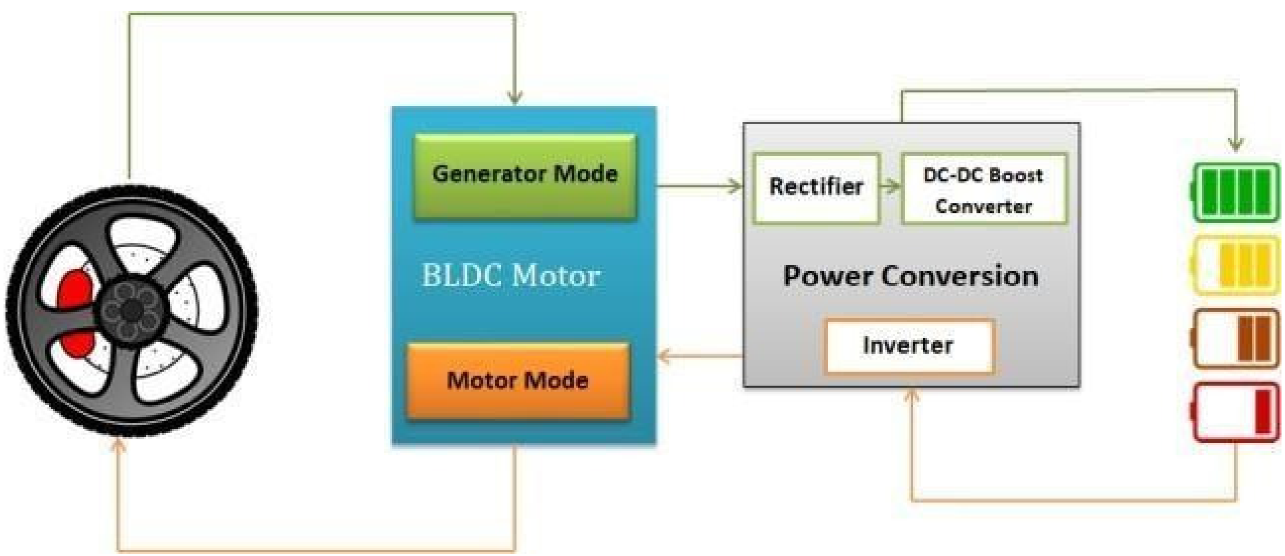
(d)=[V^2(final)-V^2(initial)]/2(StoppingDistance)

=0-$(9.72)^2$/2(4)

