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# DESIGN OF A PLUG-IN HYBRID EV'S FED BY PV, BATTERY AND WIND POWER

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**ABSTRACT**

This research offers a plug-in hybrid electric vehicle's (PHEV) internal combustion engine a renewable energy-based substitute for the first time. A new battery/photovoltaic/wind hybrid power source is suggested to replace the internal combustion engine. It consists of a tiny wind turbine placed in front of the plug-in hybrid electric vehicle (PHEV), behind the air conditioning system's condenser, and a small photovoltaic (PV) module mounted on the PHEV's roof. The battery serves as the primary energy storage device in the suggested power source using vehicle-to-grid (V2G) technology. A PV module and a wind energy conversion system (WECS), which includes a miniature wind turbine, serve as the clean and renewable energy-based auxiliary power sources. A battery/PV/wind hybrid power source prototype has been built, and experimental verifications are presented that clearly show using the PV module and micro wind turbine adds 19.6 km to a plug-in hybrid electric vehicle's (PHEV) cruising range during two sunny days, and provides a higher power efficiency and speed of 91.2% and 121 km/h, respectively, compared to the PHEV's normal operation. The PHEV weighs 1880 kg. The additional contributions of this study are the creation of a suitable three-phase stator current for the traction motor via the use of pulse width modulation (PWM) technology and very precise DC-link voltage control.

## 1. INTRODUCTION

The development of electric vehicles (EVs), hybrid electric vehicles (HEVs), and plug-in hybrid electric vehicles (PHEVs) is on the rise due to environmental and economic concerns, displacing internal combustion engine vehicles. As a result, the need for various kinds of EV charging stations is growing throughout the world. A plug-in hybrid electric vehicle (PHEV) is more efficient than a conventional hybrid electric vehicle (HEV) since it runs entirely on its electric motor. The second feature that adds to the advantages and popularity of PHEVs is the V2G technology that is included into them. The benefits of a plug-in hybrid electric vehicle (PHEV) are especially apparent when they are integrated with a microgrid or smart grid to control and balance load demand. Three primary categories may be used to group the efforts made to advance PHEV technology. Improving the quality of the batteries used in PHEVs is the main objective of the first category. A few studies in this area include analyzing how a PHEV's battery ages based on its internal resistance and voltage recovery, assessing how a V2G connection affects PHEV batteries, offering a Li-ion battery pack that is appropriate for a PHEV, assessing how ultracapacitors affect a Li-ion battery's performance degradation, and maximizing the revenue from charging PHEV batteries.

Research studies that suggest PHEV-related accessories and facilities, such wireless chargers and battery chargers based on resonant converters, make up the second group. The primary disadvantage of a plug-in hybrid electric vehicle (PHEV) is that, when the car's battery runs low and reaches a predefined state of charge (SOC), the internal combustion engine of the vehicle generates the electricity required to power the electric motor.

