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Design of Two-Wheeler Hybrid Electric Vehicle using MATLAB-Simulink

Prof. Sandip P. Gath[1], Shantanu B. Wani[2], Saurabh N. Jape[3], Kishor B. Bolij[4], Siddharth S. Gunjoti[5], Pratik B. Hivale[6]
[1]*Project Guide, Department of Electrical Engineering , Rajiv Gandhi Collage of Engineering, Karjule Harya*
[2, 3, 4, 5, 6]*ElectricalEngineering, Rajiv Gandhi College of Engineering, Karjule Harya*

Abstract: With the rising gap between the supply and demand of oil and the market monopoly of the countries with oil reserves, the world has turned its back on traditional fuels. Not to mention the everyday rising pollution. The work and advancement in electric vehicles are reaching their peak every day and new inventions are being made in this sector, just like the mega-market players and industries. A lot of research is concentrated on the four-wheelers nevertheless, two- wheelers are a major part of transportation in the world and as compared to the four-wheelers two-wheelers don't find the same spotlight. Our project highlighted this problem and created the simulation model of a two-wheeler hybrid electric vehicle which is a series-parallel hybrid. This simulation is constructed using MATLAB-Simulink software. This is a simulation model of a two- wheeler hybrid electric vehicle which uses a DC source (Battery) as a power source accompanied by the IC Engine. This system can shift load between the battery and IC engine so that power output can be constant, and the system can run smoothly. A DC-DC bidirectional chopper is used to convert power between battery and generator which increases the efficiency of the system. In a proposed system a two-wheeler is taken into consideration with an IC engine of rpm of 2000 (for reference) is taken into consideration for simulation.

I. INTRODUCTION

Recently the world has been attracted toward the non- traditional power sources which have resulted in the increment of research on producing clean and sustainable energy sources for propelling machines and generating electricity. The reason is the decrease in the number of resources and visible changes in the environment. One of the things that constitute the most in both these factors is the mode of transportation. In India, the vehicle population is growing at the rate of over 5% per annum and today the vehicle population is approximately 40 million. The vehicle mix is also unique to India in that there is a very high proportion of two-wheelers 76% (SIAM, 2011). The growth rate of vehicles is the backbone of economic development and the Indian automotive industry (the second-fastest growing in the world). Today, in the country of about 7-8 million vehicles are produced annually. In 2011, the country reported 141.8 million registered motor vehicles The overall transport sector in India is estimated to emit about 15 percent of the CO_2 emissions. But consider this– the total consumption of oil is responsible for 57 percent of the CO_2 in the country today. And among all oil-consuming sectors, CO_2 emissions from transport are increasing at the fastest rate at more than 6 percent per annum. This is daunting for any national combat plan for climate and public health. Even globally, curbing warming gases from the transport sector has proven to be the most difficult. How can we avoid an increase in GHG gases if cars drive the trend? To answer this question electric vehicle came to the market and started booming as they were offering a clean, efficient, and reliable source to drive the vehicle. But with electric vehicles into the market, the large spotlight was captured by the four-wheelers as the market leaders such as Tesla, BYD, and Volkswagen Renault–Nissan–Mitsubishi Alliance flooded the market with an exotic range of EVs. But in doing this the manufacturers overlooked the population that drives two-wheelers which is mostly rural and constitutes as many as four-wheelers in India which constitute around 30 % of the total pollution which demands the attention of the mass. Recently in the market, the key players that are in the two-wheeler industry are Hero Electric. Hero Electric is the largest player in the Electric Two-Wheeler are TVS, Bajaj, Ather, Ampere, Okinawa Auto-tech, and Hero Electric which is a mostly pure or plug-in hybrid but none of them have provided the hybrid with IC engine which could indeed be one of the best solutions presently having faced the battery efficiency. The project has taken this approach of creating a simulation of such type of two-wheeler hybrid vehicle which uses an IC engine along with the Battery which can provide a new perspective for the research in this sector. We have used a DC-DC bidirectional chopper for the conversion of power between generator and battery which also charges the battery while the system is running. It integrates computation, visualization, and programming in an easy-to-use environment. In the construction of this system while working on this we could confirm that this holds the potential to transform into a new way of transporting and could perform as good as if not better than the EV that is on the market right now. The project also highlights the future scope for research in this sector by providing valid research data to map the efficiency and holes in the simulation.

