PERFORMANCE ANALYSIS ON INTEGRATION OF SOLAR, WIND POWER PLANT WITH DIESEL POWER PLANT FOR ELECTRIC VEHICLE APPLICATION

P.Venkatesan[1], K A Ramesh Kumar[2], P.Jamuna Rani[3] and S.Uma[4]
[1]Department of Electrical and Electronics Engineering, Mahendra Institute of Technology, Namakkal, India
[2]Department of Engineering Science and Technology, Periyar University, Salem, Tamil Nadu, India
[3]Department of Chemistry, Mahendra Institute of Technology, Namakkal, India
[4]Department of MCA, Sona College of Technology, Salem, Tamil Nadu, India
[1]drvenkatesanp@gmail.com and [2]karameshkumar77@periyaruniversity.ac.in

ABSTRACT
Ntegrating renewable energy sources into traditional power production systems is critical for long-term energy development and decreased environmental impact. The page offers up-to-date information on the development of an energy-efficient hybrid solar-wind-diesel system (SWDHS) technology to minimize organic fuel usage. The research findings indicated three research directions: MPPT analysis for solar hybrids, SWDHS design, and control and energy conversion system enhancement. The mixed integer linear programming method and the particle group optimization algorithm are two extensively used formulations in optimization. A large percentage of these algorithms are executed on the MATLAB/Simulink environment. The equipment is outfitted with a diesel generator system. A performance comparison of their efficacy is given. The MPPT methodologies, optimization algorithms, and objective functions employed are detailed, along with the SWDHS project's feasibility calculation findings. Presents ways for lowering diesel fuel usage through the use of specialized equipment and energy storage devices. It also investigates the possible problems and possibilities connected with this hybrid power generating system, which would pave the way for efficient and environmentally friendly electric car charging infrastructure.

Keywords: Photo Voltaic, small wind power plants, diesel power plants, integration, electric vehicle.

1. INTRODUCTION
The world is approaching a crucial turning point in the energy transition as a result of the quick depletion of fossil resources and mounting worries about climate change. Solutions have developed in the midst of this paradigm shift: hybrid renewable energy systems (HRES) with diesel engines, particularly those that combine solar and wind power technology. innovative approaches to problems with energy sustainability [1,2].As per the sources cited by the Energy Information Administration (EIA), Figure 1 showcases the noteworthy progression in the worldwide adjustment to renewable energy between 2010 and 2020, emphasizing the pivotal function of renewable energy in restructuring the energy framework. From 1,240 TWh in 2010 to 2,960 TWh in 2020, energy capacity growth during these years has been consistent. The shift towards cleaner and more sustainable energy sources worldwide is seen in this noteworthy increase, which can be attributed to various factors including technology advancements, environmental concerns, and supportive laws.

These systems increase the overall stability and reliability of energy output by mitigating the intermittency issues that come with using individual renewable energy sources. While wind energy can be utilized even when solar energy is low, solar energy is at its peak during the day [4]. The probability of power outages during inclement weather is decreased by integrating different sources, which increases the stability of the energy supply. Hybrid systems that use energy storage technology also make it easier to store extra energy during times of high output. This allows for the utilization of energy during times of low production, which improves system efficiency and lowers waste [5]. Furthermore, grid stability may be considerably enhanced by HRES that uses diesel engines. Due to their intermittent nature, stand-alone renewable energy sources can put stress on current networks, changing voltage and frequency [6]. These variations can be more effectively controlled by implementing hybrid systems with energy storage capacity, and

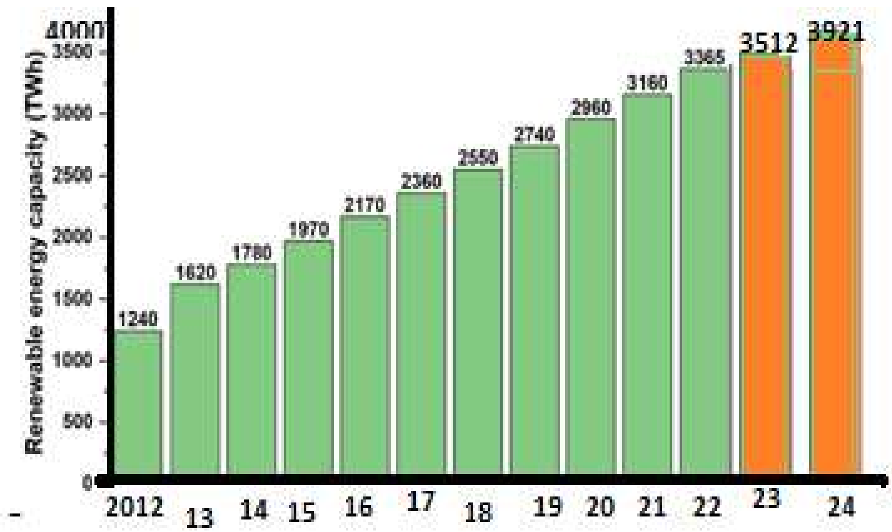

Fig. 1: Global renewable energy adaptation for the years (2012–2024)

During periods of high demand, electricity can be pumped into the system. This facilitates the seamless integration of renewable energy into the current energy infrastructure by enhancing grid stability and lowering system congestion. While diesel-powered HRES systems present viable options, there are obstacles in the way of their adoption [7, 8]. Particular emphasis needs to be paid to technically complex issues like managing energy storage and maximizing the integration of various sources. Economic viability needs to be assessed in light of the long-term advantages, taking into account both the initial installation and continuing maintenance expenses. In order to promote the use of hybrid systems and guarantee a smooth transition to greener energy, frameworks for regulations and policy must also be established. Redefining the global energy landscape through the integration of solar and wind power into HRES with diesel has immense potential.