It is evident that using an internal combustion engine running on gasoline in a plug-in hybrid electric vehicle (PHEV) is not a viable option due to environmental concerns. A thorough analysis of the available literature makes it clear that no research project has produced a workable answer. Nonetheless, several studies have been done to use solar energy in various kinds of vehicles—small unmanned vehicles, in particular. In this context, a set of prerequisites for a compact, solar-powered unmanned aerial vehicle were presented and examined. After a review of the subject, it was determined that solar energy was not suitable for use in small-capacity electric cars with realistic weight and dimensions. In order to solve the previously described issue, this research presents a brand-new battery/photovoltaic/wind hybrid power source that may be used in plug-in hybrid electric vehicles (PHEVs). The internal combustion engine of a plug-in hybrid electric vehicle (PHEV) has been replaced in the proposed hybrid power source by a tiny photovoltaic module mounted on the vehicle's roof and a micro wind turbine situated in front of the vehicle, below the air conditioning system's condenser. Thus, the PHEV's cruise range has been increased by using clean, renewable energy sources like solar and wind. A battery-powered hybrid power source prototype has been constructed, and experimental validations are provided to confirm that the use of a micro wind turbine and PV module increases the cruising range of a plug-in hybrid electric vehicle (PHEV) weighing 1880 kg by 19.6 km over the course of two sunny days. Additionally, the system offers a high power efficiency of 91.2% and a top speed of 121 km/h. The additional contributions of this study are very precise DC-link voltage control and the use of PWM technology to provide an adequate three-phase stator current for the traction motor. This is how the remainder of the paper is structured. In Section 2, the suggested battery/photovoltaic/wind hybrid power source is constructed and put into practice. Section 3 provides details regarding the built hybrid power source and experimental verifications; Section 4 wraps up the study. 2. The application of the hybrid power source for PHEVs that combines wind, solar, and batteries. Fig. 1 depicts the setup of the battery/photovoltaic/wind hybrid power source that is suggested to be used in plug-in hybrid electric vehicles. Its components include a Li-ion rechargeable battery, which serves as the primary energy storage device; a bidirectional DC/DC boost-buck converter connected to the Li-ion battery; a single-phase bidirectional DC/AC inverter connected between the battery and grid to enable V2G operation; a PV module, which serves as an auxiliary power source; a unidirectional DC/DC boost converter connected to the PV module; a WECS, which serves as the other auxiliary power source; a unidirectional DC/DC boost converter connected to the WECS; a three-phase bidirectional PWM DC/AC inverter connected to the traction motor, which is essentially a three-phase permanent magnet synchronous motor (PMSM); and a combined power control and maximum power point tracking (MPPT) unit. It is recalled that the maximum power point (MPP) of each PV module connected to the system is tracked by the MPPT unit in a photovoltaic (PV) system. A three-phase rectifier, a permanent magnet synchronous generator (PMSG), and a miniature wind turbine make up the WECS itself. To maintain a specified constant value, the DC-link voltage is continually adjusted. The two comparable unidirectional DC/DC boost converters that are linked to the PV module and WECS are seen in Fig. 2's electric circuit. The converter has an average power efficiency of 98%, and its gain is stated as

## 2.NON-CONVENTIONAL ENERGY SOURCES

### 2.1 INTRODUCTION

The project's nonconventional energy sources, such as the wind, hydro, photovoltaic, and battery systems, are briefly covered in this chapter. together with the essential concepts and background knowledge.

### 2.2 WIND SYSTEM

#### 2.2.1 Introduction

You can find wind practically anywhere in the globe. The earth's rotation and unequal heating on its surface are the reasons for its existence, which guarantees the availability of wind resources forever. Out of all energy generating methods, GRID-connected wind power is growing at the fastest pace, with worldwide annual growth rates between 20 and 25%. It is unlikely that any other energy technology has expanded or is expanding at this pace. In 2004 and 2005, the total installed capacity was 47.6 GW and 58.9 GW, respectively. The idea that wind power is a commonplace method of supplying energy is growing. Many nations throughout the globe have set lofty goals for wind power due to its allure as a source of energy.

### 2.3 SOLAR PHOTOVOLTAICS

#### 2.3.1 Introduction

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Becquerel was the first to notice the photovoltaic effect, which converts solar energy. It is usually understood to mean that when light is shone on a solid or liquid system, an electric voltage appears between two electrodes linked to the system. Solar cells are energy conversion devices that employ the photovoltaic effect to transform sunlight into electrical current. A solar cell, or more broadly a photovoltaic cell, is a single converter cell. A solar array, or solar module, is a group of these cells intended to maximize the generation of electric power; this is how the term "photovoltaic arrays" originates.

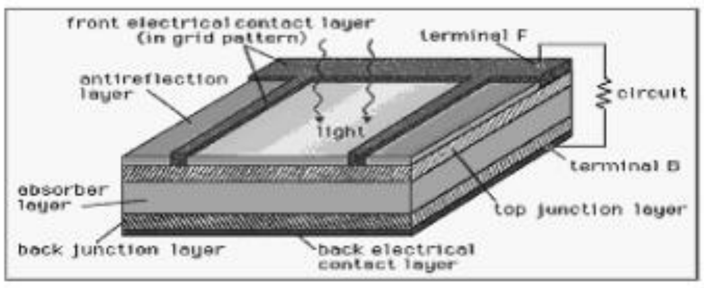



**Fig.2.2:** Solar cell

### BATTERY

### 3.1 Energy Storage

Power is a more versatile use of energy than other forms since it can be efficiently converted into other forms because to its remarkable organization. It can, for example, switch its mechanical structure with around 100% yield or its hotness with 100% yield. Nevertheless, since nuclear power is an arbitrary kind of power measured in iotas, it cannot convert nuclear power into energy with great competence. Accordingly, the typical fossil nuclear energy station's overall warmth to electrical transformation competency is much less than half.