II. METHODOLOGY

Two areas of industry and governments in the United States, Europe, and Japan have formed strategic initiatives to cooperate with new significant importance in automotive engineering are improvement in fuel economy and reduction of emissions. The automobile technologies, over the years several 'non-traditional' solutions have been presented: Electric Vehicles (EV), Hybrid Electric Vehicles (HEV), and Fuel Cell Vehicles (FCV). AEV seems the only promising technology able to satisfy the market requests since they match good performances in terms of both consumption and reliability. In a conventional vehicle, knowing loaded mass, desired maximum acceleration, and maximum climb, it is possible to find the power required by the engine. Consequently, while running under different conditions (speed, climb, etc.) maximum speed, estimated fuel consumption, and emissions can be calculated. Only at the end, the vehicle's performance is verified in carrying out a predetermined mission. In an Electric Vehicle (EV), the design process for the accumulation system and the electric mover - the only power source onboard is similar.

Electric generator power will correspond to the necessary power at the wheel while it's Methodology Procedure. In the case of a Hybrid Electric Vehicle (HEV) propulsion system design, the approach is different because it involves different choices for preliminary design data. In fact, in the design of a hybrid vehicle, there are more degrees of freedom than the conventional or electric vehicle design, thus it is possible to specialize the propulsion system and architecture for the common usage of the vehicle is asked to. For example, in the ―parallel‖ architecture the total power requirement can be distributed between the Internal Combustion Engine (ICE) and the Electric Motor (EM). Whilst in the ―series‖ one the choice is between the power to be supplied by the ICE and by the storage system to the electric motor. Moreover, to obtain the maximum performance in terms of fuel economy and emissions reduction, there are also configurations including some characteristics of ―series‖ and parallel‖ layouts. Usually, in-vehicle system designs some parameters are chosen in advance considering specifications, corresponding to the car required performances, and the others are used for the performance verification, but just even one wrong choice among these parameters, can avoid achieving possible efficiency. Hence, these must be considered as non- stationary complex energy systems, involving the most appropriate control strategy to manage the powertrain components, to achieve the best performances.

Many different approaches have been proposed: static optimization methods, intelligent control techniques (rules/fuzzy/neural network), game theory, and route control strategies. The principal approach's drawback is related to focusing on a particular issue of the HEVs, which is to consider the drive train devices and the control strategies independently of each other. To fix a power train profile and optimize the control strategy parameters or vice versa leaves open the question of whether the selection of better control law or different drive train components could result in better performances. An alternative approach is to use dynamic optimization algorithms, which allow finding out the minimum fuel consumption independently of any particular control law. This way is non-causal in that it finds the minimum fuel consumption using knowledge of past and future power.

The demands representing a limit of performance of causal control law. Nevertheless, being this approach is time and, implicitly, specific driving cycle-dependent, it cannot be implemented on a real vehicle control system for a real-time control strategy. Therefore, being all the decisions on hybrid propulsion system design (powertrain layout, control strategy, etc.) strictly connected to the mission profile it is worth furnishing a comprehensive methodology to assist the designer during the HEV propulsion system design process. This methodology consists of two distinct phases like,

1) Solving an optimization problem to detect the best powertrain components characteristics and choose the best rules-based control strategy.
2) Application and calibration of the control strategy parameters and adjustment of the whole drivetrain, and of the powertrain components characteristics. In this paper, the first phase will be presented, which is composed of three main steps:

a) First component sizing, in which components characteristics are determined based on vehicle mission.
b) Pre-optimization, in which a generic scheme of a hybrid powertrain is considered, and all the possible control strategies are imposed to rule the energy flows between energy devices to calculate all possible vehicle architectures.
c) Design optimization: using an optimization algorithm borrowed from the Graph Theory, the Dijkstra algorithm, the method allows the identification of the optimal powertrain architecture.

