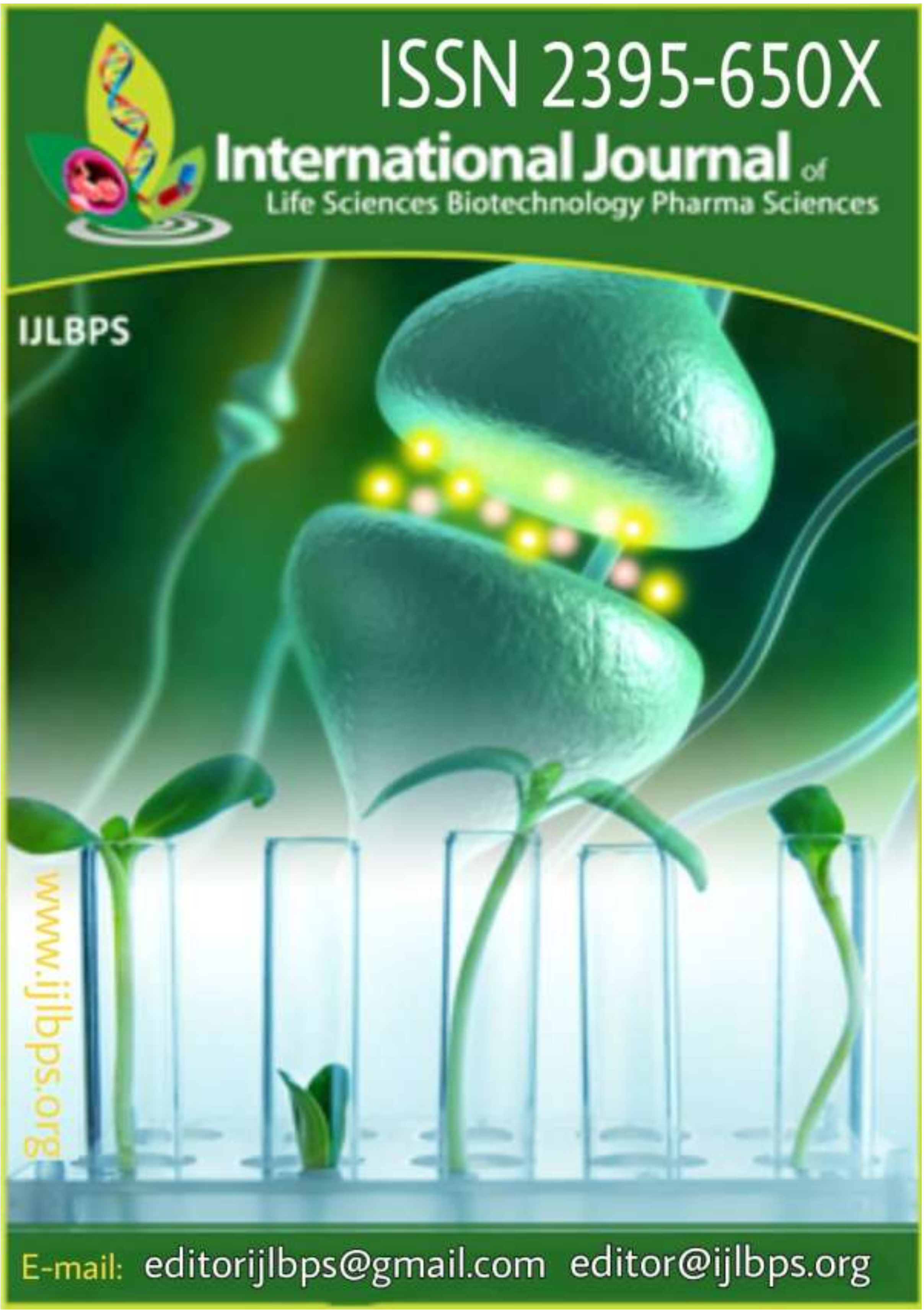
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Performance Evaluation of Switched Reluctance Motor Drive Control for Electrical Vehicles Driven by Solar PV Systems

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Abstract

Due to their potential to reduce greenhouse gas emissions, electric vehicles (EVs) have become a major focus of research and development efforts. One of the most promising electric vehicle (EV) motors is SRMs (switched reluctance motors). Electric vehicles can travel greater distances thanks to the usage of photovoltaic (PV) panels on their vehicles. Based on the phase winding characteristics of SRMs, we propose a three-port converter to regulate the energy transmission between PV panels, batteries and SRMs. In total, four of the six operating modes can be used while driving, and the other two can be used to charge the battery while parked. In the driving modes, the PV panel's MPPT and SRM's speed control are both accomplished by energy decoupling. Without external hardware, the grid-connected charging architecture can be established in standstill charging modes. Using a multi-section charging control scheme, the PV panel directly charges the battery, maximizing energy usage. Tests and simulation results based on Matlab/Simulink demonstrate the suggested tri-port converter's efficiency, which could have economic implications for increasing EV market acceptance.

Keywords: PV, Electrical Vehicle, SRM,MPPT

1.

Introduction

Motor drives, power converters, batteries, and energy management frameworks have all made significant advancements in EVs [1–4]. All in all, EV driving distances tend to be somewhat limited because of existing battery technology limitations [5–7]. As for motor drives, PM machines are the norm, whereas rare earth minerals are needed in large quantities, limiting the widespread usage of electric vehicles [8], [9]. Photovoltaic (PV) boards and exchanged switched reluctance motor (SRM) are familiar with supplying electricity and driving motors separately in order to overcome these challenges. To begin, a controllable energy supply is achieved by including the best PV board of the EV. In today's world, a typical passenger car has enough surface area to accommodate a 250-watt photovoltaic panel. A second advantage of an SRM is that it does not require PMs from rare earth elements and is robust enough to attract increased interest in electric vehicle (EV) applications. Because of its low power thickness, PV boards can be used to charge batteries for a long period of time. Most of the PV-bolstered EV's structure is similar to that of the half-electric vehicle (HEV), which uses the PV board to replace the inward ignition motor (ICE). Fig. 1 depicts the EV's photovoltaic-powered framework. Off-board charging stations, a PV, batteries, and power converters are some of its most important components. One way to reduce the energy transition forms is to modify the motor to include some locally available charging capacities, keeping the final objective in mind. For example, a 20-kW split-stage PM motor for EV charging is described in detail in the study, however it has a high consonant material constraint in the back (EMF). A typical SRM is required for a different configuration. A 2.3-kW SRM can be charged and rectified using a machine that is locally available.

windings as the inductor for the information channel. The concept of measuring the driving topology is offered. Because of the IPMs, a four-stage half bridge converter is used to drive and grid-charge the system.even if large-scale manufacturing and the use of half/full extension topology reduce the unwavering quality of mass production modularization (e.g., shoot-through issues). For module HEV, Paper [10] provides a simple topology for adjustable energy stream. However, for grid-charging, the grid must be linked to the generator rectifier, which builds the energy transformation process and reduces the charging efficiency of the grid. However, there has yet to be developed a convincing architecture and control mechanism for PV-bolstered EVs. The most extreme power point tracking (MPPT) and sun-oriented energy use are unique components for PV-enhanced EVs because of the PV's unique characteristics. This study proposes a minimal effort tri-port converter to organize the PV board, SRM, and battery in order to achieve simple and adaptive energy stream modes. There are six operational modes that allow for more flexible regulation of the energy flow.