### 3.2 Battery

A basic battery that produces electricity from chemical energy. The most popular device for branched pack energy storage is the battery, which stores energy in electrochemical form. Electrochemical batteries come in the following primary types: In a main battery, the electrochemical reaction cannot be reversed, and the battery is disposed of when it has been fully discharged. It shows situations where a high power density is necessary for a single usage because of this. Rechargeable batteries are another name for secondary batteries. Chemical energy is transformed into electrical energy by this kind of battery. The secondary battery's internal electrochemical process is reversible. Once depleted, it may be instantly refilled with contemporary injection from an external source. The image displays the internal output of a standard electrochemical mobile. It has amazing electrode plates with chemical electrolyte and insulating separators.

### 3.3.1 Lead-Acid

Because of its great performance-to-price ratio and maturity, this is the most widely used kind of rechargeable battery presently, even if it has a poor power density in terms of weight and volume. In a PB acid battery, during discharge, lead sulfate and water are produced, the electrolyte is lowered by water sulfuric acid, and the electrolyte's specific gravity falls as SOC drops.

### 3.3.2 Nickel-Cadmium

NiCd is an advanced electrochemistry where nickel hydroxide is the weakest electrode and cadmium product is the best electrode. The electrodes are positioned in a potassium hydroxide electrolyte inside a chrome-plated steel container after being spaced apart by NylonTM spacers. Primarily used to power the user's rechargeable pack, the NiCd battery has a sealed cell and weighs half as much as a typical Pb-acid battery.

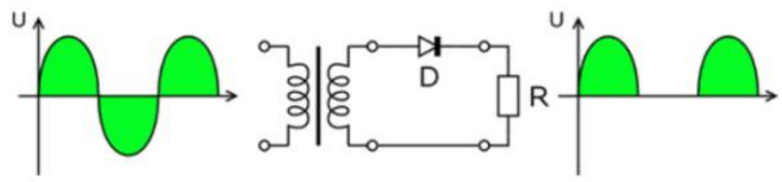
## 4.CONVERTERS

### 4.1. AC-DC CONVERTER

Rectification is the process by which an electrical device called a rectifier changes alternating current (AC), which alternates direction occasionally, to direct current (DC), which flows in a single direction. Rectifiers are used for a variety of purposes, such as radio signal detectors and parts of power supply. Solid-state diodes, vacuum tube diodes, mercury arc valves, and other parts may be found in rectifiers. An inverter is a device that converts DC to AC, doing the opposite purpose.

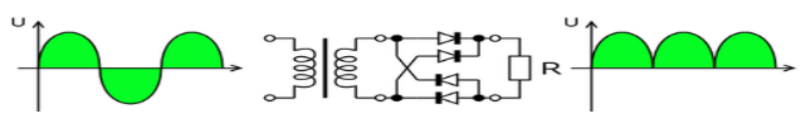
### 4.1.1. HALF-WAVE RECTIFIER

Either the positive or negative half of the AC wave is passed while the other half is blocked in half wave rectification. It is particularly inefficient for power transmission since only half of the input waveform reaches the output. One diode in a one-phase supply or three diodes in a three-phase supply can be used to accomplish half-wave rectification.