This analysis highlights these integrated systems' revolutionary potential by examining the opportunities, problems, and policy implications that are related to them. In order to integrate solar, wind, and diesel hybrid energy into cars while they are moving, a novel hypothesis has been examined in this work. The MATLAB Simulink software package is used to model the wind turbine and motor (in accordance with the mass model). A thorough model of the conversion process was created, and the two primary interacting subsystems of the kinetic energy conversion process were separated. MATLAB software was also used to analyze the findings of the energy conversion chain analysis. Next, a theoretical model for the turbine's whole energy harvesting process is created by analyzing the generator's control structure, design, and model through a series of mathematical computations. The wind and how moving cars utilize it. Lastly, as an experimental tool, the model is fictitiously applied to automobiles, demonstrating that wind-powered cars can in fact be a cutting-edge technology that lowers and eliminates energy expenses for all forms of transportation. Figure 2 depicts the fundamental designs of the HRES and diesel generator integration for electric vehicle charging.

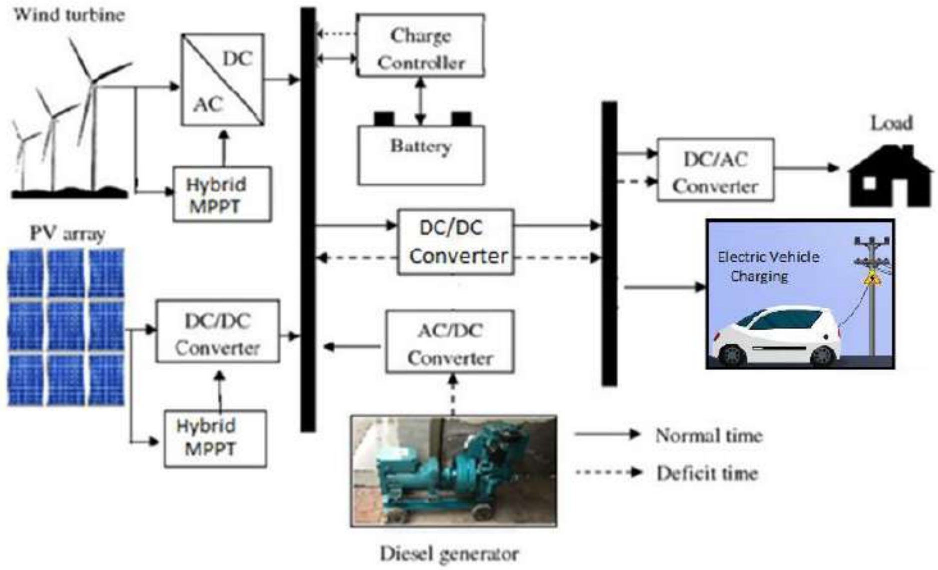

Figure. 2: Basic arrangements of integration of HRES with diesel Generator integration for EV charging.

Electric cars, wind turbines, solar panels, a battery pack, a hydraulic pump storage system, and a diesel generator are all part of the proposed system. Figure 2 shows a schematic representation of a hybrid microgrid, similar to the one under study. This section provides a detailed discussion of solely electric car models. The existing literature provides the model for the other microgrid components. The models of the diesel generator, wind turbine, and batteries are based on the research of Maleki and Askarzadeh [21], the solar panels are based on the model presented in [22], and the hydraulic pump storage system is based on [23]

2. SYSTEM MODELING

Generally speaking, economic modeling and component modeling are the two pillars of whole system modeling. The system components aid in predicting net power output, while the economic model facilitates our assessment of the suggested model's viability. There is always a trade-off between power generation and total cost. To ascertain the ideal configuration, renewable energy ratio, and suggestions for plant scale optimization, system output characteristics and economic factors must be analyzed.

2.1. Modeling of Electric Vehicles

A mathematical model was developed to investigate the energy storage capability of electric cars; the model used four driving cycles, calculating the force applied on the car and the length of each cycle; As a result, the energy consumption of electric cars is calculated by factoring in the electric motor's performance while calculating the resistance to movement. Motion cycles on the model that is being displayed have been studied. Based on the outcomes of simulations, battery life is mathematically evaluated. A MATLAB Simulink software environment has been used to construct an electric car simulation model. It has been done to evaluate the produced electric cars' energy reserves. The way that electric cars are integrated into the grid and how much they use are determined by this fact. According to the theory, representatives of local public organizations would use electric cars for mobility as they will no longer need to rely on fossil fuels that must be transported long distances. as well as lower carbon emissions [12]. Due to the low income levels, short travel distances, and the fact that motorbikes are not suitable for meeting everyone's travel demands, compact electric cars are taken into consideration for rural regions [24].