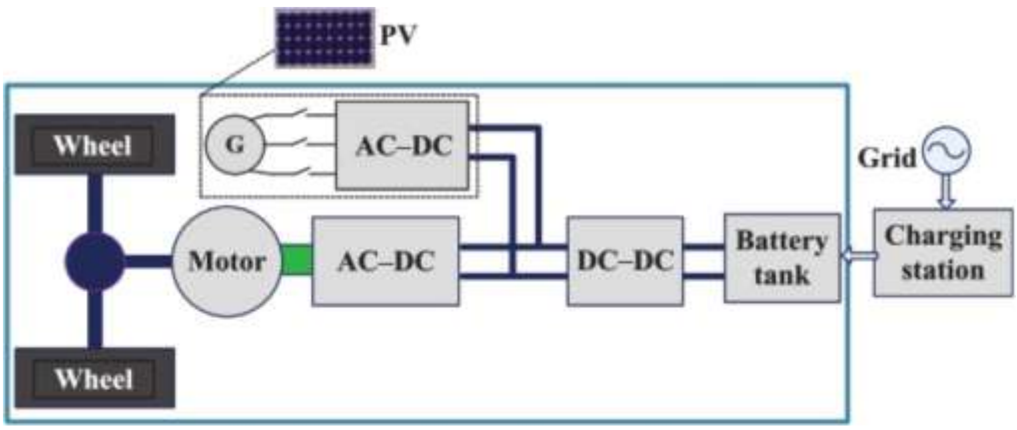
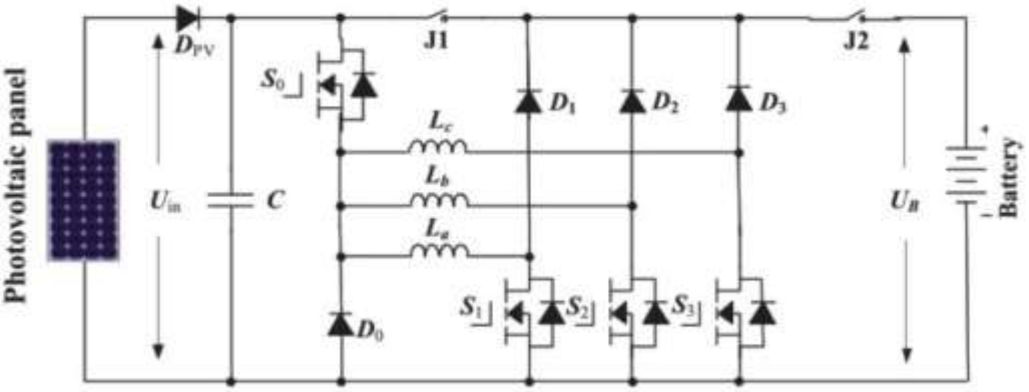


Figure1 .PV-fedHEV.



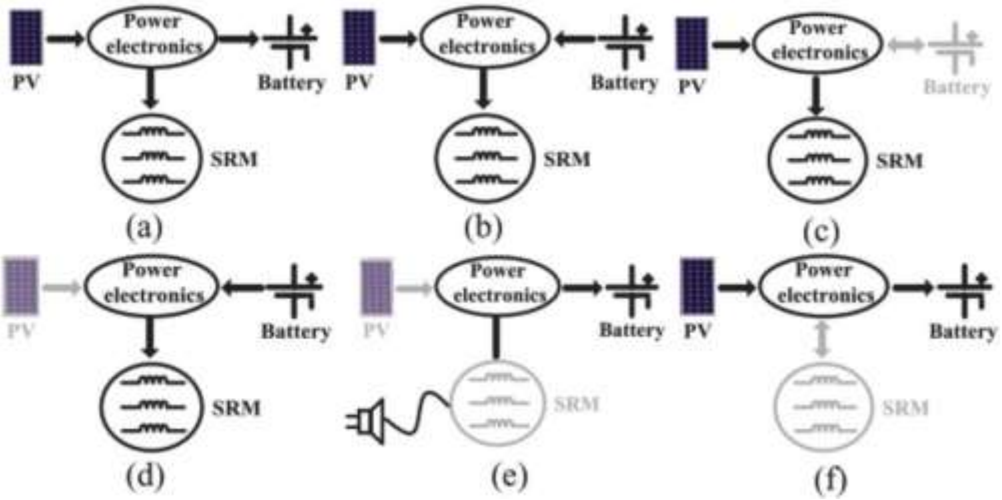


Figure 3.Six operation modes of the proposed tri-port topology. (a) Mode 1. (b)Mode 2.(c) Mode 3.(d)Mode 4.(e) Mode 5.(f)Mode 6.

2. Electric Vehicle

An electric vehicle (EV), often known as an electric drive vehicle, is a vehicle that travels by means of electric motors. There are several types of electric vehicles, such as automobiles, trains, trucks, planes, and boats that are all powered by electric energy. As electricity became a more popular means of propulsion for motor vehicles in the mid-19th century and the gasoline automobiles of the time couldn't keep up, electric vehicles began to emerge as a viable alternative. Although the internal combustion engine (ICE) dominates motor vehicle propulsion, electric power is still ubiquitous in other vehicle types, such as trains and smaller vehicles of various kinds.

There has been a revived interest in electric transportation infrastructure as a result of increased environmental concerns and predictions of peak oil in recent decades. To put it another way, the electricity used to power electric vehicles comes from a variety of sources, from fossil fuels to nuclear power to renewable energy sources like tidal energy and wind power. Transmission to the vehicle can be accomplished by using overhead power lines, wireless energy transmission, such as inductive charging, or a direct connection through an electrical cable, depending on how the energy is generated. It can then be stored in a battery, flywheel, or supercapacitor onboard the vehicle. Non-renewable fossil fuels are the most common source of energy for vehicles powered by engines that operate on the combustion principle. In electric or hybrid vehicles, the capacity to recover energy ordinarily lost during braking and store it in the vehicle's battery as electricity is a significant advantage.In 2003, the first mass-produced hybrid gasoline-electric car, the Toyota Prius, wasintroducedworldwide,andthefirstbatteryelectriccarproducedbyamajorautocompany, the NissanLeaf will debut in December 2010. Other major auto companieshave electric cars in development, and theUSA and other nations are building pilotnetworksofcharging stations torecharge them.