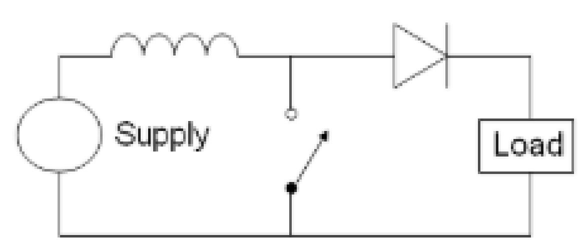

### 4.1.2. FULL-WAVE RECTIFIER

A full-wave rectifier changes the input waveform in its entirety to an output with a constant polarity (positive or negative). Full-wave rectification is more effective since it transforms the input waveform's two polarities to DC (direct current). Instead of only one diode needed for half-wave, four diodes are needed in a circuit with a non-center tapped transformer.



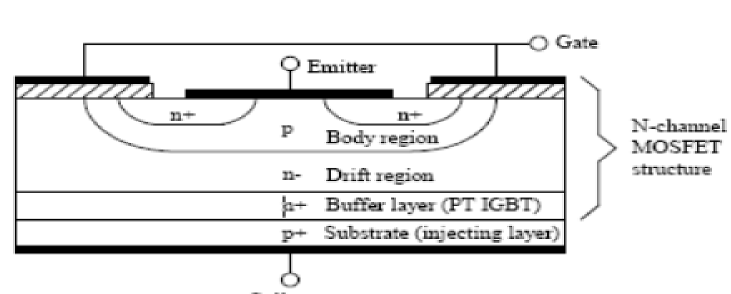

### 4.2. BOOST CONVERTER

A power converter having an output DC voltage higher than its input DC voltage is called a boost converter, sometimes known as a step-up converter. It is a kind of switching-mode power supply (SMPS) that has a minimum of two energy storage components and two semiconductor switches (a diode and a transistor). Capacitors are often used in filters (sometimes in conjunction with inductors).




## 5. INSULATED GATE BIPOLAR TRANSISTOR (IGBT)

In order to create IGBT, the greatest features of PMOSFET and BJT were combined. Because of this, an IGBT has low onstate power loss, similar to a BJT, and high input impedance, similar to a PMOSFET. Moreover, IGBT is not affected by the second breakdown issue that BJT has. Due to all of these advantages, IGBT is very well-liked among power electronics experts. IGBT is sometimes referred to as gain-modulated FET (GEMFET), conductively-modulated field effect transistor (COMFET), or metal oxide insulated gate transistor (MOSIGT). Initially, it was also known as an insulated gate transistor (IGT). The three-terminal power semiconductor known as an insulated-gate bipolar transistor, or IGBT, is renowned for its quick switching and excellent efficiency. Many contemporary gadgets, including air conditioners, electric automobiles, freezers with variable speeds, and audio systems with digital amplifiers, use this device to switch electricity. Amplifiers that employ it often create complicated waveforms using low-pass filters and pulse width modulation because of its fast on/off construction.




IGBT Cross Section in N-Channel The route collector, p+, n-, p (nchannel), n+, and emitter is another path that exists from collector to emitter. Thus, in the IGBT construction, there is an additional intrinsic transistor Q2 represented by n-pn+. The connection between Q1 and Q2, two transistors. This provides the IGBT's whole comparable circuit.

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PURPOSE

IGBT becomes forward biased when collector and emitter are made positive. Two junctions between the n- and p-regions (junction J2) are reversed biased when there is no voltage between the gate and the emitter, which prevents current from flowing from the collector to the emitter. An n-channel, or inversion layer, forms in the top portion of the p region immediately under the gate, as in a PMOSFET, when the gate is rendered positive with respect to the emitter by voltage VG, with gateemitter voltage greater than the threshold voltage VGET of IGBT. By using n+ emitter regions, this n-channel short circuits the n-region. Through the n-channel, electrons from the n+ emitter start to move toward the ndrift region. IGBT is forward biased, meaning that the n-drift area is injected with holes by the p+ collector region, which is positive, while the emitter is negative. To put it simply, holes from the p+ collector area and electrons from the p-body region flood the n-drift region. As a consequence, the conductivity of the n-region greatly improves and the injection carrier density in the n-drift area rises noticeably. As a result, IGBT activates and starts conducting IC forward current.