III. SYSTEM DEVELOPMENT

A. *Hybrid Electric Vehicle (HEV)*

What is a hybrid? A hybrid vehicle combines any two power (energy) sources. Possible combinations include diesel/electric, gasoline/flywheel, and fuel cell (FC)/battery. Typically, one energy source is storage, and the other is the conversion of fuel to energy. The combination of two power sources may support two separate propulsion systems.

Thus, to be a True hybrid, the vehicle must have at least two modes of propulsion. For example, a truck that uses diesel to drive a generator, which in turn drives several electrical motors for all- wheel drive, is not a hybrid. But if the truck has electrical energy storage to provide a second mode, which is electrical assists, then it is a Hybrid Vehicle. These two power sources may be paired in series, meaning that the gas engine charges the batteries of an electric motor that powers the car, or in parallel, with the car directly.

A HEAN is formed by merging components from a pure electric vehicle and a pure gasoline vehicle. The Electric Vehicle (EV) has an M/G which allows regenerative braking for an EV; the M/G installed in the HEV enables regenerative braking. For the HEV, the M/G is tucked directly behind the engine. The M/G is connected directly to the engine in Honda hybrids. The transmission appears next in line. This arrangement has two torque producers: the M/G in motor mode, M-mode, and the gasoline engine. The battery and M/G are connected electrically.

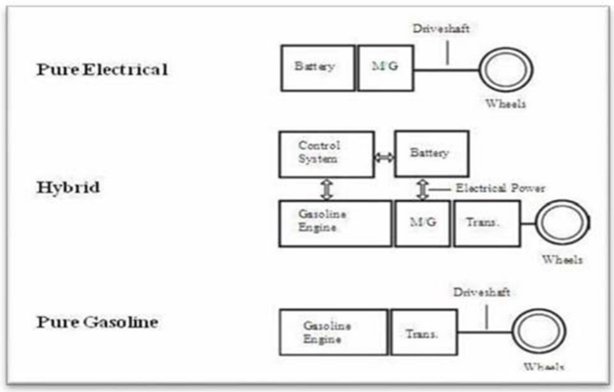

Figure 2: Power flow diagram

IV. BLOCKS USED FOR SIMULATION

A. Battery

This block provides the necessary power needed to work to the system which then calculates the voltage and current by using the current and voltage coming through the battery. The calculation block is used to calculate the power, loss, and other parameters in the battery which is then fed to the Dc-Dc converter which then steps downs the voltage and provides the voltage to the motor for working which is then provided to the vehicle. This block is the source of DC power. This block models a battery. If you select Infinite for the Battery charge capacity parameter, the block models the battery as a series of internal resistance and a constant voltage source. If you select Finite for the Battery charge capacity parameter, the block models the battery as a series of internal resistance plus a chargedependent voltage source defined by:

V = Vnom*SOC/(1-beta*(1-SOC))

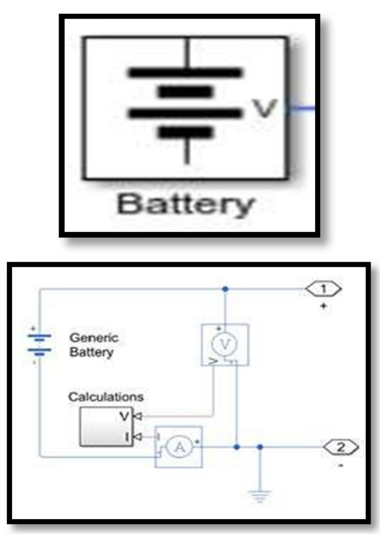

Figure 3: Battery

Where SOC is the state of charge and Vnom is the nominal voltage. Coefficient beta is calculated to satisfy a user-defined data point. Provided are the battery parameters that were taken into consideration for the simulation of this model.
The rechargeable battery business exclusively focuses on the electric vehicle sector (including pure EVs and hybrids). Other industry areas such as energy storage and the decrease in battery prices due to increased economies of scale are projected to gain from battery technology improvements focused on EVs.
Batteries come in various sizes and shapes, ranging from tiny cells used in hearing aids and wristwatches to small, thin cells used in smartphones to large lead-acid batteries used in cars and trucks. In the past, the only way to increase a battery's performance was to increase its size. This made it difficult for engineers to design a battery that could be used in various applications. However, this has changed with the introduction of new technologies such as lithium-ion and lithium polymer batteries. The battery is an electrochemical device that converts chemical energy into electrical energy. It has several parameters that describe its performance in a given application.