=-94.4784/8

=11.8098m/sec^2

IV. APPENDIX-1: DESIGN VIEWS AND PHOTOGRAPHS



A. *Circuit Analysis:-*

ThreePhaseStatorCurrent:-

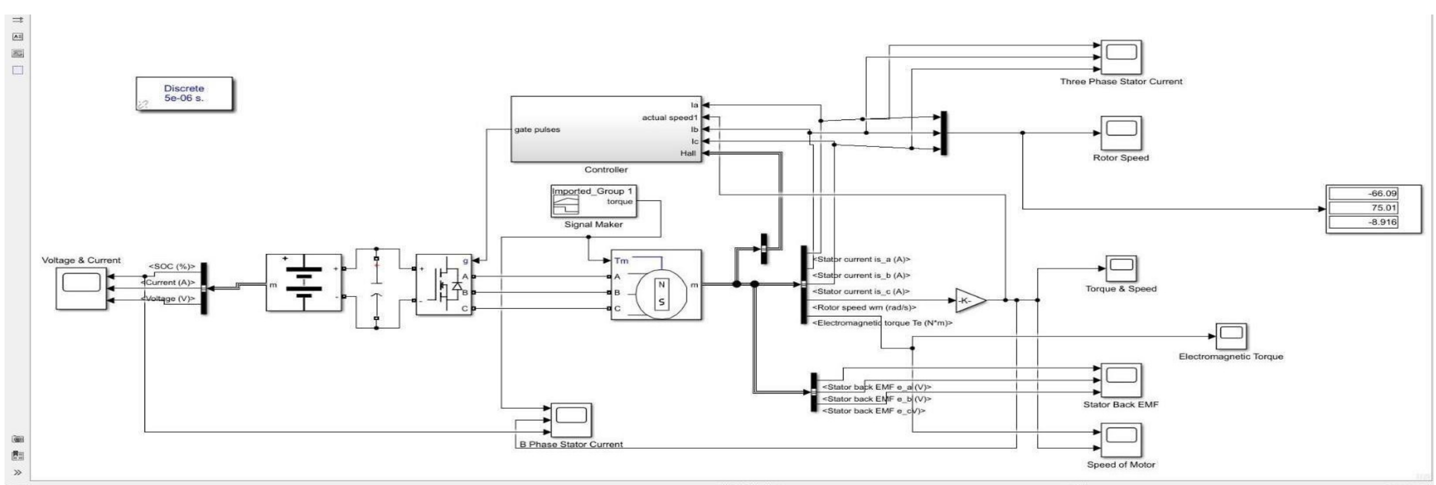


Figure-1(OperationalPhasesofElectricVehiclePropulsion)

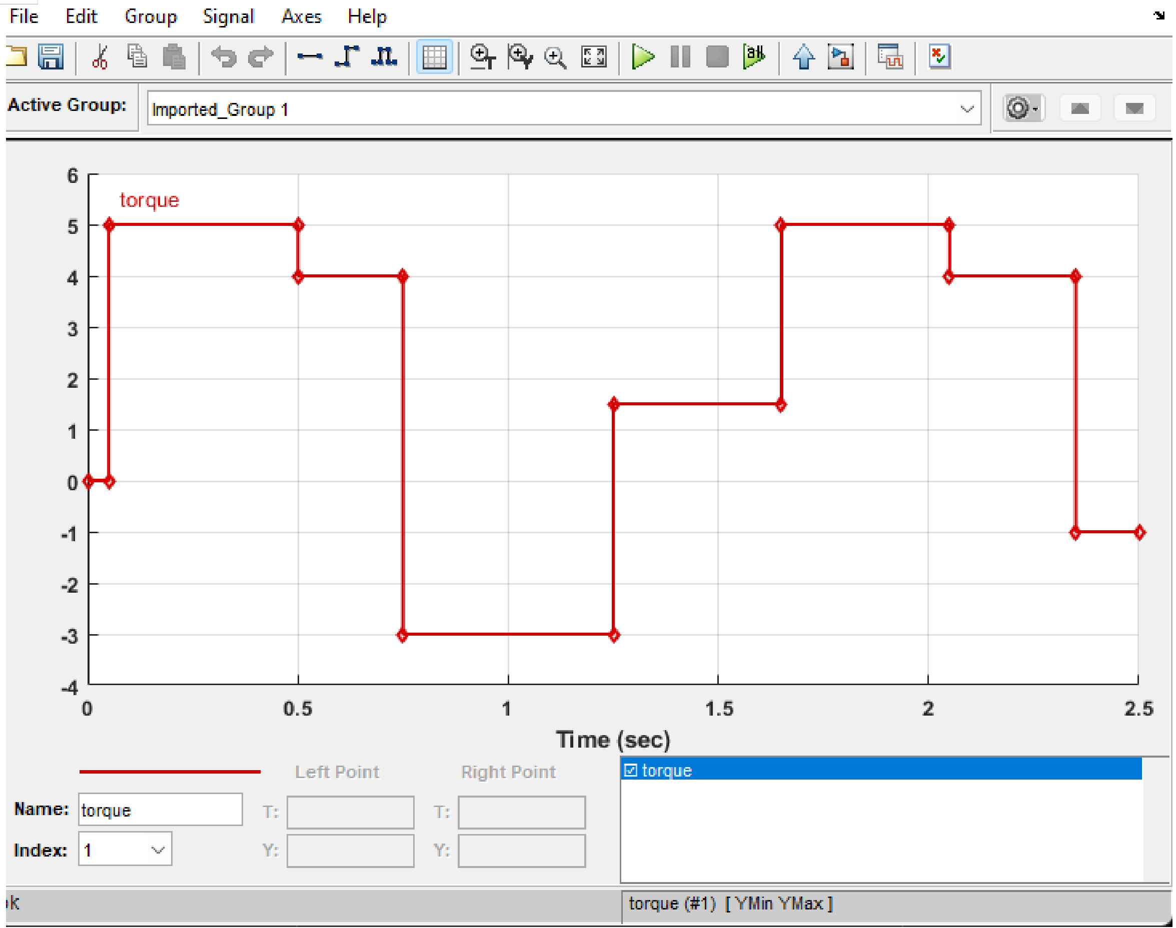


Figure-2(TorqueGenerated)