## 6.PULSE WIDTH MODULATION

### 6.1 WHAT IS PWM

The best way to switch the power devices of the solar system controller and ensure consistent voltage battery charging is to use pulse width modulation, or PWM. When using PWM regulation, the solar array's current tapers based on the state of the battery and the necessity for recharging. Take a look at a waveform like this one, which shows a voltage transitioning between 0 and 12 volts. It should be very evident that a "suitable device" attached to its output would observe the average voltage and believe it is being fed 6v, or precisely half of 12v, as the voltage is at 12v for exactly the same amount of time as it is at 0v. Therefore, we may adjust the 'average' voltage by changing the positive pulse's width.

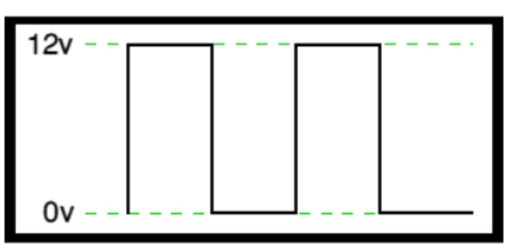


Fig.4.1 Average voltage exactly half of 12v

Similarly, as fig. 4.2 below illustrates, the average voltage will be 3/4 of 12 volts, or 9 volts, if the switches maintain the voltage at 12 for three times as long as at 0 volts.

### 6.1.1 PULSE WIDTH MODULATOR

So, how can a PWM waveform be created? Actually, it's pretty simple; the TEC website has circuits accessible. To begin, create a triangular waveform, as the picture below illustrates. This is contrasted with a d.c. voltage that you may modify to get the desired on/off time ratio. The output rises as the triangle crosses the "demand" voltage. when the voltage of the demand is below the triangle.

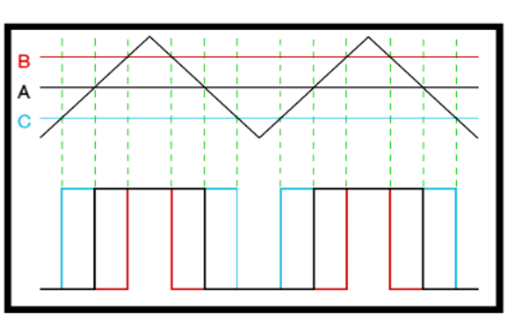


Fig 4.4 Pulse Width modulator Wave form

### 6.1.3 WHY THE PWM FREQUENCY IS IMPORTANT

A huge amplitude digital signal that oscillates between two extremes of voltage is called PWM. Additionally, a lot of filtering is required to smooth out this large voltage variation. Any PWM filter will also smooth down and significantly lower the amplitude of the waveform you make when the PWM frequency is near to the frequency of the waveform you are creating. Therefore, it's a good idea to maintain the PWM frequency far higher than the frequency of any waveform you produce.

### 6.1.4 MOTOR SPEED CONTROL (POWER CONTROL)

Most of the time, changing the voltage to a DC motor is what comes to mind when we consider regulating its speed. This usually involves the use of a variable resistor and offers a limited operational range. For most applications, the torque decreases down quicker than the voltage declines, which limits the working range. Very low voltages are insufficient for most DC motors to function properly. If this procedure is used too slowly, it may potentially lead to the coils overheating and the motor failing eventually.

## 7.PI CONTROLLER

Using just the proportional and integral terms as PI control is one way to implement Proportional Integral Derivative (PID) control. Even more so than complete PID controllers, the PI controller is the most often used version. The modified variable input that is provided into the system is the value of the controller output, u(t).

$e(t)=SP-PV$

$u(t)=u_{bias}+K_c e(t)+\frac{K_c}{\tau_I}\int_0^t e(t)dt$

When the controller is initially switched from manual to automated mode, the value of u(t) is usually assigned to the ubias term, a constant. If the error is zero when the controller is switched on, this results in "bumpless" transmission. A PI controller has two tuning values: the integral time constant (τI) and the controller gain (Kc). A larger value of Kc indicates that the controller will react to mistakes that deviate from the set point more aggressively. Kc is a multiplier on the integral term and proportional error. The goal value is known as the set point (SP), and the measured value that may differ from the intended value is known as the process variable (PV), according to the 55 Department of Electrical and Electronics Engineering. The difference between the SP and PV is the error from the set point, which may be expressed as $e(t)=SP-PV$.