2.1. Vehicle Types

- Hybridel ectric vehicle

Conventional (often fossil fuel-powered) engines are combined with electric propulsion in a hybrid vehicle. Cars such as the Toyota Prius are a good illustration of this type of vehicle.

- Electric vehicles for both on and off-road use

Electric cars, electric trolleybuses, electric bicycles and scooters, electric motorbikes and scooters, neighborhood electric vehicles, golf carts, milk floats, and forklifts are all on the road in a variety of purposes. Tractors and electric all-terrain vehicles are two examples of off-road vehicles.

e-vehicles that travel on the rails

Streetcars or trams that use pantographs to draw power from an overhead line. For electric cars to run on a fixed rail line, overhead lines or electrified third rails can be used to power them without the need for large onboard batteries. There are a number of different types of electric locomotives, trams/streetcars/trolleys, light rail systems, and rapid transit systems in use around the world today. When it comes to power-to-weight ratios, electric trains have the best of both worlds because they don't have to carry a massive internal combustion engine or batteries. 320 km/h (200 mph) is now possible for double-deck TGV trains in France, and electric locomotives can produce far more power than diesel-powered ones.

The short-term surge power they have for quick acceleration is also higher, and regenerative brakes can return braking power to the grid rather than waste it. this

3. Maximum PowerPointTracking

3.1 Photovoltaic (PV) modules are operated by MPPT, or Maximum Power Point Tracking, an electrical system that ensures the modules produce all the power they are capable of. In contrast to mechanical tracking systems, MPPT does not "physically" shift modules to position them toward the sun. To maximize the power output of the modules, MPPT uses an entirely electronic system that adjusts the modules' electrical working points. Increasing the battery charge current is one way to utilize the extra power generated by the modules. However, MPPT and mechanical tracking systems are two fundamentally independent technologies that can be used together. The goal of MPPT methods is to automatically identify the voltage VMPP or current IMPP at which a PV array can produce the most electricity at a given temperature and irradiation level. The MPPT approaches that are most regularly employed are discussed in this section in any order.

3.2 Fractional Open-Circuit Voltage

Themethodisbasedontheobservationthat,theratiobetweenarrayvoltageatmaximum powerVMPPtoits opencircuit voltage VOCisnearlyconstant.

(1)

This factor k1has been reported to be between 0.71 and 0.78. Once the constant k1isknown,VMPPiscomputedbymeasuringVOC periodically.Althoughtheimplementationof this method is simple and cheap, its tracking efficiency is relatively low due to theutilizationof inaccuratevaluesof the constant k1inthecomputation ofVMPP.

3.3 Fractional Short-Circuit Current

The method results from the fact that, the current at maximum power point IMPP isapproximatelylinearlyrelatedtotheshort circuitcurrent ISCofthePVarray.

(2)

Like in the fractional voltage method, k2is not constant. It is found to be between 0.78and 0.92. The accuracy of the method and tracking efficiency depends on the accuracy ofK2and periodicmeasurementofshortcircuitcurrent.

3.4 PerturbandObserve

3.5 The MPPT algorithm in the P&O technique is based on sampling PV current and voltage to determine PV output power and power change. The solar array voltage is periodically increased or decreased by the tracker. If a specific perturbation increases (decreases) the output power of the PV, then the subsequent perturbation is generated in the same (opposite) direction. When the maximum power point is reached, the duty cycle of the DDC chopper is altered and the procedure is repeated. The MPP acts as a fulcrum for the system. The oscillation can be reduced by reducing the perturbation step size.

3.6 However, the MPPT is slowed considerably by short step sizes. For this problem, a perturbation size that gradually decreases toward the MPP will be used to solve it. Under rapidly changing air conditions, the P&O approach can, however, fail. Hill-climbing and P&O approaches have been improved through a variety of research initiatives. For the purpose of determining the perturbation sign, a three-point weight comparison P&O approach is used. It compares the actual power point to the two preceding points. A two-step algorithm proposed by Reference enables faster tracking in the first stage and finer tracking in the second stage.

3.7 IncrementalConductance

The method is based on the principle that the slope of the PV array power curve is zeroat the maximum power point.

$$\Delta I/\Delta V = -I/V \text{ , at MPP}$$
$$\Delta I/\Delta V > -I/V \text{ , left of MPP}$$
$$\Delta I/\Delta V < -I/V \text{ , right of MPP}$$

Instantaneous conductance can be measured by subtracting it from the incremental conductance (ie, I/V). The procedure increments or decrements the array reference voltage until the equation (4) is satisfied. At this point, the PV array continues to operate at its maximum power output level. This technique necessitates high sampling rates and quick power slope calculations.

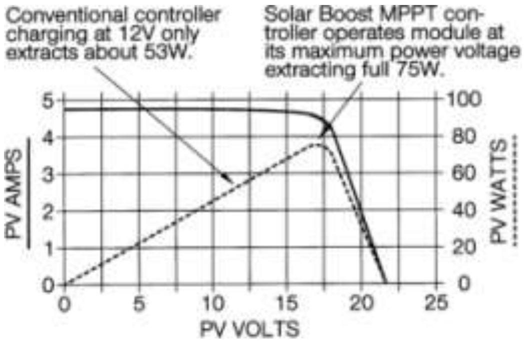
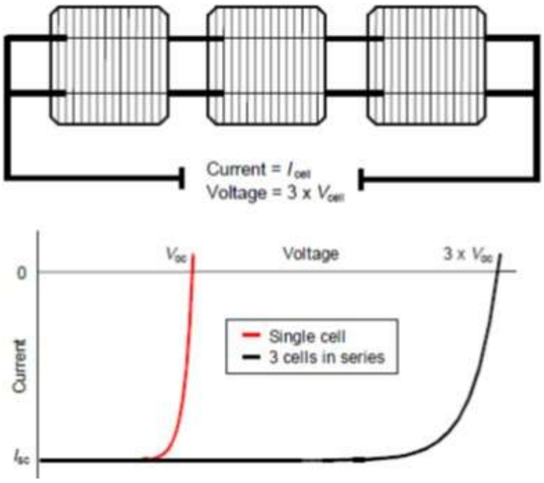


Figure.4PVcharacteristics

4. PhotovoltaicInverter

In most cases, the amount of electricity generated by a single cell is insufficient to meet the needs of most applications. Several cells must be linked together in order to supply the necessary amount of power. Series connection and parallel connection are the two most common ways to connect cells. Two electrical connections are required for each cell in the group in both instances.