Initially, for every cycle time segment V(t), ascertain the required acceleration values to compute the dynamics in order to construct a model to investigate the autonomy of electric automobiles in motion cycles. The derivative of velocity with respect to time is the vehicle's acceleration value [18]:

$as=(t)/\ dt$, m/s (1)

Calculating the dynamic force involves multiplying the acceleration by the mass of the electric vehicle and accounting for the spinning components' coefficient of inertia.

$Fn=(1+\gamma)\cdot m\cdot as$, N (2)

where $\gamma = 0.1$ is the coefficient of inertia of the rotating parts.

An electric vehicle's particular resistance force for each instant of motion is determined by adding the rolling force Fr to the overall air resistance force Fa.

$Fc=Fa+Fr$, N (3)

The greater the total air resistance, the faster the electric vehicle is moving, and the larger its frontal area; also, the body's streamlined appearance is important.

$Fa=Si\cdot ki\cdot V2$, N (4)

where Si is the frontal area of the electric vehicle, m^2; ki is the streamlining coefficient,$N\cdot s^2/m^4$ defined as:

$k=0.5\cdot CX\cdot \rho_{air}$ (5)

where CX is the coefficient of aerodynamic air resistance and ρ_{air} is the air density (1.225 kg/m3). For the body of a typical electric car, we will choose CX = 0.35 N·s2/m·kg.

2.2 Solar photovoltaic power systems

Developing mathematical models and computations to mimic the behaviour of photovoltaic (PV) solar cells under many circumstances is the process of studying PV solar cells. Researchers, engineers, and manufacturers may better understand the properties, efficiency, and performance of solar cells thanks to this modeling technique. Solar photovoltaic (PV) energy systems, which use the PV effect to transform sunlight into electrical energy, are the cornerstone of renewable energy technology. This method is carried out in solar panels consisting of silicon-based linked solar cells [9]. Here are several ways to explain the PV effect:

$I_{To}=I_{ph}+I_{an}$(1)

The current produced by the solar cell is denoted by I_{To}, the photocurrent resulting from photons absorbed is represented by I_{ph}, and the dark current is shown by Ian. I_{To} is directly correlated with the intensity of incoming solar radiation in terms of produced current.

Equation: This may be used to determine a solar cell's power output.

$P_{to}=I_{to}.V_{to}$ (2)

where Ito is the current, V_{to} is the voltage produced by the solar cell, and P_{to} is the power output. The Shockley diode equation [10] can be used to predict the voltage (V) between a solar cell's terminals:

$V=V_c - I.R_s$ (3)

whereV_c is the solar cell's open-circuit voltage and R_s is its series resistance.

Equation [10] may be used to determine the efficiency (η_{PVs}) of a solar PV system, which is the ratio of solar energy transformed into electrical energy:

$\eta_{PVs} = P_{max}/P_{inc}$(4)

where$P_{inc}$is the incoming solar power and P_{max} is the solar panel's maximum power output. A few examples of the variables that might affect efficiency include temperature, sun irradiation, and material qualities.

A PV system's instantaneous power output in kW may be explained as follows [11,12]: $P_{PV,t} = C_{PV}\eta_{PV} \cdot \left(\frac{G_{T,t}}{G_{T,STC}}\right) \cdot [1+\alpha_P (T_{C,t} - T_{C,STC})]$ (5)

where CPV stands for the PV array's rated capacity (kW), η_{PVs} for the PV derating factor (%), G_T,t for incident solar radiation (kW/m^2), GT,STC for incident solar radiation (kW/m^2) at Standard Temperature Conditions (STC), αp for the PV cell's temperature coefficient of power (%)/oC, TC,t for PV cell temperature (^{o}C), TC,STC for PV cell temperature (^{o}C) at STC, and Rs for the cell's internal resistance. The Simulink model of the PV cell is derived from Equation (5). Figure 3 displays the solar PV mode.

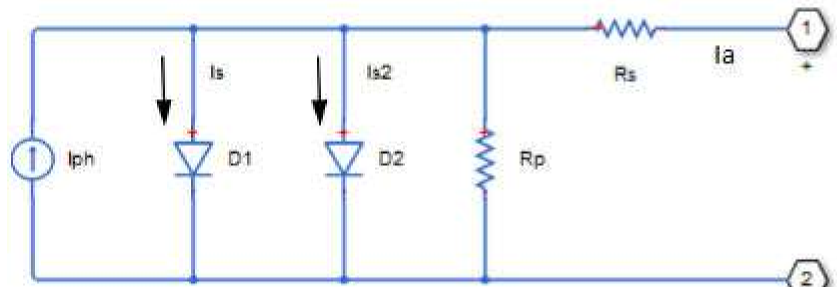

Figure 3: He solar PV cell model

2.3 PMSG Modeling Blocks

RSC and GSC can be considered as two controllable voltage sources. A reference frame with the stator voltage space vector aligned with the q axis may be used to represent these two voltage sources. The reference frames for the stator voltage are in alignment with the PMSG model, RSC control, and GSC control. Through the aforementioned control blocks, RSC and GSC voltages are produced. Blocks for feedback control may be constructed in Matlab/Simulink. The PMSG model in the same DQ repository can then incorporate the converter controls. The link between RSC and GSC, or the dynamics of the DC bus capacitor, is one that has not been modelled. It is also necessary to consider the dynamics of the intermediate circuit capacitor. Figure 4 displays the overall block diagram of the dynamic model.