The following parameters are taken into consideration while choosing an appropriate battery for specific use:

- Specific Power: Several batteries have a high energy density but a low specific power, which indicates they can store a large quantity of energy but quickly supply a little amount of power. This signifies that vehicles can travel large distances at a low pace in terms of transportation. However, high-specific-power batteries often have a poor energy density due to the quick depletion of accessible energy by high discharge currents (e.g., high acceleration).
- Specific Energy: Specific energy, often known as energy density, is the amount of energy per unit mass. It's also known as gravimetric energy density or simply energy density, though energy density refers to the amount of energy per unit volume. The joule per kilogram (J/kg) is the SI unit for specific energy.
- Safety: One of the most important factors to consider when selecting a battery pack for an electric vehicle is safety. A single positive incidence in the media might shift public opinion against this kind of vehicle. When steam engines burst and fuel tanks burst into flames 100 years ago, there were similar anxieties. A thermal runaway battery is the main problem. While well-designed safety circuits and sturdy enclosures nearly remove this risk, a severe disaster is still conceivable. Additionally, when a battery is used incorrectly or as it matures, it must be secure.
- Life Span: The term "life span" refers to the number of cycles a person has completed and how long they have lived. The majority of EV batteries have a guarantee of eight to ten years or 160,000 kilometers (100,000 miles). Aging-related capacity loss is difficult to regulate, especially in hot regions. Automobile manufacturers are oblivious to the aging process of batteries under a range of customer and environmental circumstances. EV manufacturers increase the size of the batteries to compensate for power loss, allowing for some degeneration during the battery's guaranteed service life.
- Performance: Performance is closely tied to the battery's level of charge, whether driving the EV in blistering summer heat or frigid winter weather. Batteries are temperature sensitive and need climate control, unlike an IC motor, which can function over a broad temperature range. The energy necessary to regulate the battery temperature as well as heat and cool the cabin comes from the battery in autos that operate solely on batteries.
- Cost: A big drawback is a cost. There is no certainty that the battery will reach BCG's stated goal price of $250–400 per kWh. Complicating things further is the demand for safety security loops, battery management systems for stability, temperature control for longevity, and an 8–10-year guarantee. The cost of the battery by itself is comparable to the cost of a regular automobile, thereby doubling the EV's cost.

B. DC-DC Bidirectional Converter

The Bidirectional DC-DC Converter block represents a converter that steps up or steps down DC voltage from either side of the converter to the other as driven by an attached controller and gate-signal generator. Bidirectional DC-DC converters are useful for switching between energy storage and use, for example, in electric vehicles. The Bidirectional DC-DC Converter block allows you to model a non-isolated converter with two switching devices, an isolated converter with six switching devices, or a dual active bridge converter with eight switching devices.
The DC-DC Converter block represents a behavioral model of a power converter. This power converter regulates voltage on the load side. To balance input power, output power, and losses, the required amount of power is drawn from the supply side. Alternatively, the converter can support regenerative power flow from load to supply. The bidirectional DC- DC converter is potentially used for an energy charging or discharging device; however, the converter displays highly non-linear characteristics since its internal system parameter varies depending on the operation mode and the disturbance engagement.

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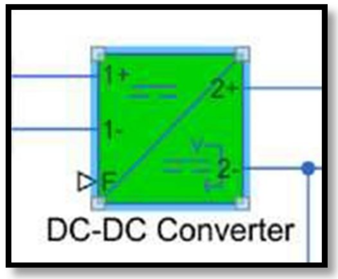