Series connection



 An example of a series string can be seen in Figure 5, which demonstrates the series connection of three distinct cells. While the current output of a single cell is equivalent, the voltage output of the string is higher because of the addition of each cell's voltage (i.e. in this case, the voltage output is equal to 3Vcell).

Figure5.Seriesconnectionofcells,withresulting current–voltagecharacteristic.

Itisimportanttohavewellmatchedcellsintheseriesstring,particularlywithrespectto current. If one cell produces a significantly lower current than the other cells (under thesame illumination conditions), then the string will operate at that lower current level andtheremainingcellswillnotbeoperatingattheirmaximumpower points.

Parallel connection

Parallel connections between three cells are shown in Figure 6. The cell group's current is equal to the sum of the individual cells' currents (3 Icell in this case), but the voltage is still the same as if the cell were a single unit. If you want to get the most out of your battery, you need to make sure all of your cells are properly matched, but this time the voltage is the most critical factor. All cells will have to work off their maximum power point if the voltage at the maximum power point is significantly different for one of the cells. The poorer cell will be driven towards its open circuit voltage and the better cells to voltages below the maximum power point voltage. This means that the power output will be lower than it should be in all circumstances.

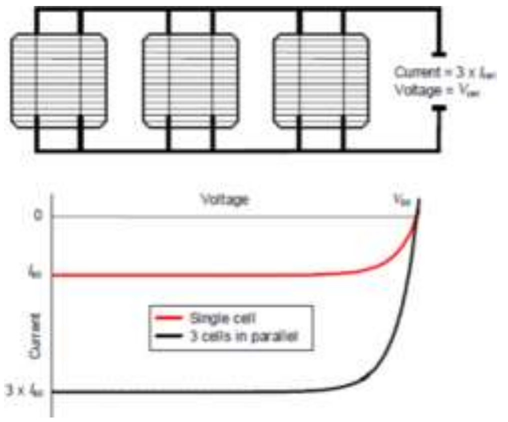


Figure6.Parallelconnection ofcells,withresultingcurrent–voltagecharacteristic.

5. Proposed System Design

Systems can be set up in two ways: standalone or grid-connected. The stand-alone PV system, as its name implies, is able to offer electricity to a specific load or loads without the need for any other power source. Storage facilities (e.g., battery banks) may be included to allow electricity to be provided at night or during periods of low sunshine. Stand-alone systems are also known as autonomous systems since they are able to operate without the need for external power. Instead, grid-connected solar power systems work in tandem with the existing electrical infrastructure. To input electricity into the grid distribution system or to power loads that can also be fed from the grid, this device can be utilized.

Adding one or more alternative power sources (e.g., a diesel generator or wind turbine) to the system is also an option. They are referred to as "hybrid" systems. However, because they allow for a reduction in storage requirements without increasing the likelihood of load loss while still being grid-connected, hybrid systems are more commonly used in stand-alone applications rather than grid-connected ones. System types are depicted in Figures 7, 8, and 9 by way of schematic designs.

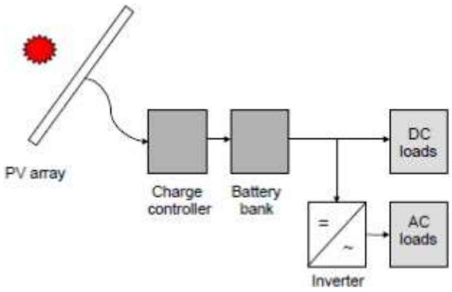


Figure.7Schematicdiagram ofastand-alonephotovoltaicsystem.

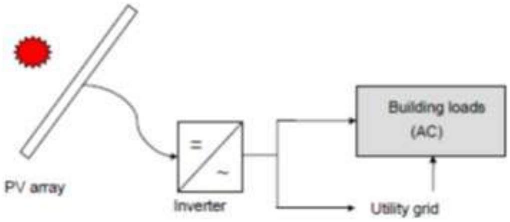


Figure8 .Schematicdiagramofgrid-connectedphotovoltaicsystem.

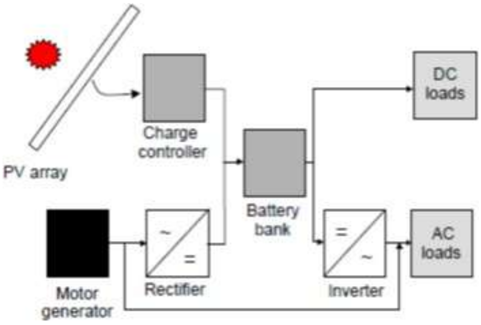
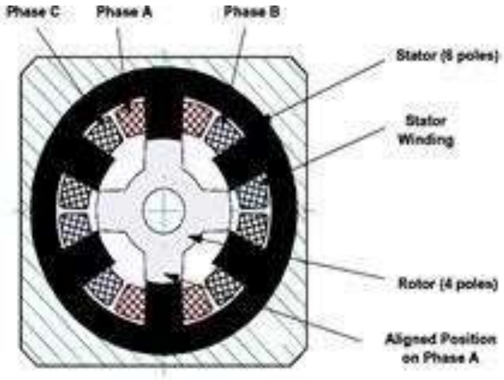


Figure 9.Schematic diagram of hybrid system incorporating a photovoltaic arrayanda motorgenerator (e.g., dieselorwind).

5.1. SwitchedReluctanceMotor

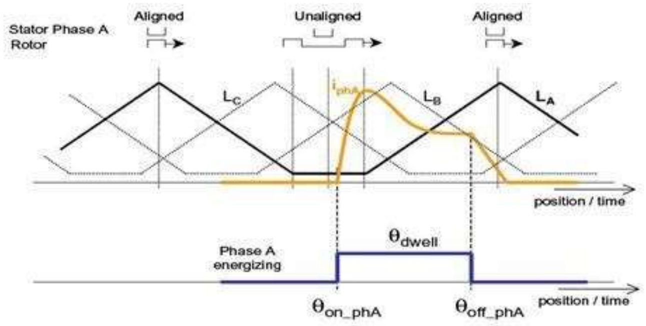
5.2. The notion of a switching reluctance motor was first proposed in 1838, but it wasn't until



the modern era of power electronics and computer-aided electromagnetic design that the motor realized its full potential. SRMs, or variable reluctance motors, are AC machines with electrically commutated ac chines, as explored by Lawrenson et al (1980). A high-speed stepper motor that doesn't require pricey permanent magnets is what these devices are. An induction-motor drive, DC commutator motor drive, and a brushless DC system are all included in this design. When compared to synchronous motors and induction motors, the SRM is more durable, simpler to produce, and more cost effective. The rotor mechanical structure is well-suited for high-speed applications, and they are well-known for their high peak torque-to-inertia ratios.

