# DR. AKHILESH DAS GUPTA INSTITUTE OF TECHNOLOGY AND MANAGEMENT, NEW DELHI

## (Formerly Northern India Engineering College)

**DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING**

**Renewable Energy Resources LAB [ETEE – 419]**

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# EXPERIMENT 1

**Aim -** To find and study the output of a PV system using MATLAB

**Software used -** MATLAB R2020b

## Theory:

Solar photovoltaic generation system are becoming increasingly important as renewable energy source since it offers many advantages such as incurring no fuel costs, not being polluting, requiring little maintenance, and emitting no noise, among others. The building block of PV arrays is the solar cell, which is basically a p–n semiconductor junction. When photons of light fall on the cell, they transfer their energy to the charge carriers. The electric field across the junction separates photo•generated positive charge carriers (holes) from their negative counterpart (electrons). In this way an electrical current is extracted once the circuit is closed on an external load

**INTRODUCTION :**

PV cell is basically a single p•n junction semiconductor diode. When illuminated by sunlight it generates electricity by the phenomenon of photoelectric effect. The power produced by a single PV cell is not enough for general use. So by integrating number of PV cells in series and in parallel will provide desired power which is termed as PV module. A PV array is an interconnection of PV modules which in turn is made up of PV cells in series and parallel.

Here we are performing the basic simulation and study of a simple pv cell,
which comprising of a simple current source and a set of parallel resistance.

## MATLAB Code -

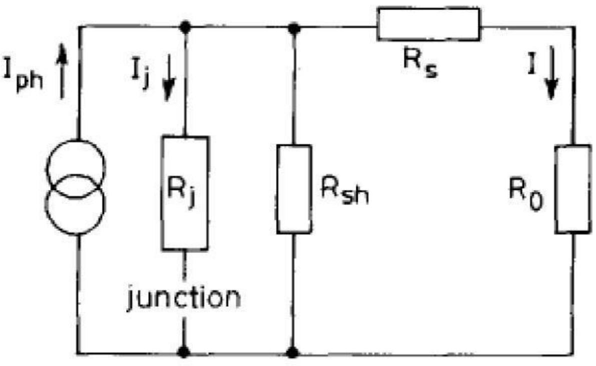
```
T=28+273;
Tr1=40;
Tr=((Tr1-32))+273;
%S=[100 80 60 40 20];
S=100;
Ki=0.00023;
Iscr=3.75;
Irr=0.000021; K=1.38065*10^(-23);
q=1.6022*10^(-19);
A=2.15;Ego=1.166;
alpha=0.473;
beta=636;
Eg=Ego-(alpha*T*T)/(T+beta)*q;
Np=4;
Ns=60;
Vo=[0:1:300]; for
i=1:1
    Iph=(Iscr+Ki*(T-Tr))*((S(i))/100);
    Irs=Irr*((T/Tr)^3)*exp(q*Eg/(K*A)*((1/Tr)-(1/T)));
```

```
Io=Np*Iph-Np*Irs*(exp(q/(K*T*A)*Vo./Ns)-1);
Po=Vo.*Io;
figure(1);
plot(Vo,Io)
axis([0 50 0 20]);
xlabel('voltlage in volts')
ylabel( 'current in amp' )
hold on ;
figure(2);
plot(Vo,Po)
axis([0 50 0 400]);
xlabel('voltage in volts')
ylabel( 'power in watts')
hold on ;
figure(3)
plot(Io,Vo)
axis([0 20 0 400])
xlabel( 'current in amp')
ylabel( 'power in watts' )

end
```

## PROCEDURE:

The building block of PV arrays is the solar cell, which is basically a p•n junction that directly converts light energy into electricity: it has a equivalent circuit as shown below in Figure




An ideal PV cell is modelled by a current source in parallel with a diode. However no solar cell is ideal and thereby shunt and series resistances are added to the model as shown in the PV cell diagram above. RS is the intrinsic series resistance whose value is very small. RP is the equivalent shunt resistance which has a very high value.

Applying Kirchoff's law to the node where Iph, diode, Rp and Rs meet, we get
$Iph=I\ J +I_{RP} +I$

We get the following equation for the photovoltaic current: I= Iph•I RP •I J

$I = Iph - Io.[exp(V+IRs/V_T)* \bullet 1] - [(V+IRs)/R_P]$

Where, Iph is the Insolation current, I is the Cell current, I0 is the Reverse saturation current, V is the Cell voltage, Rs is the Series resistance, Rp is the Parallel resistance, VT is the Thermal voltage , K is the Boltzman constant, T is the Temperature in Kelvin, q is the Charge of an electron .