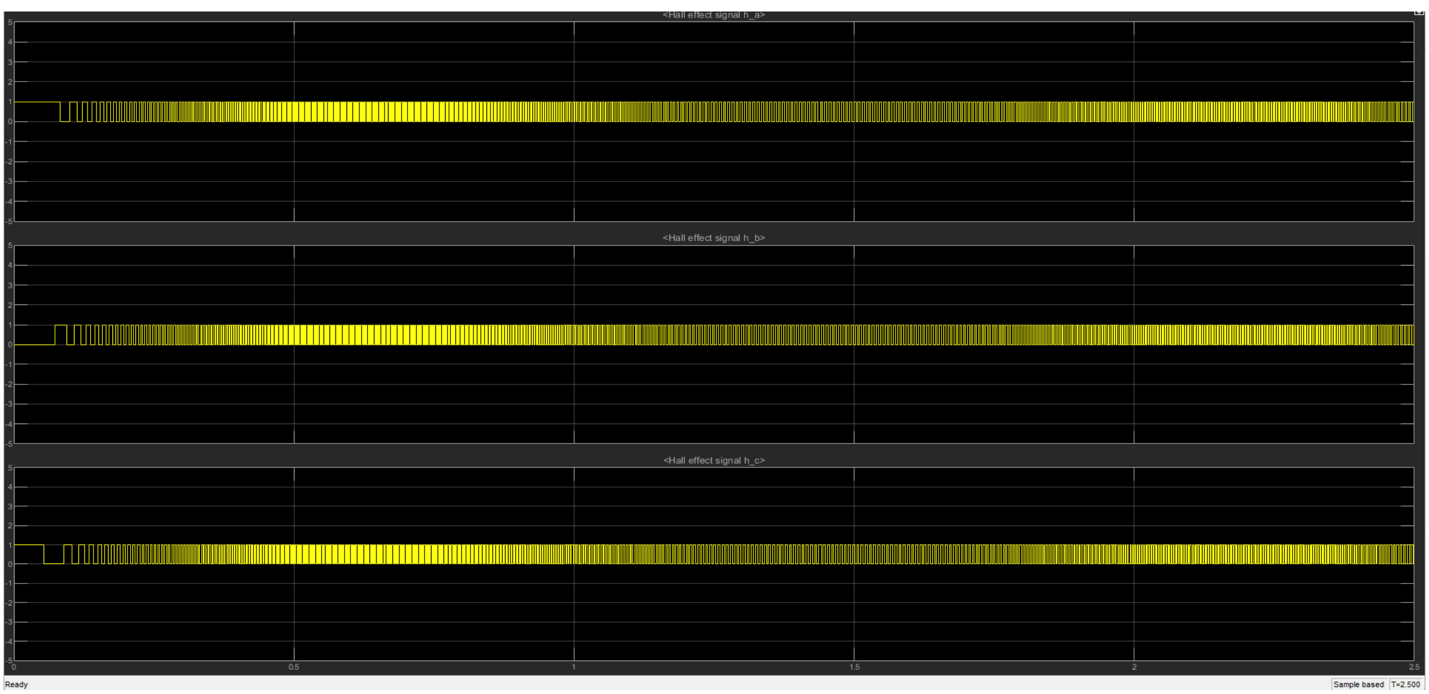


Figure-3(HallEffectSimulation)