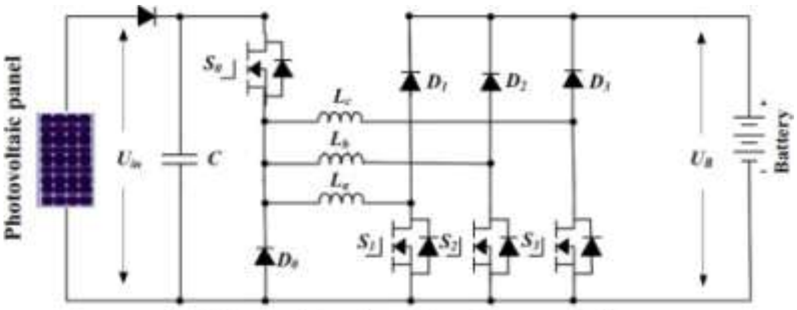
Figure.10ConstructionaldiagramofThree-PhaseSRM

Additional advantages include unipolar control of the reluctance motor, which reduces the number of switching devices required in the converter. Because of these factors, the driving system can be more basic, cost-effective, and reliable. It's easy to make, durable, and can function even if one portion fails. No shoot-through issues are possible because of its power converter Because of their straightforward mechanical design, SRMs have promise as low-cost electromechanical energy conversion devices. The production cost, efficiency, and torque/speed characteristics are all strong points of the switching reluctance motor. This project intends to design a better SRM control strategy in light of the above advantages and the rise of SRM as a rival to induction and DC machines. Using this motor in day-to-day life will be much easier once the problem of high torque ripple is addressed. Because the rotor and stator are aligned in this chapter's control schemes, this chapter provides a detailed understanding of SRM, which will help you grasp how these control schemes work.

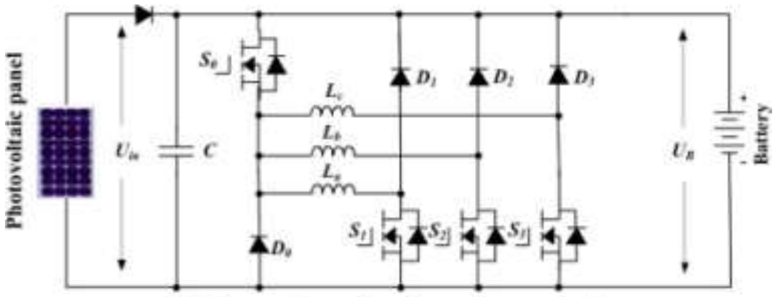


Its inductance profile is triangular, with maximum inductance when aligned and minimum inductance when not aligned, as can be seen in the figure below. Figure 10 depicts the idealized triangle inductance profile of all three phases of an SRM, with phase A highlighted, as shown. When compared to the other phases, A, B, and C each have an electrical shift of 120. The dwell angle (pronounced "dwell") refers to the length of time that a phase is powered up. It is determined by the angles at which the power is turned on (on) and off (off).

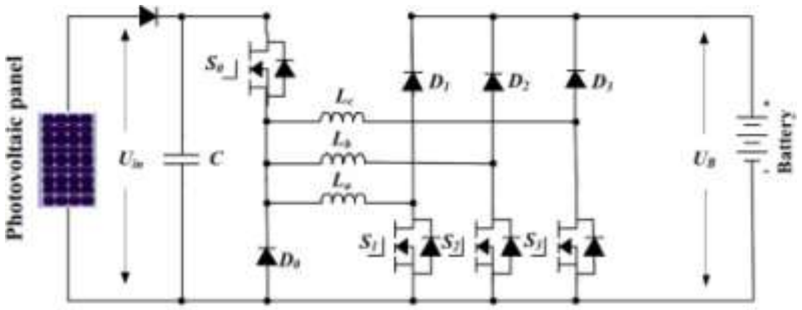
Figure.11PhaseEnergizing



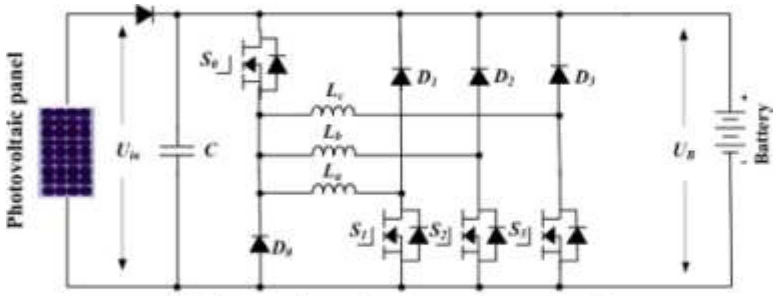
(a) Operation circuit under mode 1



(b) Operation circuit under mode 2

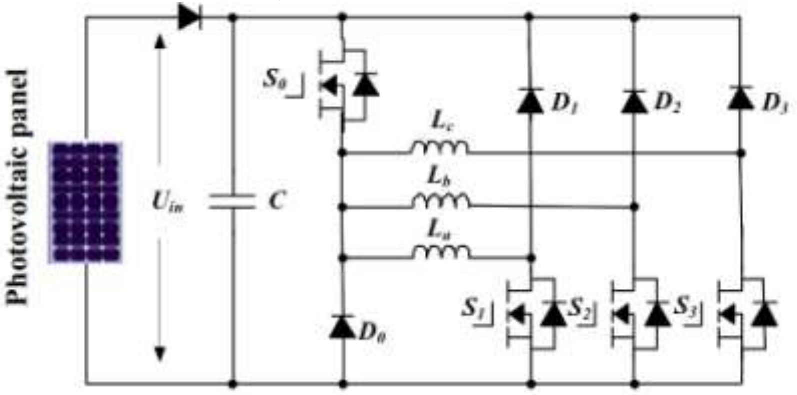


(a) Operation circuit under mode 1

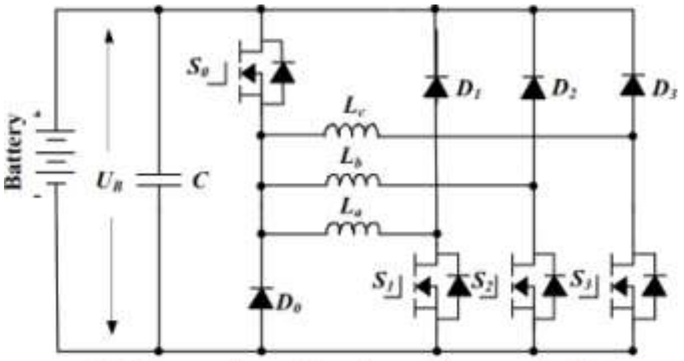


(b) Operation circuit under mode 2

Figure 12 depicts the proposed topology and working modes. In the suggested tri-port topology, three energy terminals, including PV, battery, and SRM, are included. Four switching devices (S0 – S3), four diodes (D0 – D3), and two relays make up the power converter shown in Figure 12. In Fig. 3, you can see that the six different operating modes can be supported by manipulating the relays J1 and J2, and the relevant relay actions can be found in Table I. In mode 1, the SRM is powered by the PV and the battery is charged. In mode 2, the SRM is powered by both the PV and the battery. In mode 3, the PV is the source of energy, and the battery is unused. ' In mode 4, the battery powers the vehicle, and the solar panel is unused. While the PV and SRM are turned off, the battery is recharged using a single-phase grid in mode 5. With the SRM turned off, the PV provides power to the battery in mode 6.