### 7.1 DISCRETE PI CONTROLLER

Discrete sampling periods are used in the implementation of digital controllers, and the integral of the error must be approximated using a discrete variant of the PI equation. In this version, Δt is used as the time interval between sampling instances, and nt is the number of sampling instances. The continuous form of the integral is replaced with a summation of the error.

$u(t)=u_{bias}+K_c e(t)+\frac{K_c}{\tau_I}\sum_{i=1}^{n_t} e_i(t)\Delta t$

### 7.1.1 OVERVIEW OF PI CONTROL

Non-integrating processes—those that ultimately revert to the same output given the same set of inputs and disturbances—require PI control. Process integration works well with a P-only controller. Integral action, which is similar to an adjustable ubias, is utilized to eliminate offset. The ITAE (Integral of Time-weighted Absolute Error) approach and IMC (Internal Model Control) are common tuning correlations for PI control. Lambda tuning is expanded upon by IMC, which takes time delay into consideration. Fitting dynamic input and output data to a first-order plus dead-time (FOPDT) model yields the parameters Kc, τp, and θp. Figure displays the PI speed controller's main block diagram.

### 7.2 ADVANTAGES AND DISADVANTAGES

In contrast to proportional-only control in general, the integral term in a PI controller causes the steady-state error to drop to zero. In the event of noisy data, the absence of derivative action could help the system remain more stable in the steady state. The reason for this is because higher-frequency variables in the inputs have a greater effect on derivative behavior. A PI-controlled system will be longer to achieve its set point and react to disturbances than a well-tuned PID system if derivative action is absent. This is because a PI-controlled system is less sensitive to actual (non-noise) and relatively quick changes in state.

### 7.2.1 INTEGRAL ACTION AND PI CONTROL

Similar to the P-Only controller, the Proportional-Integral (PI) algorithm calculates and sends a controller output (CO) signal to the last control element (such as a valve or variable speed pump) at each sample time, T. The controller error, e(t), and the controller tuning settings have an impact on the calculated CO obtained via the PI method.

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## 8 MAXIMUM POWER POINT TRACKING

The electrical system known as Maximum electricity Point Tracking, or MPPT, helps photovoltaic (PV) modules generate as much electricity as possible by controlling them in this way. The modules are not "physically moved" by the MPPT tracking system to aim more directly toward the sun. The completely electronic MPPT system adjusts each module's electrical operating point to enable it to supply the highest amount of power that is possible. Afterwards, more battery charge current is made available by harvesting more power from the modules. While mechanical tracking systems and MPPT may work together, they are entirely separate technologies.

A fractional voltage across the circuit

The approach is predicated on the finding that there is a virtually constant ratio between the array voltage at maximum power (VMPP) and its open circuit voltage (VOC). It has been observed that this factor, k1, ranges from 0.71 to 0.78. After determining the constant k1, VMPP is calculated by regular VOC measurements. Due to the use of erroneous values for the constant k1 in the VMMP calculation, this method's tracking efficiency is rather poor despite its simple and inexpensive implementation.

B. The Short-Circuit Current Fraction

The approach is based on the observation that the PV array's short circuit current (ISC) and current at maximum power point (IMPP) are roughly linearly correlated. K2 is not constant, just as in the fractional voltage technique. It turns out to be in the range of 0.78 and 0.92. Periodic measurement of short circuit current and K2 accuracy determine tracking efficiency and technique accuracy.

C. Disturb and Watch

The MPPT algorithm in the P&O technique is based on calculating the PV output power and power change by sampling the PV voltage and current. The solar array voltage is regularly increased or decreased by the tracker. A further perturbation is created in the same (opposite) direction if the previous perturbation causes the output power of the PV to rise (reduce). This is the case for 60 Department of Electrical and Electronics Engineering. Consequently, the dc chopper's duty cycle is adjusted, and the procedure is repeated until the maximum power point is attained. The system really oscillates around the MPP. The oscillation may be reduced by reducing the size of the perturbation step. Small step sizes, however, cause the MPPT to lag. A variable perturbation size that decreases with proximity to the MPP is needed to tackle this issue.