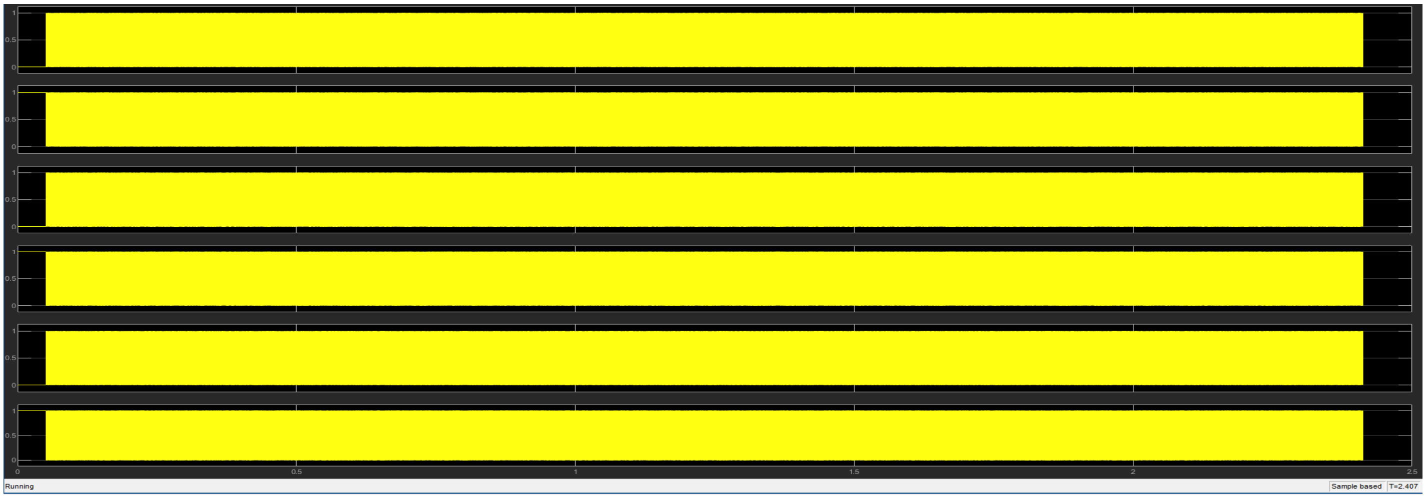


Figure-4(SwitchScopeSimulation)

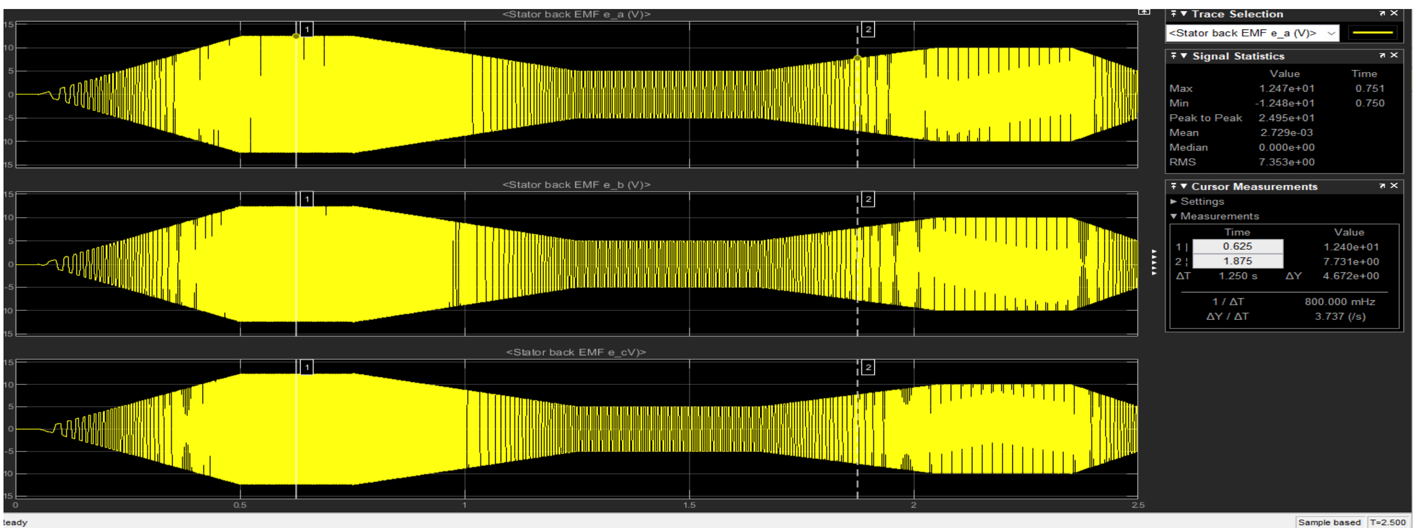


Figure-5(StatorBackemfSimulation)