Figure 4: DC-DC Converter

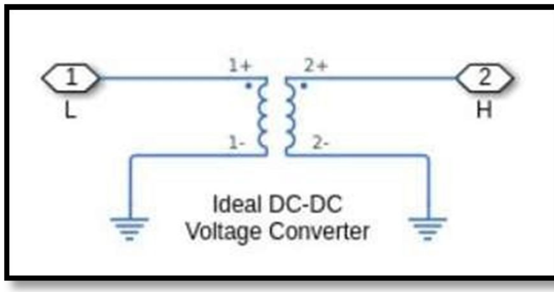

Figure 5: Ideal DC-DC Voltage Converter

This circuit illustrates the converter's behavior.
The P fixed component draws a constant power and corresponds to converter losses that are independent of load current. The power drawn is set by the Converter losses at zero output power parameter value. The resistor Rout corresponds to losses that increase with load current and is determined from the value you specify for the Percentage efficiency at the rated output power parameter.
The voltage source is defined by the following equation:

v = Vref – I load D + load Rout

Where:
Vref is the load side voltage set point, as defined by the value you specify for the Output voltage reference demand parameter. Alternatively, you can provide this value as input to the Vref port when the Voltage reference parameter is set to External.
D is the value you specify for the Output voltage droop with the output current parameter. Having a separate value for droop makes the control of how output voltage varies with load-independent of load-dependent losses. Instead of specifying D directly, you can specify the Percent voltage droop at rated load.
The current source value i is calculated so that the power flowing into the converter equals the sum of the power flowing out plus the converter losses.
To specify the converter behavior when the voltage presented by the load is higher than the converter output voltage reference demand, use the Power direction parameter: Unidirectional power flow from supply to regulated side — Current is blocked by the off- state diode, and the current source current i is zero. Set the conductance of this diode using the Diode off-state conductance parameter.
Bidirectional power flow — Power is transmitted to the supply side and it becomes negative.

C. Motor and Generator

PSMW block represents a generic motor and drives operating in torque-control mode or equivalently current-control mode. The block supports both motoring and generating regimes, and you can use it to represent servomotor and traction applications at a system level. The motor's permissible range of torques and speeds is defined by a torque-speed envelope, and the output torque tracks the torque reference demand ―Tr‖ with a time constant ―Tc‖.
The block must be connected to a DC supply network. If you model losses using the Single efficiency measurement option, the electrical losses are the sum of a constant term plus two additional terms that are proportional to the square of the torque and the square of the speed respectively. For all losses modeling options, the supply series resistance is not included as part of the efficiency calculation. The block produces a positive torque acting from the mechanical C to R ports. The speed controller block uses the

reference speed and rotor rpm to control the speed.

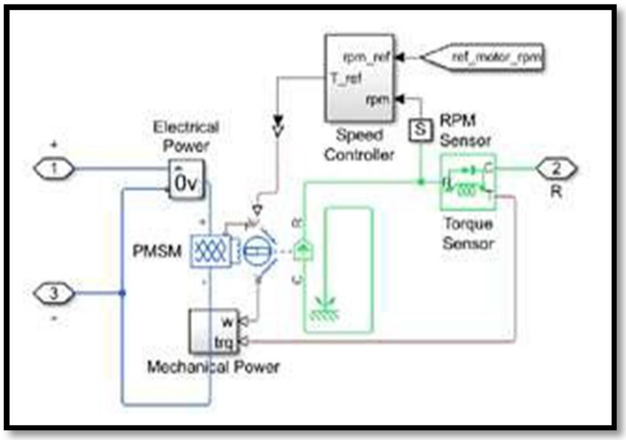

Figure 6: PSMW

The inputs arrive from the block which is a dc-dc converter torque sensor that converts the quantity to readable measurement and provides that to the mechanical block which calculates the power of the motor.
The generator has a similar resemblance to the motor but just the change is that the power given to the generator is by the IC engine which provides a torque that is converted into the electrical energy and then provided to the motor and drives block which is then converted into the electrical energy which is fed to the dc-dc converter to charge the battery. A mechanical block is provided to calculate the power of a generator as well.