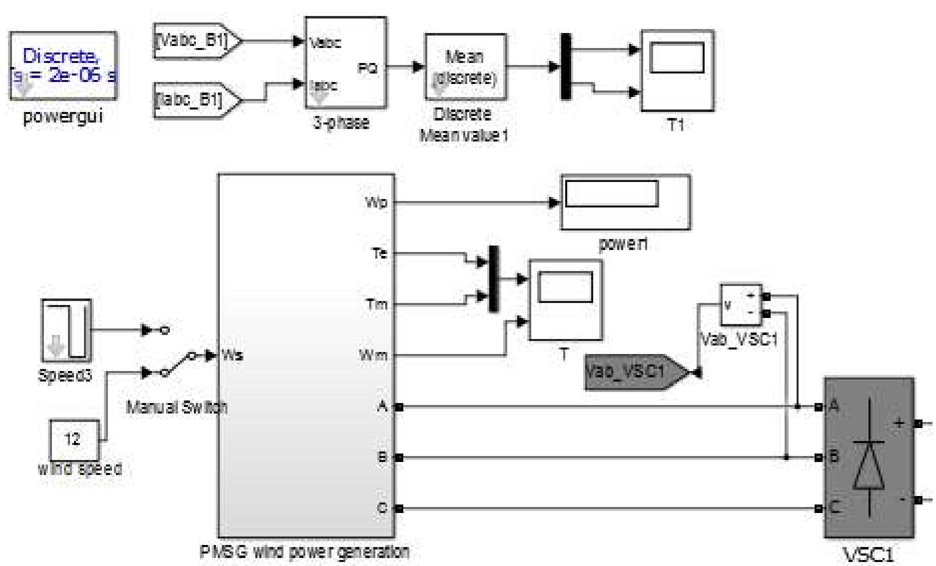

Figure 4: The overall block diagram of the dynamic model

It is possible to treat v_{qs} as constant in the simulation block if the stator voltage of the PMSG is taken to be constant. The transmission line can be viewed as an extra stator resistance and stator leakage inductance if it connects the PMSG to the infinite bus and is regarded as an R_L line component. The infinite bus voltage serves as the source of the stator voltage. A complete model of the transmission line dynamics is required if it is more complicated.

2.3 Maximum Power Point Tracking (MPPT)

Optimal Solar and WT operating modes are set by the MPPT controller. MPPT is intended to maintain the maximum possible power factor of the turbine and thus maintain maximum power output. This can only be accomplished by precisely tracking the target turbine rotor speed, which is challenging given the erratic fluctuations in wind speed. The three kinds of MPPT in wind algorithms are: Height Search (HCS)/Disturbance and Observation (P&O) Algorithm, Torque Algorithm Optimum (OT)/Torque feedback algorithm, and Tip Speed Ratio (TSR) Algorithm. According to Zhang et al. (2022), MPPT control is based on careful observation of the rotor speed's probability density function (PDF) form. The rotor speed's PDF precisely matches the intended PDF thanks to the MPPT control law's design. This was accomplished by combining the OT algorithm with the linear least squares (LLS) approach to solve the Fokker–Planck–Kolmogorov (FPK) equation. In order to lessen variations in rotor speed and torque, the suggested Hybrid MPPT nonlinear optimum control contributes to a rise in solar and WT power. Here the hybrid MPPT were proposed for hybrid RES for EV charging.

2.4 Grid Side Controller

The grid-side controller (GSC) regulates the DC link voltage in order to manage the flow of both reactive and active electricity into the grid. To attain maximum power, the generator's rotation speed may be adjusted by the machine-side controller (MSC) in response to variations in wind speed [18]. Direct torque control (DTC) and field-oriented control (FOC) are the two categories into which MSCs fall (Figure 5). In WECS, generators are controlled using both of these methods. The three-phase current of the wind turbine is split into two orthogonal components [20] that define the magnetic flux and electromagnetic torque in the FOC control method. Two PI controllers are used in the modulation step to create a reference voltage vector, which causes the measured current to follow the reference current. The shaft speed, which is ascertained by the encoder as feedback, is a prerequisite for FOC [19].

A DPC control method founded on a suitable reactive and positive generation reference generation approach is suggested [25] to solve the mechanical issue brought on by torque variations. In order to address imbalanced grid voltage circumstances, other DPC techniques were later developed. With the benefit of quick dynamic reaction, a predictive current control technique has been devised [26]. Making this kind of prediction-based visualization can be a little challenging. The sliding mode control (SMC) approach, which is the basis of a comparatively simpler control scheme [27], is resilient to changes in parameters and fluctuating grid voltage scenarios. On the other hand, there was no talk of enhancing electricity quality. Hu et al. [28] suggested a novel method known as hybrid control to get over the aforementioned issue and boost control flexibility.