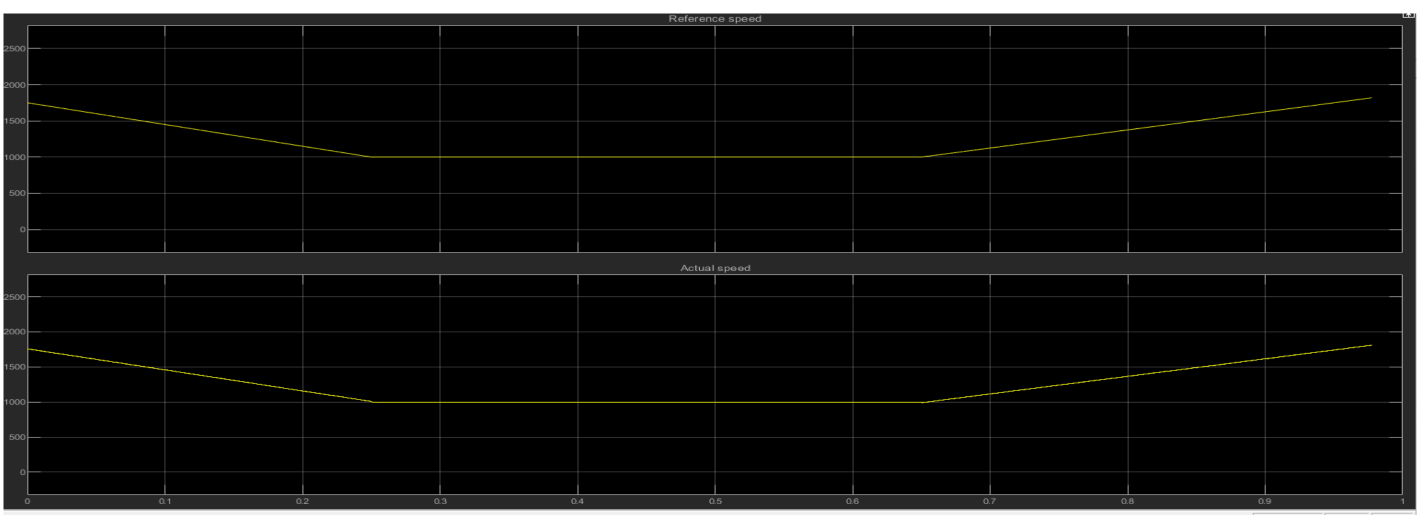


Figure-6(ReferenceVsMeasuredSpeed)