The current source Iph represents the cell photo current; Rj is used to represent the non-linear impedence of the p-n junction; Rsh and Rs are used to represent the intrinsic series and shunt resistance of the cell respectively. Usually the value of Rsh is very large and that of Rs is very small,hence they may be neglected to simplify the analysis. PV cells are grouped in larger units called PV modules which are further interconnected in series•parallel configuration to form PV arrays or PV generators.The PV mathematical model used to simplify our PV array is represented by the equation:

I=np *Iph•np*Irs[exp([ q/KTA]*[ v /ns ]) •1]

where I is the PV array output current; V is the PV array output voltage; ns is the number of cells in series and np is the number of cells in parallel; q is the charge of an electron; k is the Boltzmann's constant; A is the p-n junction ideality factor; T is the cell temperature (K); Irs is the cell reverse saturation current. The factor A in equation determines the cell deviation from the ideal p-n junction characteristics; it ranges between 1-5 but for our case A=2.46

The cell reverse saturation current Irs varies with temperature according to the following equation:

$Irs=Irr *[T/Tr]^3* exp( [ qEg/Ka[1/Tr \bullet 1/T])$

Where Tr is the cell reference temperature, Irr is the cell reverse saturation temperature at Tr and EG is the band gap of the semiconductor used in the cell.
The temperature dependence of the energy gap of the semi conductor is given by:

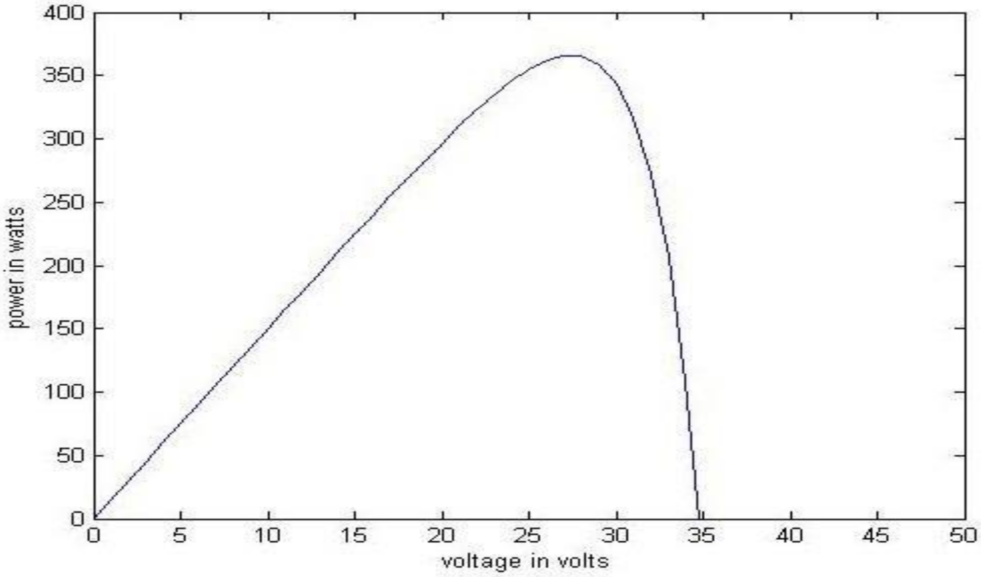
$EG= EG(0) - \alpha T^2 /T+\beta$
The photo current Iph depends on the solar radiation and cell temperature as follows: Iph=[ Iscr + Ki(T – Tr)] *S/100

where Iscr is the cell short•circuit current at reference temperature and radiation, Ki is the short circuit current temperature coefficient, and S is the solar radiation in mW/cm2. The PV power can be calculated using equation (3.5) as follows:

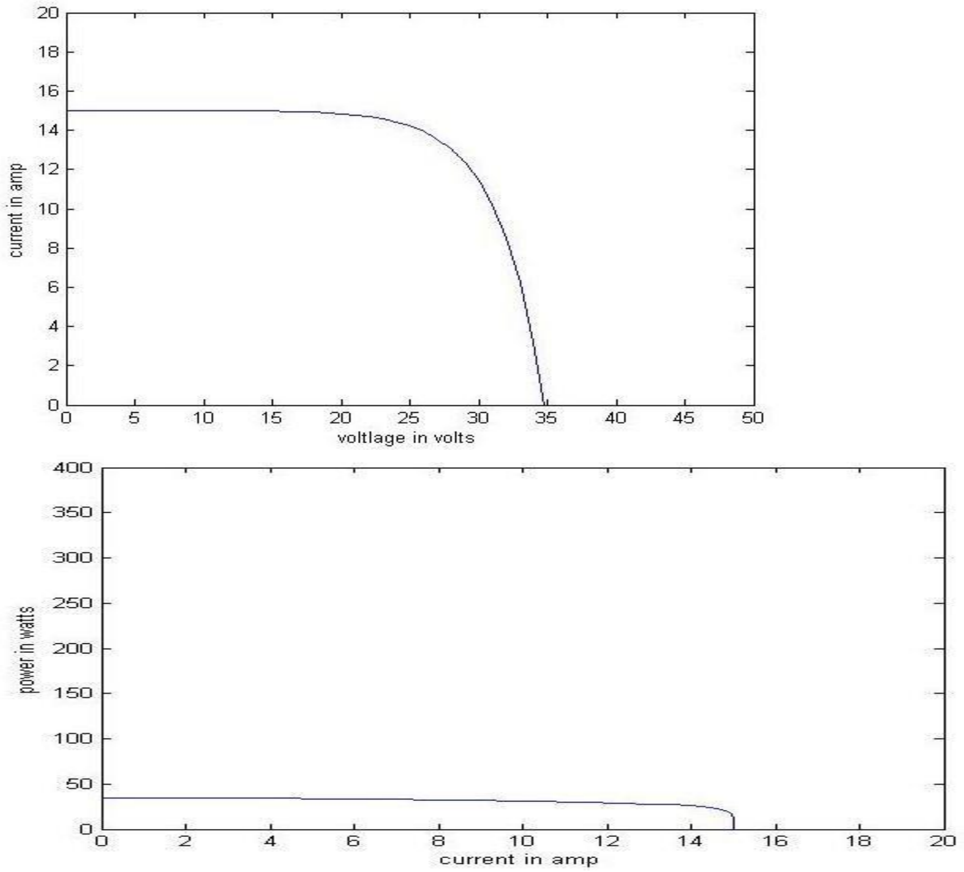
P=IV= npIphV[(q/KTA *v/Ns )•1]

## Output -

**a).**


power in watts
voltage in volts
0 50 100 150 200 250 300 350 400
0 5 10 15 20 25 30 35 40 45 50

**b).**


current in amp
voltlage in volts
0 2 4 6 8 10 12 14 16 18 20
0 5 10 15 20 25 30 35 40 45 50
power in watts
current in amp
0 50 100 150 200 250 300 350 400
0 2 4 6 8 10 12 14 16 18 20

**Conclusion -** The current to voltage characteristic of a solar array is non•linear, which makes it difficult to determine the MPP. The Figure below gives the characteristic I•V and P•V curve for fixed level sola irradiation and temperature.

The IV and PV curves for various irradiance but a fixed temperature (250C) is shown below in Figures ...The characteristic I•V curve tells that there are two regions in the curve: one is the current source region and another is the voltage source region. In the voltage source region (in the right side of the curve), the internal impedance is low and in the current source region (in the left side of the curve), the impedance is high. Irradiance temperature plays an important role in predicting the I•V characteristic, and effects of both factors have to be considered while designing the PV system. Whereas the irradiance affects the output, temperature mainly affects the terminal voltage. The figures give the simulated I•V and P•V characteristic for various temperatures at a fixed irradiance at 1000 W/m2

# EXPERIMENT 2

**Aim -** To find and study the output of a WEC system using MATLAB Simulink.

**Software used -** MATLAB R2020b

## Theory

Wind electric generator converts kinetic energy available in wind to electrical energy. The wind turns the blades of a windmill•like machine. The rotating blades turn the shaft to which they are attached. The turning shaft typically can either power a pump or turn a generator, which produces electricity. The amount of energy produced by a wind machine depends upon the wind speed and the size of the blades in the machine. In general, when the wind speed doubles, the power produced increases eight times. Larger blades capture more wind. As the diameter of the circle formed by the blades doubles, the power increases four times.

The fundamental equation governing the mechanical power capture of the wind turbine rotor blades, which drives the electrical PM generator, is given by

$$P=1/2 \ \rho A C p v^3$$

where ρ is the air density (kg/m3), A is the area swept by the rotor blades, V is the air velocity (m/s), Cp represents the power coefficient of the wind turbine. Therefore, if the air density, swept area and wind speed are assumed constant the output power of the wind turbine will be a function of the power coefficient. The wind turbine is normally characterized by its Cp–TSR characteristic.

where the TSR is the tip•speed ratio and is given by

$$TSR = \omega \ mR/V$$

R and ω m are the turbine radius and the mechanical angular speed, respectively and V is the wind speed. The power coefficient has its maximum value at the optimal value of the tip•speed ratio (TSRopt) which results in optimum efficiency of the wind turbine and capture of maximum available wind power by the turbine.