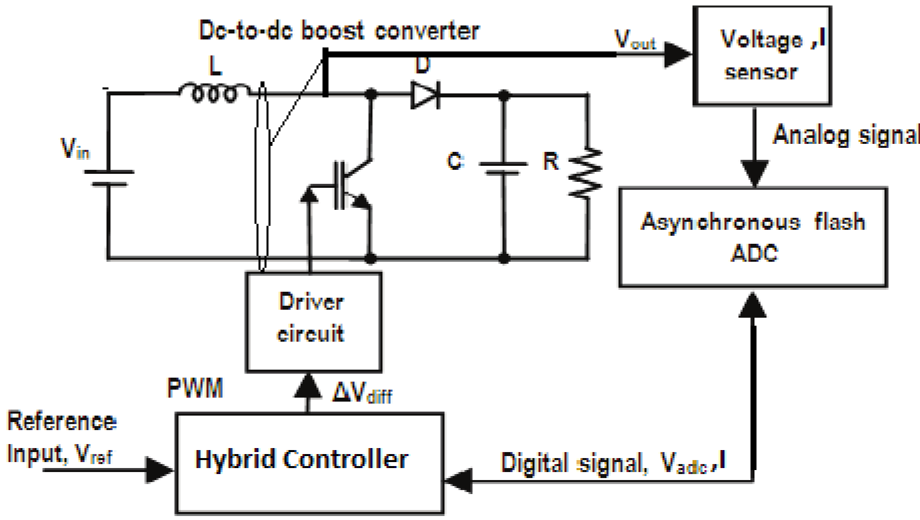

Figure 5: Proposed a new technique called hybrid control.

2.5 EV Batteries

Batteries for cars and energy storage devices that use batteries Systems for storing energy produced by renewable energy sources (RES), such as solar and wind photovoltaics, are referred to as battery energy storage systems. Then, these systems may effectively release stored energy to satisfy customer demand, offering a reliable power source and perhaps resulting in savings. An energy-storage device with the capacity to be recharged is a battery, often known as a storage battery or rechargeable battery. One can distinguish between a number of battery types, such as lead acid batteries, nickel-cadmium batteries, solid state batteries, lithium ion batteries, lithium Ferro phosphate batteries, lithium sulfur batteries, and flow batteries.

2.6 Integration of RESs and EVs

To reduce pollution, the power grid should incorporate electric cars and renewable energy sources. Due to their comparatively reduced pollution emissions as compared to other vehicle kinds, electric vehicles are quickly becoming more and more popular. The research projects included in this section aim to lower emissions by combining the usage of electric cars with renewable energy sources. By reducing reliance on fossil fuels, the aforementioned projects seek to minimize emissions.

EV Parking - Charging Station Connecting electric vehicles to an external power source is made possible by EV charging stations. This enables completely electric and plug-in hybrid vehicles to have their batteries recharged. While some charging stations focus on the essentials and adopt a more simplified design, others include sophisticated features like network connectivity, smart metering, and cellular compatibility. When an electric car is connected to a charging station, the area is called an electric vehicle park and is reserved especially for the storage of electric vehicles.

The integration of renewable energy sources (RES) like solar and wind power in tandem with electrification is the primary area of research attention for other RES. More research is still needed to fully understand how offshore wind farms and other alternative energy sources, such geothermal and wave energy, may be integrated. Nonetheless, in isolated locations or on difficult-to-reach islands, this strategy could provide workable ways to charge electric cars.

3. **SIMULATION MODEL AND RESULTS**

A MATLAB simulation model of the wind energy conversion system was created. As the wind generator, a permanent magnet synchronous generator is selected. The generator's input is the variation in wind speed. The wind turbine's three-phase output voltage is linked to an unregulated three-phase rectifier. An AC voltage rectifier is attached to the boost converter. The load is linked to the boost converter's output. Measured DC voltage and current are sent to the MPPT controller. The maximum power of the wind turbine for a given wind speed is determined by the MPPT controller by calculating the duty cycle of the boost converter. Using IGBT as the switch, the boost converter is built. Capacitors, inductors, switches, and diodes are used in the construction of the boost converter. With its many tools and features, MATLAB makes it easier to simulate and optimize battery-powered solar photovoltaic electric cars. It is possible for researchers to develop mathematical models that simulate how battery systems, photovoltaic solar cells, and electric car charging procedures work. The performance of wind, diesel, and solar battery-powered electric cars under various situations may be simulated and analyzed by entering pertinent parameters and real-world data.

Through the use of MATLAB's optimization tools, researchers may precisely adjust the performance of cars fuelled by solar, diesel, and wind energy. They may adjust variables including battery size, charging schedule, and charging speed to increase energy efficiency, reduce charging time, and increase the range of electric vehicles. Through optimization, the best possible balance is reached between energy generation, electric car charging, solar, wind, diesel, and battery storage.