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StatorBackEMF:-

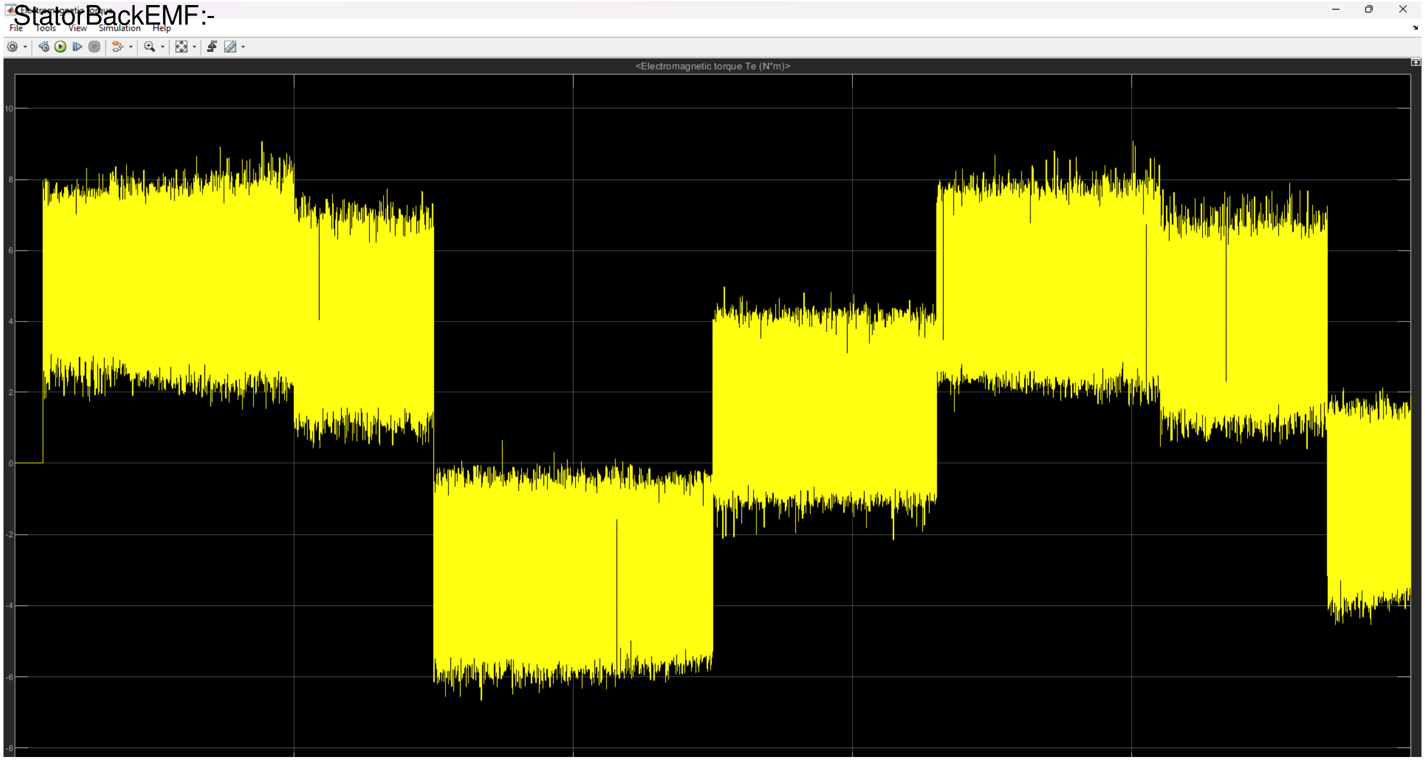

Figure-7(ElectromagneticTorque)

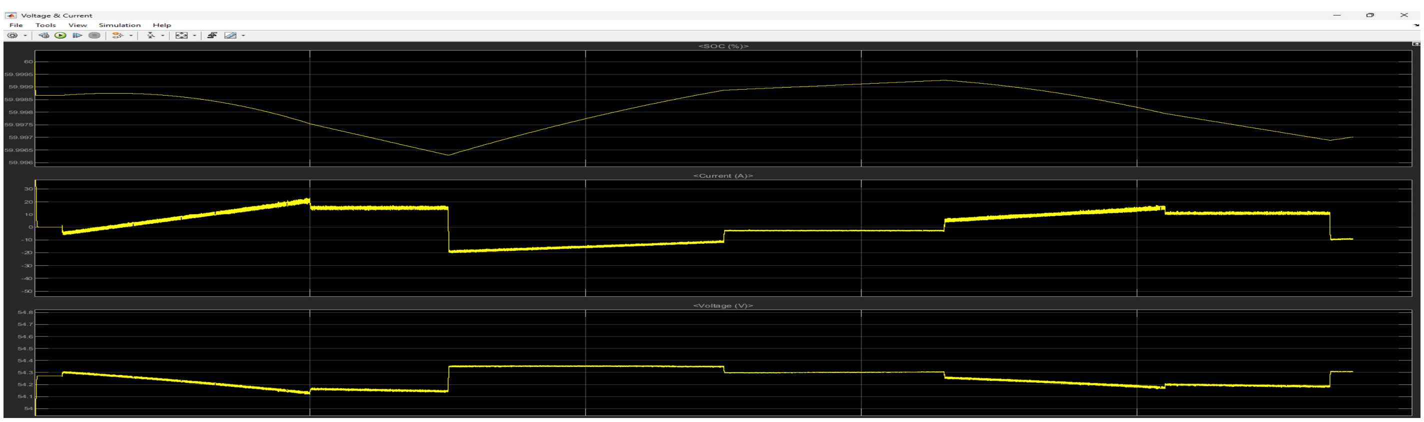

Figure-8(Voltage&Current)