(c) Operation circuit under mode 3

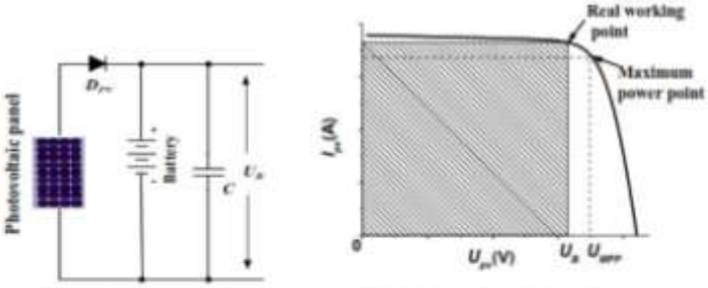


(d) Operation circuit under mode 4

Figure.12Theequivalentcircuitsunderdrivingmodes.

5.3. ControlStrategyunderDifferentModes

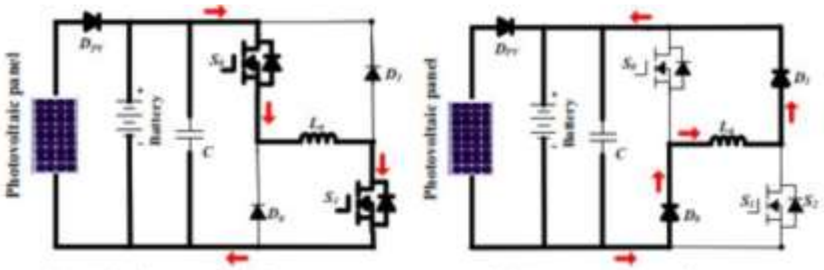
InordertomakethebestuseofsolarenergyfordrivingtheEV,acontrolstrategyunderdifferentmodesisdesigned.



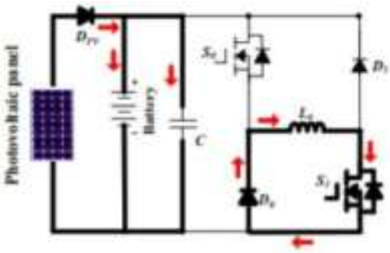
(a) Compound power source (b) Working point of the PV

Figure.13 Powersupply at mode 2.

A. Driving Mode with a Single Source There are three basic types of solar power systems: PV-driven, battery-driven, and PV and battery supplied in parallel. Mode 2 can be used to provide enough energy and make full use of solar energy when PV power cannot sustain the EV under heavy load conditions. Figure 13 depicts the analogous power source; the PV panel working points are shown in Fig. Paralleling the battery with the PV panel causes the PV panel voltage to be clamped to the UB voltage of the battery. Winding excitation, energy recycling, and rechargingareallmodesofoperationinmode 2. freewheeling states, as shown in Figure 14. Modes 3 and 4 have similar working states tomode 2. The difference is that the PV is the only source in mode 3 while the battery is theonly source inmode 4.



(a) Winding excitation state (b) Energy recycling state



(c) Freewheeling state

Figure.14 Workingstatesat mode 2.

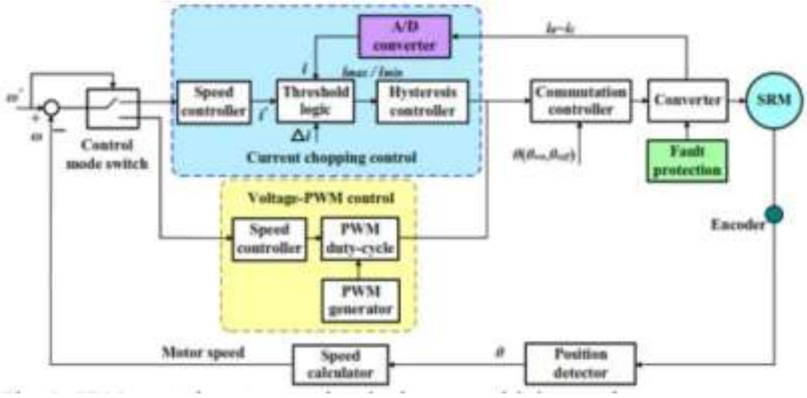


Figure.15SRMcontrolstrategyundersingle-sourcedrivingmode

D-Charging Hybrid Control Strategy A As seen in drive mode 1, the PV serves as the power supply and the freewheeling current serves to charge the battery in the driving-charging hybrid control system. The MPPT of the PV panel and the speed control of the SRM are two separate control objectives. Switching to a dual-source mode from a PV-driving mode Mode 3 begins by setting the motor speed to a predetermined value. Afterwards, J2 is activated and J1 is deactivated, enabling mode 1. The maximum power of a PV panel can be tracked by adjusting the turn-off angle. The dual-source mode operates in three stable states (mode 1). Figure 16 depicts the control scheme for charging while driving. It is seen in Figure 16 that the SRM turns on at a certain angle, and it turns off at the same angle. In order to manage the charging current to the battery, you can vary the turn-on angle of the SRM; this will allow you to control the speedoftheSRM.

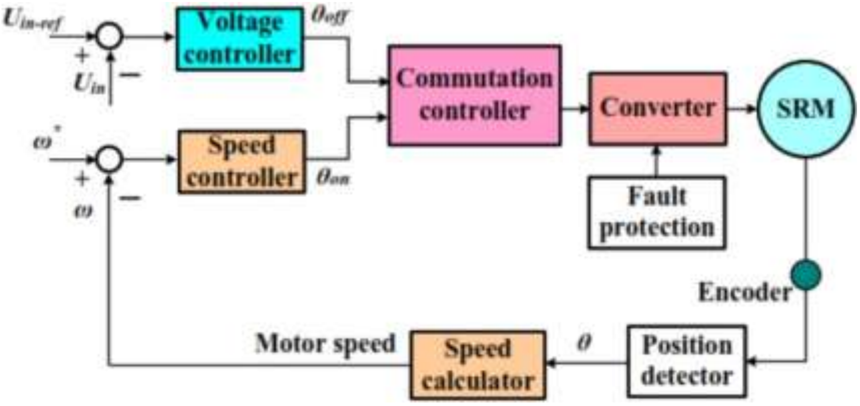


Figure.16Controlstrategyunderdriving-chargingmode(mode1).