D. Steady Conductance

The technique is predicated on the idea that at the greatest power point, the PV array power curve's slope is zero. (dP/dV) is equal to 0. Due to (P = VI), it results in: By comparing the incremental conductance (ΔI/ΔV) and the instantaneous conductance (I/V), the MPP may be monitored. The array reference voltage is increased or decreased by the algorithm until the requirement of equation (4.a) is met. The PV array continues to operate at this stage after the Maximum power is attained. High sample rates and quick power slope computations are necessary for this strategy.

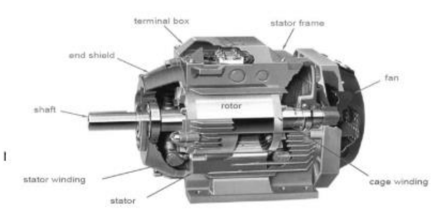
## 9.INDUCTION MOTOR

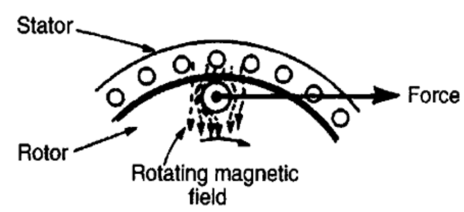
### INTRODUCTION OF INDUCTION MOTOR:

An asynchronous AC motor that uses electromagnetic induction to power its spinning element is known as an induction motor (IM). Because the rotor bars with short circuit rings resemble a squirrel cage (hamster wheel), the motor is also sometimes referred to as a squirrel cage motor. Through its rotor, an electric motor transforms electrical power into mechanical power. There are several methods for supplying the rotor with electricity. In an induction motor, the power is induced inside the spinning unit, while in a DC motor, the power is directly delivered to the armature from a DC source. Because the rotor, or revolving component, is the secondary side of the transformer and the stator, or stationary part, is basically the main side, an induction motor is frequently referred to as a rotating transformer. Induction motors have extensive use, particularly in industrial drives where polyphase induction motors are often employed.

### INDUCTION MOTOR GENERAL PRINCIPLE

Typically, an electrical motor's spinning components are where electrical power is converted into mechanical power. A dc motor is referred to as a conduction motor because the electrical power is directly conducted in the armature, or rotating part, of the motor through brushes or commutates. In contrast, an induction motor obtains its power through induction rather than conduction, much like the secondary of a two-winding transformer receives its power from the primary. This is the reason an induction motor is so named.



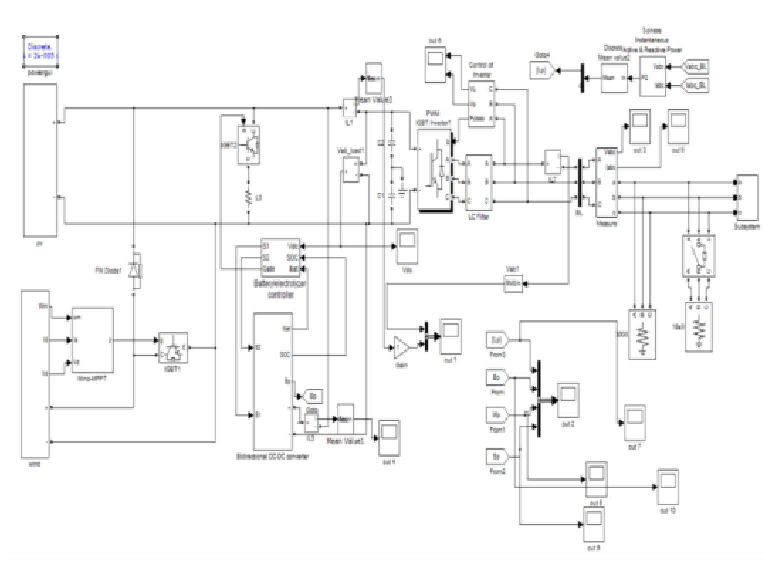

**TYPES OF ROTORS: Rotors** with squirrel cages A squirrel-cage rotor is the most often used kind. It is composed of bars that run the length of the rotor and are joined at either end by rings. The bars are constructed of aluminum or solid copper, which is the most popular kind. In order to lower noise and harmonics, the rotor bars of squirrel-cage induction motors are slightly skewed rather than straight.