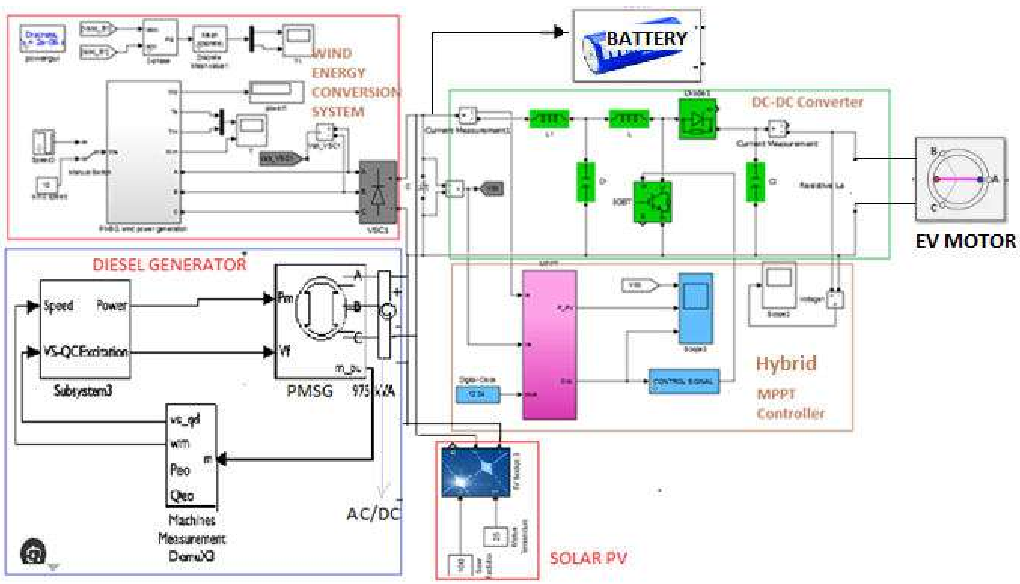

Figure 6: Simulation for HRES with diesel Generator integration for EV application

Figures 7 to 9 show the active power, voltage, and current of wind turbines, diesel generators, and solar generators under four different distribution schemes. Because of the DC operating principle, diesel generators' DC active power response differs greatly from the other three kinds. When it comes to DC, a diesel generator is used to charge the suggested, and more generator modules are then employed to satisfy demand.

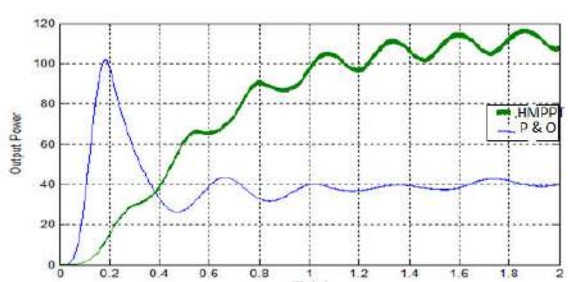

Figure. 7: Simulation for HRES with diesel Generator integration for EV application

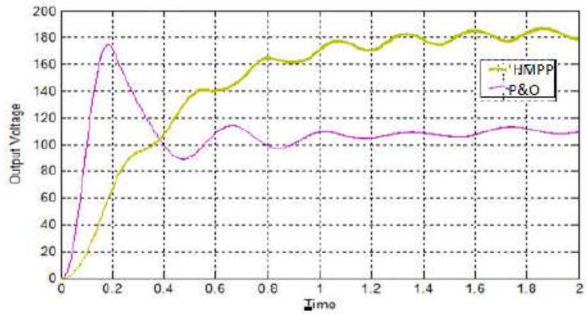

Figure. 8: Simulation for HRES with diesel Generator integration for EV application

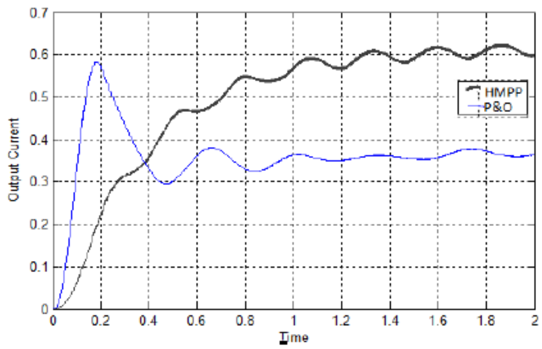

Figure. 9: Simulation for HRES with diesel Generator integration for EV application

These findings indicate that while renewable output supplies the system with enough active reactive power to ensure stability and operational flexibility, the voltage response of the suggested module is almost nil. The installation of the hybrid control caused the voltage to maximize at 0.8 s, stabilize at 1 s, and stable, according to comparative studies of all scenarios and dispatch mechanisms for all three modules, including the diesel, wind, and PV generator.

Power compensation is provided for a variety of control schemes when operating in an unbalanced grid voltage environment. Better dynamic responsiveness is also achieved by doing away with the requirement for PI controllers, switching tables, pulse width modulators, and coordinate conversion.