D. Power Split

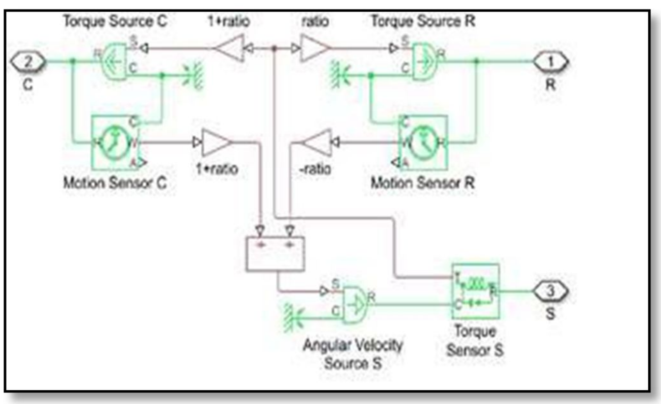

Figure 7: Power Split

The above example shows the basic architecture of a power-split hybrid transmission. The planetary gear, along with the motor and generator, acts like a variable ratio gear as shown in the proposed system. In this test, the vehicle accelerates, maintains the faster speed, and then decelerates back to the original speed. The power management strategy uses just stored electrical power to affect the maneuver, the combustion engine only delivers the power required to maintain the original speed.
Losses for the motor, generator, battery, and planetary gear are modeled. You can use this system-level model to gain an understanding of system performance and to support the design of the power management strategy. The example can be directly compared with the parallel hybrid example hybrid parallel and the series hybrid example hybrid series.
The power split is an aspect of this system that splits the output coming from the IC engine and provides output to the generator as mentioned above and provides an output to the machine to drive the vehicle. It has multiple motion sensors and torque sensors to provide a mechanical output at the end of the generator as well as the vehicle. The vehicle body is also taking power from the motor and dependencies depend upon the amount of rpm that the motor has generated to sustain the need to power the vehicle and the additional power is supplied by the engine rpm.

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E. IC Engine

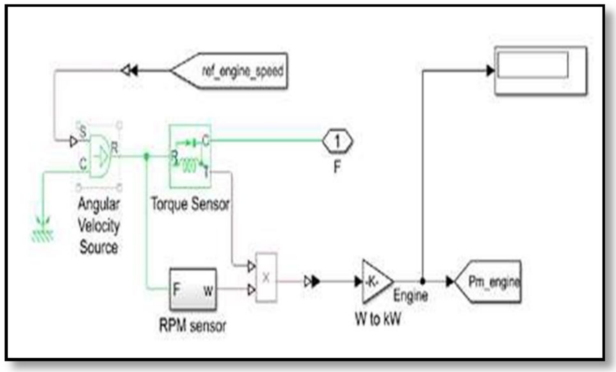

Fig. 8 IC Engine

The behavior exhibited by the engine is of a fixed speed mode hence it can be said that it is a constant angular velocity source. Input is taken from the reference engine speed and further provided to the torque system to give the mechanical output to the power split.

F. Simulation and Working of Proposed System

Our project has two power sources primary (IC engine) and secondary (Electric Engine).Hybrid powertrain configuration includes the series, parallel and series-parallel powertrain configurations. A powertrain is a set of machines included in the power transmission of a vehicle.

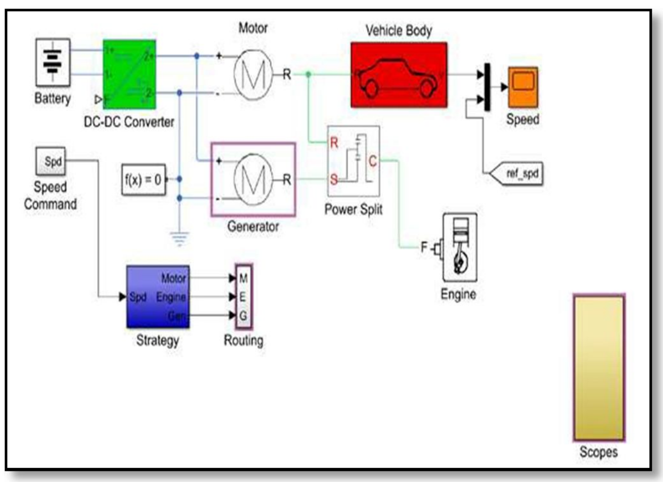

Figure 9: Project Block

Series Powertrain- In a series powertrain, the engine does not provide any kind of propulsion torque to the drive instead it provides the potential energy of the fuel into the mechanical energy which is then converted into the electrical energy using a generator which is fed to the motor and thus given to the mechanical transmission. Parallel Powertrain- In this propulsion system both the engine and the motor operate at the same time and provide the energy to the mechanical computing and then given to the transmission of the vehicle speed allowing the optimum speed of the engine. Series-Parallel Hybrid powertrain- In this powertrain the engine not only provides the power to the transmission but also charges the battery. Our hybrid electrical vehicle made in MATLAB Simulink is the Series-Parallel kind of hybrid which charges the battery along with providing power to the transmission.