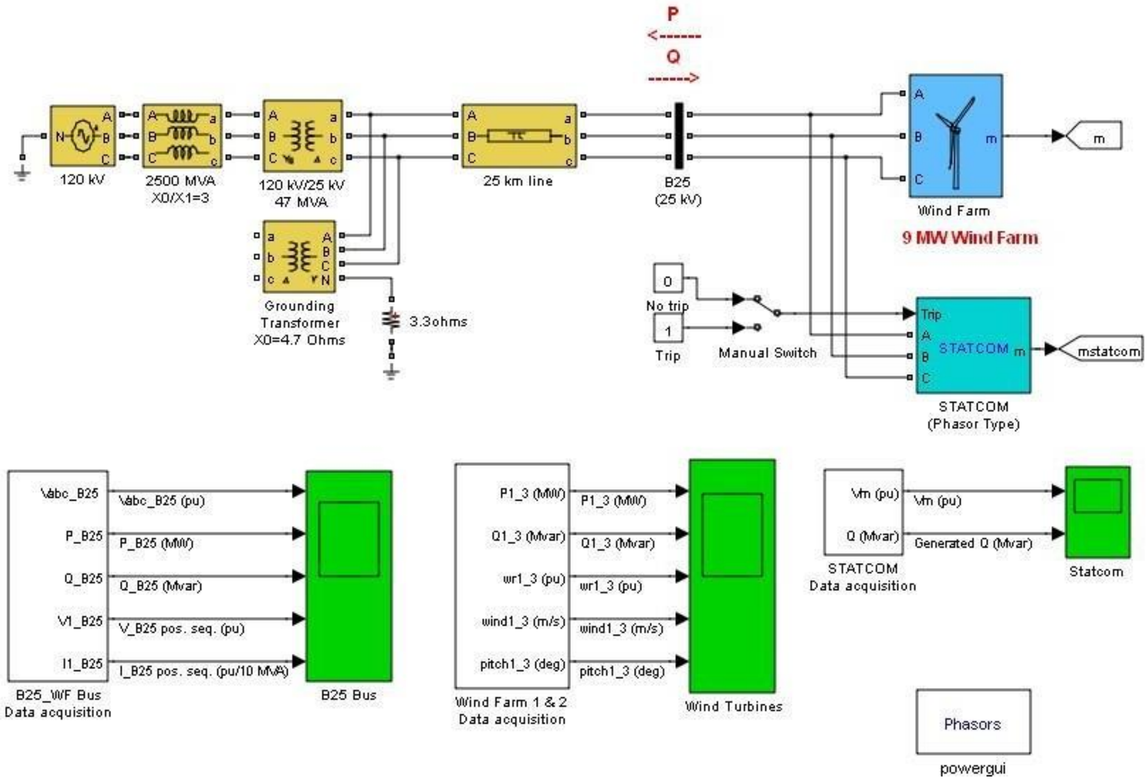
$$\omega \ opt = TSR \ opt \ v/ \ R$$

ω opt is the optimum speed of the rotor.

**INTRODUCTION:**

A wind farm consisting of six 1.5•MW wind turbines is connected to a 25•kV distribution system exports power to a 120•kV grid through a 25•km 25•kV feeder. The 9•MW wind farm is simulated by three pairs of 1.5 MW wind•turbines. Wind turbines use squirrel•cage induction generators (IG). The stator winding is connected directly to the 60 Hz grid and the rotor is driven by a variable•pitch wind turbine. The pitch angle is controlled in order to limit the generator output power at its nominal value for winds exceeding the nominal speed (9 m/s). In order to generate power the IG speed must be slightly above the A synchronous speed. Speed varies approximately between 1 pu at no load and 1.005 pu at full load. Each wind turbine has a protection system monitoring voltage, current and machine speed.