Table 1: Comparison of proposed hybrid algorithm with other algorithms

Sl.No	Year	Algorithm/ Technique	Hardwar/Software Tools	Types of Machines
1	2015	Genetic	MATLAB & dsPIC30F4011	SEIG
2	2016	Neural	PSCAD/EMTDC & dSPACE1104	PMSG
3	2015	LMA	MATLAB & DS1104	IPMSG
4	2016	FLC, P&O	PSIM & DSP	SCIG
5	2016	PSF	MATLAB/Simulink	BDFRG
6	2014	Fuzzy-SMC, Grey wolf	MATLAB/Simulink	IG
7	2015	Back stepping algorithm	MATLAB/Simulink	PMSG
8	2024	Hybrid Algorithm	MATLAB/Simulink & DSP	PMSG

Table 1 presents a comparison between the suggested hybrid method and other algorithms. The induction motor utilized in the electric vehicle (EV) driving cycle is analyzed. It works at a maximum torque of either greater or lower at any given moment. 2-1: Vector Control (Hybrid Control) Electric actuators have advanced significantly [13] as a result of semiconductors' flexible capabilities in power and signal electronics [14]. The hardware configuration for HRES with diesel generator integration for EV application is shown in Figure 10.

Figure. 10: Hardware setup for HRES with diesel Generator integration for EV application

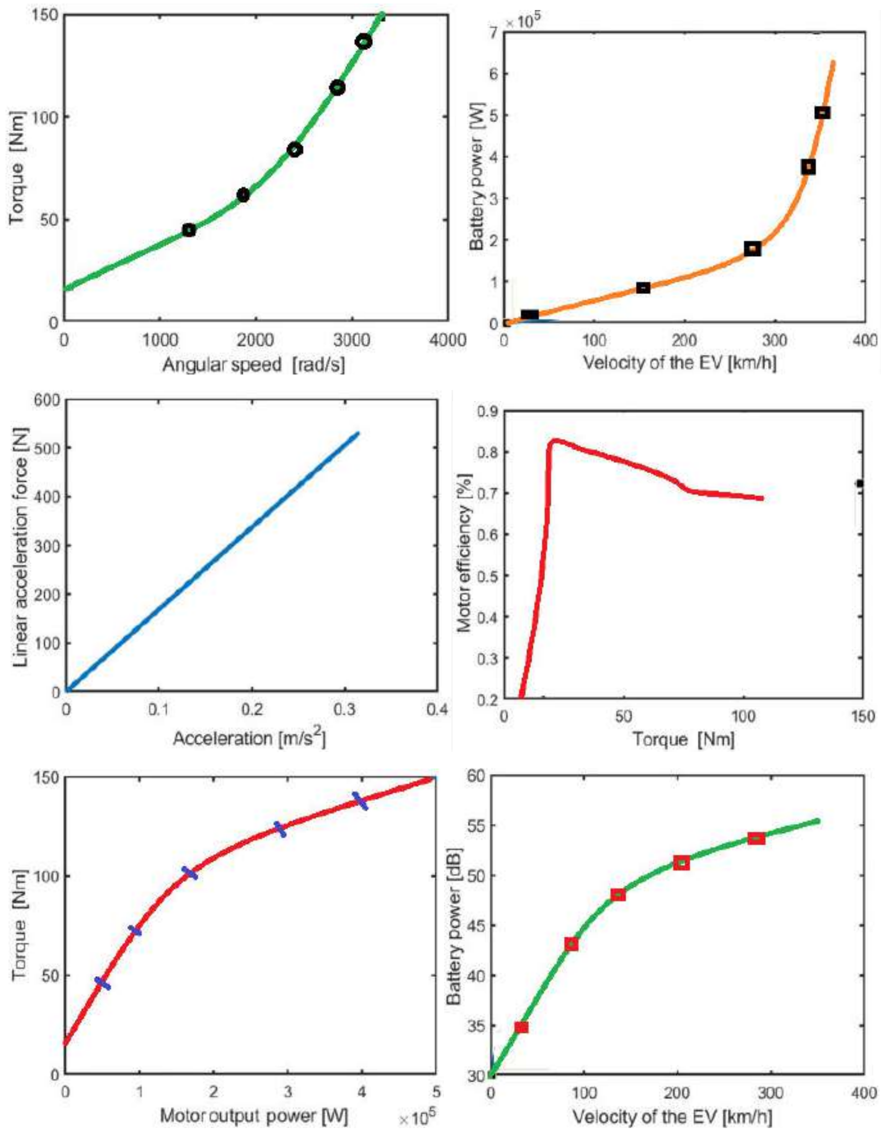

Figure 11: The performance comparison parameters of torque, velocity, power, battery power, angular velocity

The torque, velocity, power, battery power, and angular velocity performance comparison characteristics are displayed in Figure 11. Because of this, the battery will use less electricity, extending the electric vehicle's range. Electric vehicle's dynamic model: To calculate the traction force based on the needed load on the vehicle under road conditions, an adequate dynamic model of the vehicle and power transmission system are required. Since the speed of an electric vehicle depends on the balance between the driving force generated by the motor and the vehicle's dynamics, vehicle dynamics may be used to determine the performance of the vehicle.