The output of the battery is fed to a DC-Dc converter which is a chopper that chops the voltage which is then fed to the motor and other accessories of vehicles. The secondary source i.e., the IC engine supplies the power to the power split (Transmission). Transmission splits the power into two motions. One motion is fed to a generator which supplies the energy back to the DC-DC converter which then charges the battery. Second output/motion fed to vehicle body along with the output of the motor. Whenever the battery is drained at a certain level while working on an IC Engine battery can be charged through a power split and generator.

V. ADVANTAGES AND DISADVANTAGES

A. Advantages

In this technology of EV hybridization and research has taken place with significant results in the sector of automation. The live example of this system used in four-wheelers is Tesla. The biggest concern of batteries is also highlighted and is a significant part of recent inventions.

Advantages of this project Include,

1) High reliability.
2) Long term sustenance.
3) Cost-Effectiveness.
4) No pollution.
5) Salient operation.
6) No hazardous effect on the environment.
7) Uninterrupted Power supply for the vehicle.
8) Provides a Dc output to directly charge the battery.
9) Can be added to the existing system of vehicles.
10) Provides a base for future research.

B. Disadvantages

Everything has some advantages and some disadvantages which are also very true in the case of this project though this project has many advantages this project carries some disadvantages which hinder its ability to outshine another electrical powertrain which are,

1) System is more complex.
2) Due to the addition of electrical components with battery components system becomes bulky.
3) High initial cost.
4) Efficiency is comparatively less than the pure or plug-in hybrid.

VI. APPLICATIONS AND CHALLENGES

A. Applications

The following simulation is of a two-wheeler hybrid electrical. Which uses a series- parallel hybrid powertrain which charges the battery as well as runs the vehicle? Which can be used to drive a two-wheeler as it needs a smaller IC engine. The same mechanism can be added to any transport medium with slight changes which can help in decreasing the pollution created by pure IC engine vehicles.

The system can be used to advance the existing system without making it outdated. This can solve a lot of our problems that may arise due to the complete scrapping of ongoing vehicles to replace them with electric vehicles.

B. Challenges

Initially the challenge is to gather sufficient data on modification of such system as no such system or very few such systems are available in two-wheeler.

Power losses that happen during the generation and transmission of power in the vehicle.

Reduce the complexity of the system and provide a simpler way which requires research in the sector of battery sizing and output correspondence.

VII. FUTURE SCOPE

Future hybrid electric vehicles will most likely carry lithium-ion phosphate (LiFePO4) batteries that are now becoming popular in other countries. The LiFePO4 batteries are rechargeable and powerful and are being used in electric bikes and scooters. Hybrid Electric vehicles and fully electric vehicles will most likely adopt this technology in the future. Another technology that is likely for future hybrid electric automotive is the increased use of super-capacitors and ultra-capacitors for storing and delivering electrical charge. Many of these batteries are currently being used in conjunction with hybrid car prototypes, so these are expected in the electric vehicle future markets as well.

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VIII. RESULT

The following simulation is of a two-wheeler hybrid electrical. This uses a series-parallel hybrid powertrain which charges the battery as well as runs the vehicle. Which can be used to drive a two-wheeler as it needs a smaller IC engine. The same mechanism can be added to any transport medium with slight changes which can help in decreasing the pollution created by pure IC engine vehicles. The system can be used to advance the existing system without making it outdated. This can solve a lot of our problems that may arise due to the complete scrapping of ongoing vehicles to replace them with electric vehicles.

IX. CONCLUSION

By this, we conclude that we successfully designed a hybrid electrical vehicle model in MATLAB/Simulink which is useful to reduce emissions and maximize fuel economy. A petrol-electric hybrid vehicle system is designed successfully which is both economic and environmentally friendly in terms because half of the distance can be travelled with help of an electric system. This project provides an alternative to conventional vehicles without disturbing the existing framework of the system. It also satisfies the need for hybridization of vehicles to make them less dependent on conventional fuels. It is a self-sufficient system as the need for battery charging is fulfilled by the IC engine and the size of the IC engine is less as compared to a conventional vehicle. The performance of simulation of two-wheeler hybrid has been investigated thoroughly investigated and results were also proposed.