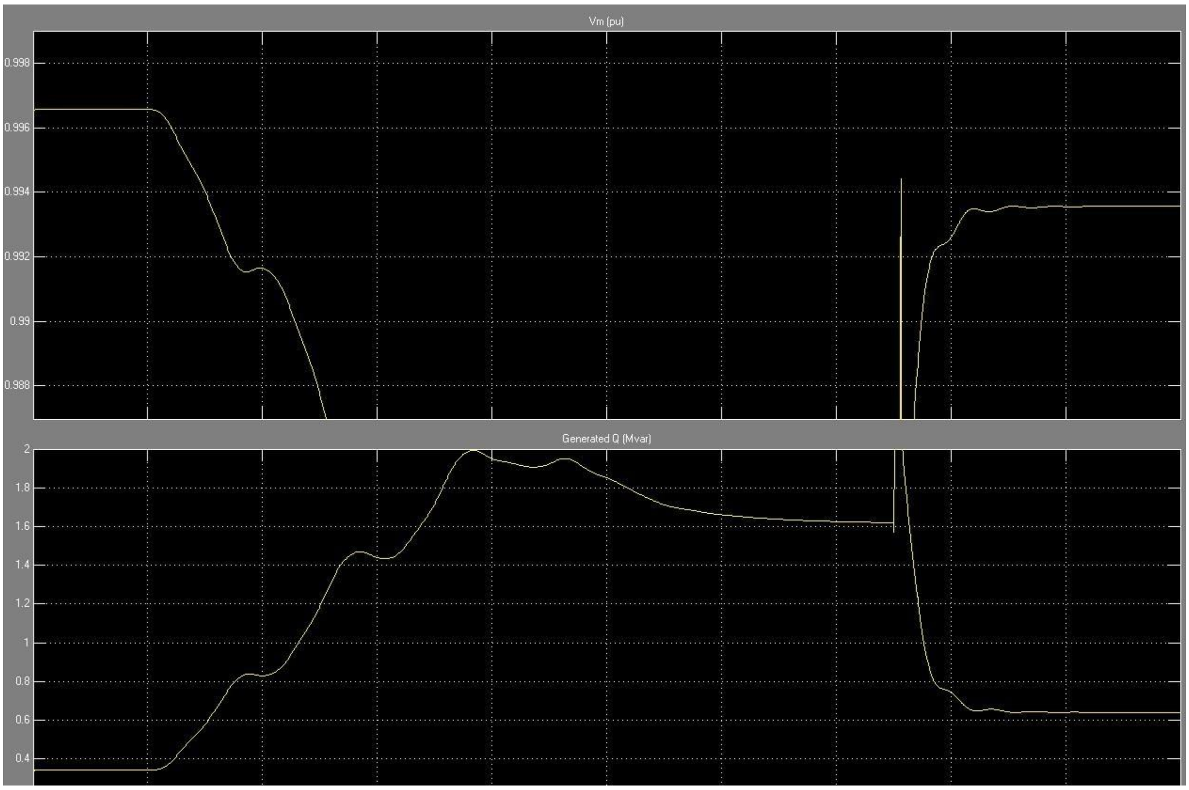
Reactive power absorbed by the IGs is partly compensated by capacitor banks connected at each wind turbine low voltage bus (400 kvar for each pair of 1.5 MW turbine). The rest of reactive power required to maintain the 25•kV voltage at bus B25 close to 1 pu is provided by a 3•Mvar STATCOM with a 3% droop setting.




# PROCEDURE:

A wind farm simulation system of the above-described type is to be modelled, simulated and obtain the voltage output of the system .

## **Result:**


Vm (pu)
0.998
0.996
0.994
0.992
0.99
0.988
Generated Q (Mvar)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4

# EXPERIMENT 3

**AIM -** To study the functioning of a fuel cell in the form distributed energy source.

## Theory

A fuel cell is an electrochemical device that converts a source fuel into electrical current. It generates electricity through reactions between a fuel and an oxidant, triggered in the presence of an electrolyte. The reactants flow into the cell and the reaction products flow out of it, while the electrolyte remains within it. Fuel cells can operate continuously as long as the necessary reactant and oxidant flows are maintained. They can perform as a storage energy device and also as a backup energy source.

Fuel cells are different from conventional batteries in that, after many charges and discharges the battery loses capacity to the point where the user has to discard it. Fuel cell does not cause any pollution in the atmosphere.

DESIGN AND WORKING OF FUEL CELL:

Fuel cell are made up of three segments which are sandwiched together: the anode, the electrolyte and the cathode. Two chemical reactions occur at the interfaces of the three different segments. The net result of two reactions is that the fuel is consumed, water or carbon dioxide is created, and electrical current is created, which can be used to power electrical devices, normally referred to as load.