A.

A Control Strategy for Grid Charging The single-phase grid charging is also supported by the suggested topology. S0 is always off, while the other three charging states are: S1, S2, and S3. There are two operating states when the grid instantaneous voltage is above zero. The grid voltage charges the phase winding La2 in Figure 17, and the appropriate equation can be written as shown in Figure 17.

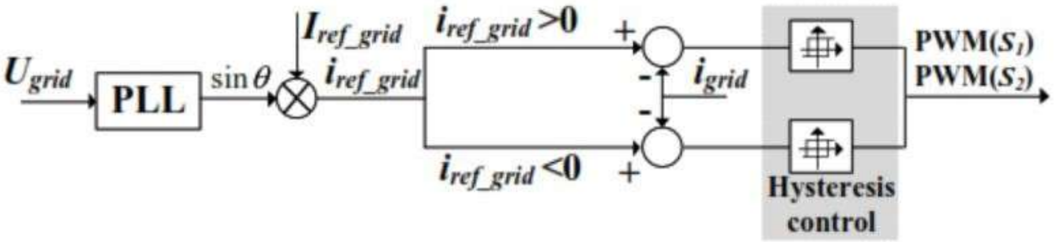


Figure.17Grid-connectedchargingcontrol.

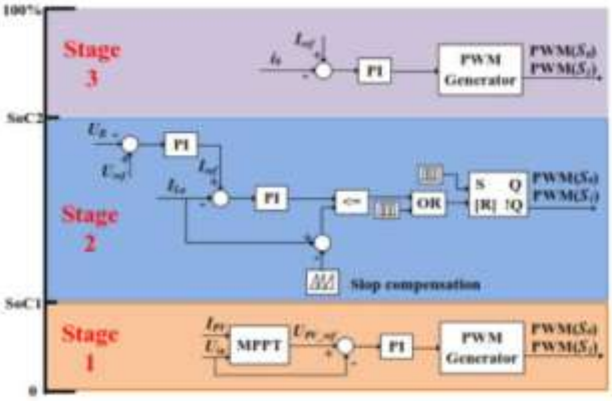


Figure.18Chargingcontrolstrategy.

6. Simulation Results

TheSRMisfirstmodeledinMATLAB/SimulinkusingparametersinTable.I.

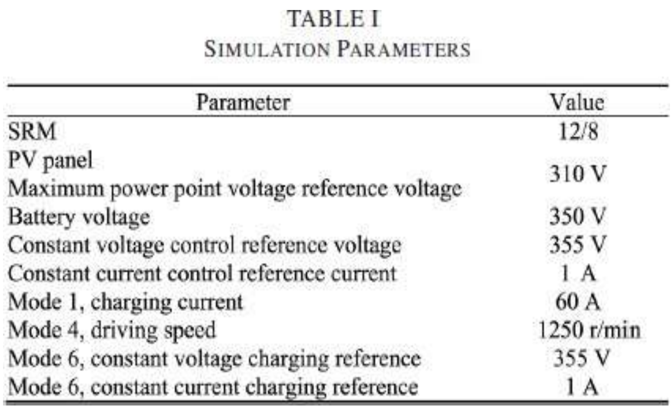


TABLE I
SIMULATION PARAMETERS

Parameter	Value
SRM	12/8
PV panel	310 V
Maximum power point voltage reference voltage	
Battery voltage	350 V
Constant voltage control reference voltage	355 V
Constant current control reference current	1 A
Mode 1, charging current	60 A
Mode 4, driving speed	1250 r/min
Mode 6, constant voltage charging reference	355 V
Mode 6, constant current charging reference	1 A

Figure.19Simulation resultsofdriving-chargingmode(mode 1)

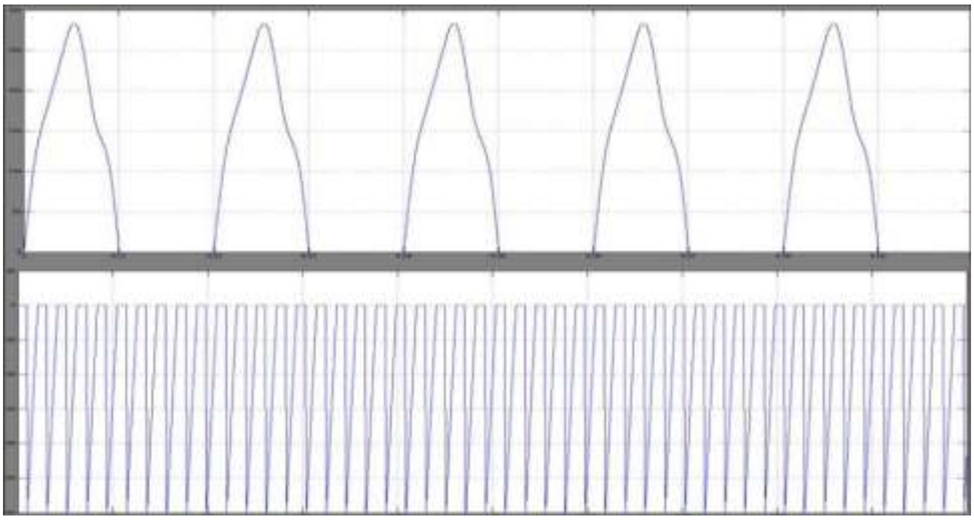
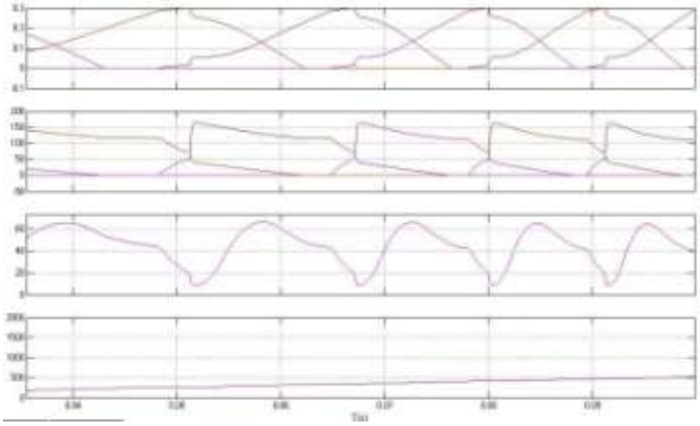


Figure.19Simulation resultsofdriving-chargingmode(mode 1)

Figure.20 Simulation resultsofthe singlesourcedriving modes(modes2–4).