ROTOR WITH SLIP RING

The bars of a squirrel-cage rotor are swapped out for windings attached to slip rings in a slip ring rotor. These slip rings may also be linked to resistors to provide a high-resistance rotor circuit, which can be helpful in beginning; when these rings are shorted, the rotor functions similarly to a squirrel-cage rotor.

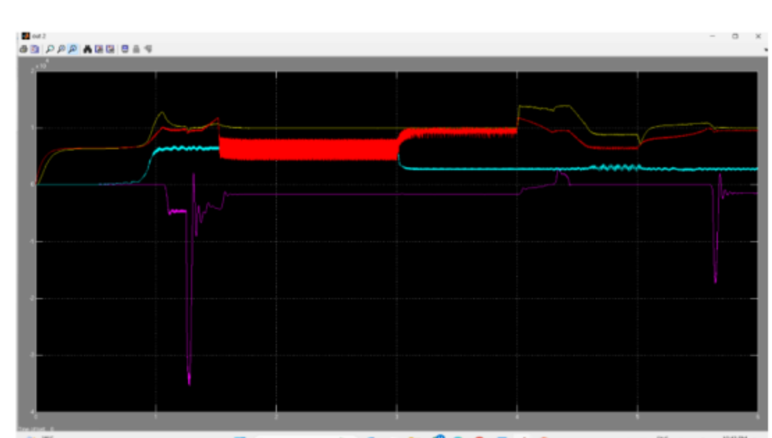
## 10 MATLAB & SIMULATION RESULTS

### 10.1 SIMULATION CIRCUIT

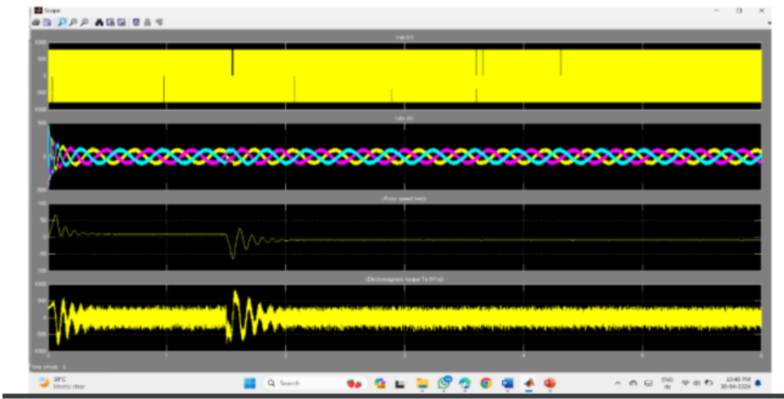


### 10.2 SIMULATION RESULTS

1. Output simulation waveforms of Battery, Solar, Wind, and load



2. Motor Phase Current and Phase Voltage, Motor Speed, and Electromagnetic Torque



## 11. CONCLUSION

This paper presents a novel battery/photovoltaic/wind hybrid power source that can replace a plug-in hybrid electric vehicle's gasoline-powered internal combustion engine. It consists of a small-sized photovoltaic module mounted on the roof of the vehicle and a micro wind turbine situated in front of the vehicle, behind the air conditioning system's condenser. In order to increase the PHEV's cruising range, two clean, renewable energy sources—solar and wind—have been used. The hybrid power source uses a battery as the primary energy storage device, a PV module, and a WECS that includes the tiny wind turbine. It also has V2G functionality. The battery/photovoltaic/wind hybrid power source prototype has been constructed. Ultimately, the findings of the simulation and the experiment are achieved. It was shown that a PHEV's cruise range may be increased by 19.6 km by using the PV module and mini wind turbine. It offers a high power efficiency and speed for two sunny days. Additionally, it was shown that the power source high uses the PWM approach to precisely control the DC-link voltage and provide the right stator currents for the traction motor. 67 Electrical & Electronics Engineering Department

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