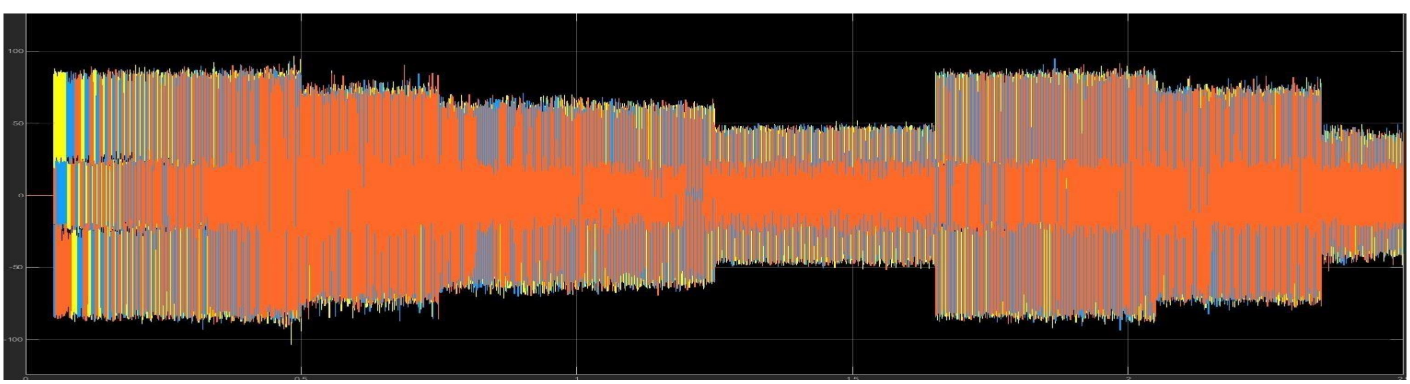

Figure-9(SpeedofMotor)

V. SOLAR PANEL REGENERATION SYSTEM

The system operates by converting solar energy into electrical power, regulating it through a solar charge controller. Thiscontrolledpower isthenutilizedtochargeasecondary batterywhilealsosupplyingpowertoaconnectedload.The solar charge controller plays a pivotal role in adjusting voltage and current to meet the specific requirements of the battery and load.

B. Circuit Diagram

1) System Overview and Features:

- Thesolarchargecontrollerisdesignedtohandleamaximumpowerof395W.
- Amonocrystallinesolarpanelisemployed,capableofgeneratingpowerinvaryingweatherconditions.
- Notably,thecontrollerfeaturesadigitaldisplayformonitoringthestatusofallsubsystems.
- Additionally,thecontrollerisprogrammedtoceasepowersupplytothebatterywhenitreachesfullcharge.

2) CalculationsandSolarPanelSizeSelection:

- SecondaryBattery:12V15Ahlead-acidtype
- SolarPanel:100W
- SolarChargeControllerMaxPower:390W
- PowerUsed:93W

3) Calculations:

- MaximumPowerDrawnfromBattery(Md):92.76W(7.73A)
- MaximumPowerfromSolarPanel(Ms):100W(8.3A)
- MaximumPower/CapacityoftheBattery(Mb):180Wh(15A)
- BatteryAhRating:15Ah
- RuntimewithoutCharging:1.9hours(1hour45minutes)
- TimeRequiredtoChargetheBattery:1.8hours(1hour40minutes)