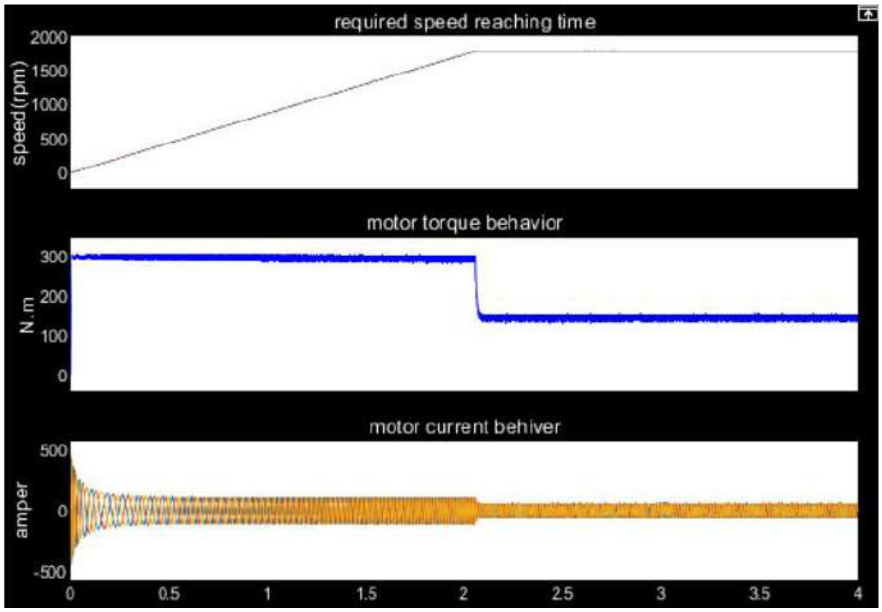

Figure 12: The Behavior of IM in Speed Reaching Time, Torque and Current

The findings of the EV simulation were displayed in Figure 12, where an induction motor running at a constant speed of 900 rpm for 4 seconds was used to simulate a change in the number of passengers. The induction motor functions with exceptional stability, according to simulation and hardware findings, making it a viable choice for driving electric vehicles.

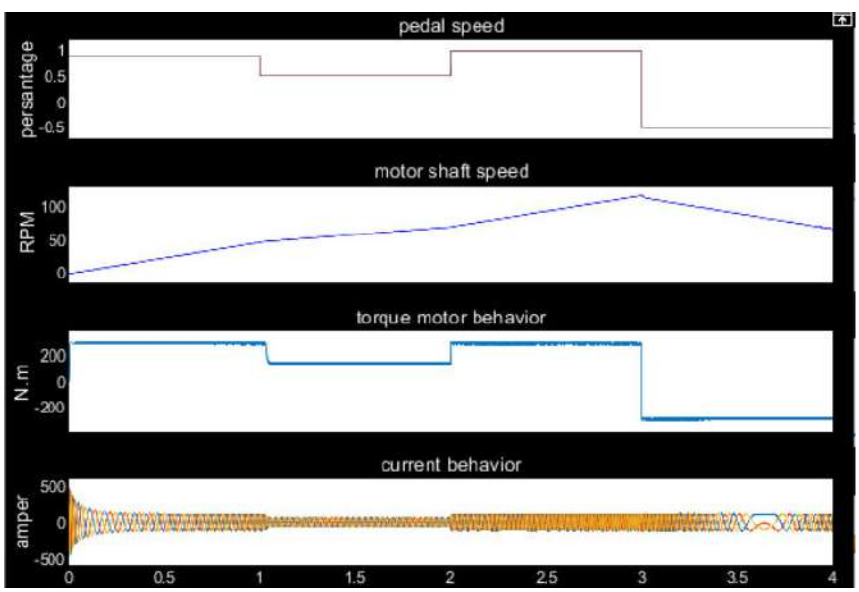

Figure 13: The Behavior of IM for Torque, Current and Motor Shaft Speed with Changes in Pedal Speeds

The simulation results for an electric vehicle using a dynamic vehicle model are displayed in Figure 13. The induction motor runs when the electric vehicle's pedal speed varies abruptly while carrying a constant load of four passengers for four seconds. In the first two seconds, the pedal speed is 89% of the engine speed; in the second and third seconds, the pedal speed is 50%, 100%, and 100% of the engine speed, respectively. Engine speed is 89% of second (4) pedal speed. Engine speed minus pedal speed equals -50%. This scenario states that the electric vehicle's braking, acceleration, cruising, deceleration, and reverse motion will all be recreated.

The IM rotates in the opposite direction and operates in the regenerative braking zone with negative torque for three to four seconds, during which time it generates electrical energy that powers the system. Battery capacity for electric vehicles. The motor must provide the necessary electrical power for the battery, in addition to any additional power needed to operate or activate the accessories for electric vehicles. Figure 18 illustrates how speeding up an electric car increases the electrical power supplied to the motor, which raises the battery's necessary power.

CONCLUSION

In this work, we simulate an electric vehicle (EV) considering its battery, transmission performance, and vehicle dynamics. Every parameter in the Matlab/Simulink model is designed to resemble an actual electric vehicle. The aerodynamic drag, linear acceleration, and rolling resistance forces are the three active forces on the simulated EV; the hill-climbing force is assumed to be on level terrain. The average motor efficiency of the model was 73%, which is within the range of expected motor efficiencies for electric vehicles. In this research, a design-stage technique for integrating EV into an isolated microgrid is described. Some of these EVs can offer supplemental services to the microgrid, but their primary use case is in rural areas. Furthermore, because of the extended times of high wind resource availability, the integration of EV lowers the usage of diesel generation and increases the number of wind units. As a result of the excess energy being stored in the EV, the cost of incorporating wind power is reduced.

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