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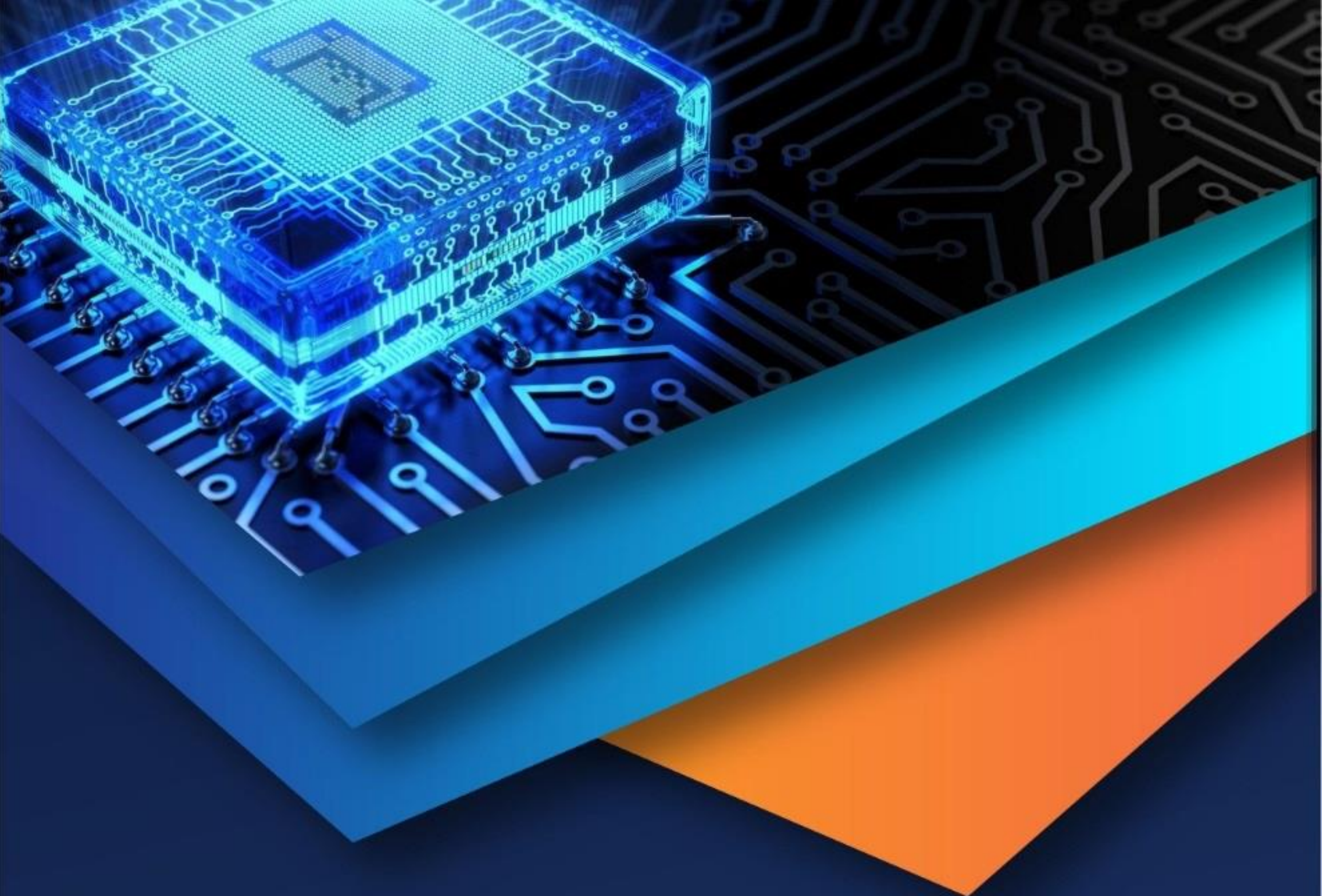

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