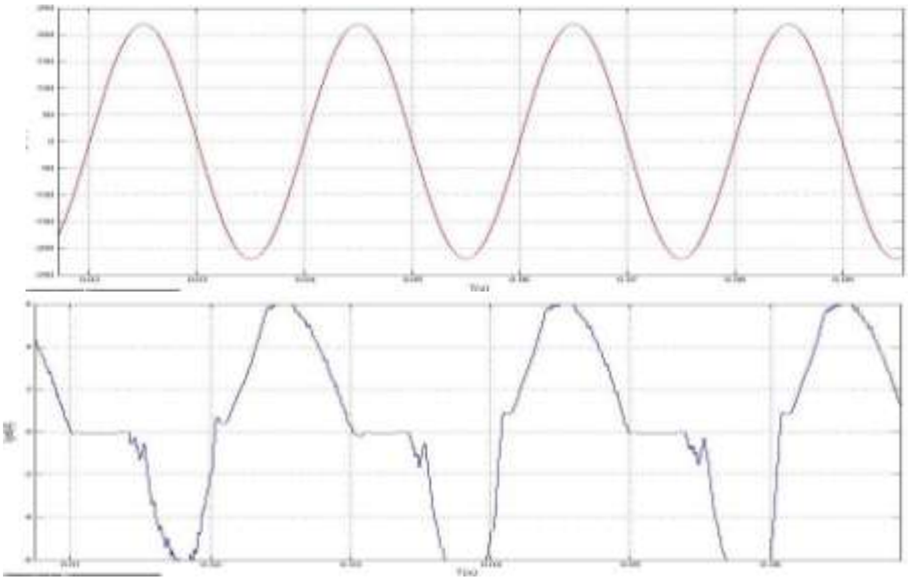


Figure.21 Simulationresultsof gridcharging (mode 5)

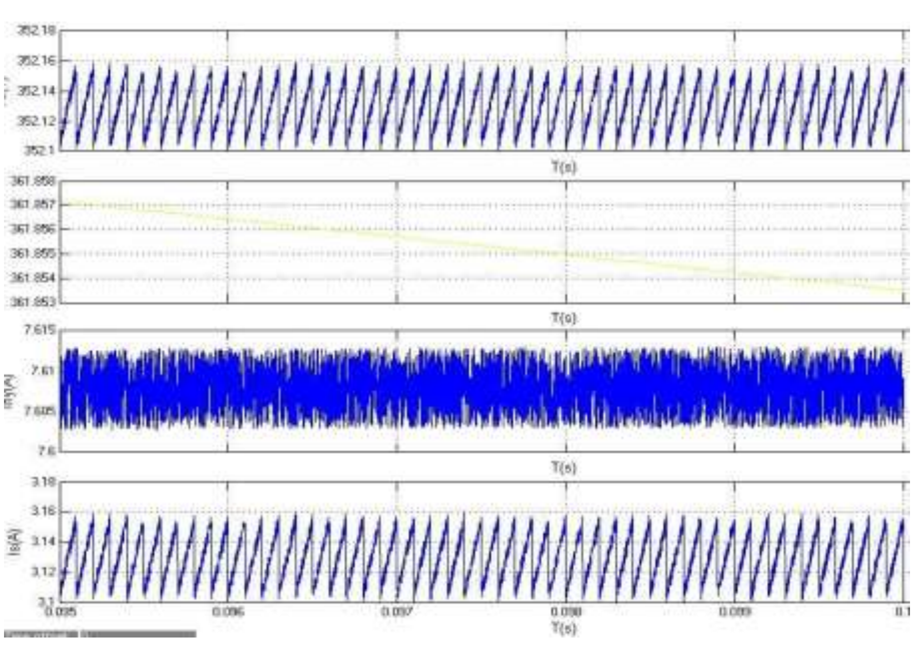


Figure.22PVChargingmode 6isthestepchangefromstage 1to 2

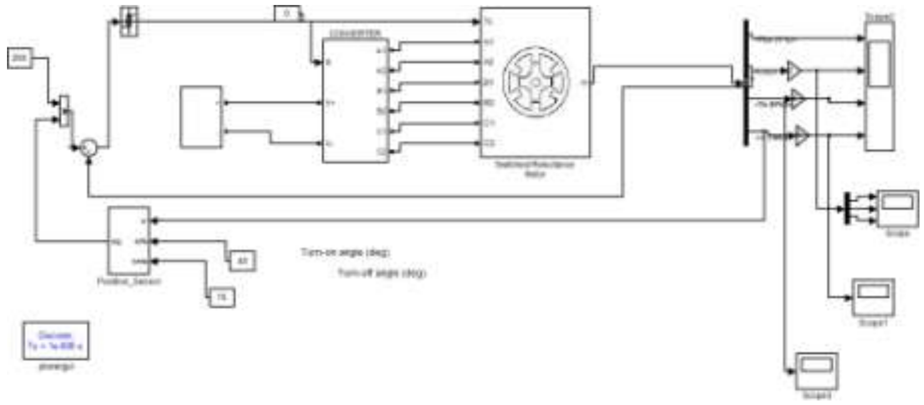


Figure23.Simulationcircuit ofproposedsystem

Conclusion

Solar panels and SRMs are used in an EV driving system to ease range anxiety while reducing system costs. Its most important contributions are as follows:

(ii) A tri-port converter is utilized to coordinate the solar panel, battery, and SRM. There are six working modes to achieve flexible energy flow in driving/charging hybrid control, driving/charging hybrid control, and charging control. A new grid-charging architecture is created without the usage of external power electronics devices (iii). (iv) A PV-fed battery charging control method is created in order to enhance charging efficiency.

Because PV-fed EVs are a more environmentally friendly and environmentally sound option than traditional internal combustion engines (ICEs), this study could help reduce the overall cost and CO2 emissions of electric vehicles. Additional uses include fuel cell-powered electric cars, which could benefit from the proposed system. Electric vehicles benefit greatly from fuel cells because of their increased power density.

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Power electronics has the potential to transform the 21st century's global energy landscape, according to a study published in the IEEE Transactions on Industrial Electronics in July 2013.

It's been a long time since we've seen an all-electric car, so we've put together a comprehensive assessment of electric motor drivelines in commercial all-electric vehicles: [3].

There are a number of different approaches that can be used to implement plug-in hybrid electric vehicle energy storage and management systems that are based on power-electronics-based solutions.

There is a battery charger for an electric vehicle traction battery switch station, published in IEEE Transactions on Industrial Electronics 60 (12):5391-99 (2013).

Energy and battery management of a plug-in series hybrid electric car using fuzzy logic is discussed in [6] by the authors of "Energy and battery management of a plug-in series hybrid electric vehicle using fuzzy logic."

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