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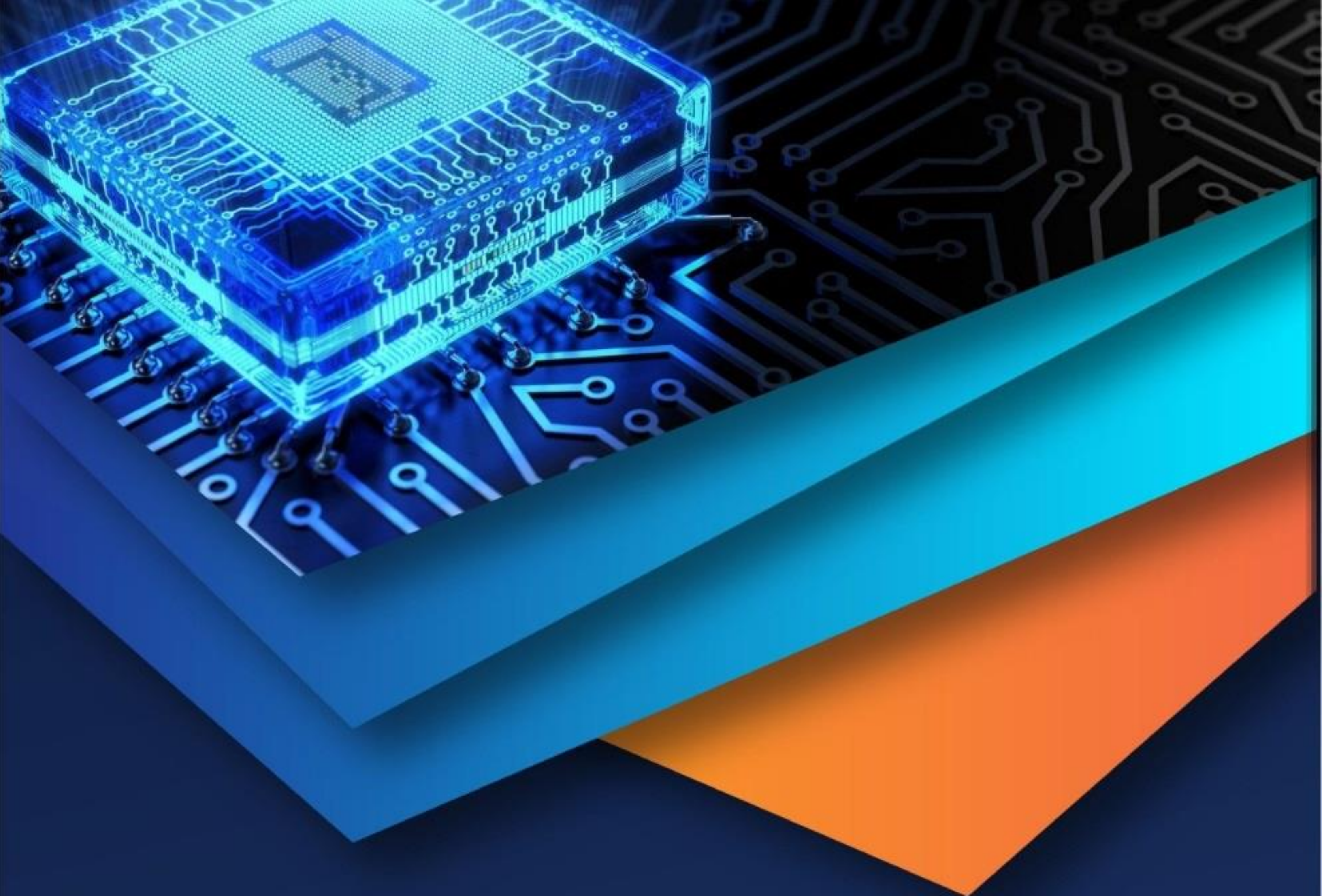
4) AdditionalComments:

- Itisessentialtoensurethattheselected solar panelsizemeetsthepower requirementsadequatelyfor effective battery charging.
- Thecalculationsoffervaluableinsightsintosystemperformanceunderspecifiedconditions.
- Environmentalfactorsandpotentialvariationsinsolar radiationshouldbeconsideredduringthesystem's design and installation.



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