At the anode a catalyst oxidizes fuel, usually hydrogen, turning the fuel into a positively charged ion and negatively charged electron. The electrolyte is a substance specifically designed so ions can pass through it, but the electrons cannot. The freed electrons travel through external wire creating electric current. The ions travel through the electrolyte to the cathode. Once reaching the cathode, the ions are united with the electrons and the two react with a third element, usually oxygen, to create water or carbon dioxide.

The most important design features in a fuel cell are:

- The electrolyte substance. The electrolyte substance usually defines the type of fuel cell.
- The fuel that is used. The most common fuel used is hydrogen.
- The anode catalyst, which breaks down the fuel into electrons and ions. The anode catalyst is usually made up of very fine platinum powder.
- The cathode catalyst, which turns the ions into water or carbon dioxide. The cathode catalyst is often made up of nickel.

A typical fuel cell produces voltage from 0.6 V to 0.7 V at full rated load. Voltage decreases as current increases, due to several factors:

- Activation loss
- Ohmic loss (voltage drop due to resistance of the cell components and interconnections)
- Mass transport loss (depletion of reactant at catalyst sites under high loads, causing rapid loss of voltage).

To deliver the desired amount of energy, the fuel cells can be combined in series and in parallel connections, where series yields higher voltage, and parallel allows a higher current to be supplied. Such a design is called a fuel cell stack. Further, the cell surface area can be increased, to allow stronger current from each cell.

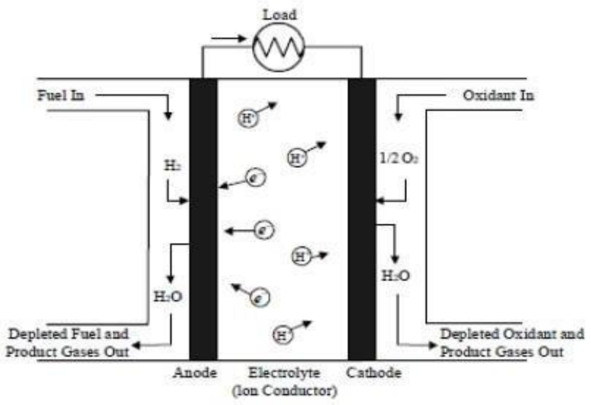
The different types of fuel cells are

- Proton Exchange Membrane Fuel Cell
- Solid Oxide Fuel Cell
- Molten Carbonate Fuel Cell

Proton Exchange Membrane Fuel Cell

In hydrogen–oxygen proton exchange membrane fuel cell (PEMFC) design, a proton•conducting polymer membrane, (the electrolyte), separates the anode and cathode sides. On the anode side, hydrogen diffuses to the anode catalyst where it later dissociates into protons and electrons. The protons often react with oxidants causing them to become what is commonly referred to as multi•fabricated proton membranes. The protons are conducted through the membrane to the cathode, but the electrons are forced to travel in an external circuit (supplying power) because the membrane is electrically insulating. On the cathode catalyst, oxygen molecules react with the electrons and protons to form water•in this example, the only waste product, either liquid or vapour.

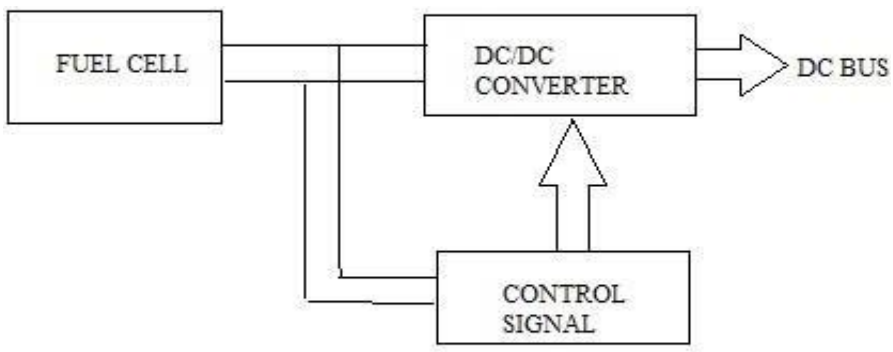
Application circuit for fuel cell is shown in Figure.The electrodes are a porous cathode and anode located on either side of the electrolytic layer. Gaseous fuel usually hydrogen; is fed continuously to the anode and oxidant; oxygen from air; is fed to the cathode as shown. When hydrogen is passed across anode in the presence of a catalyst, hydrogen separates into protons and electrons. The electrons pass through an external circuit as a current while the protons goes through the electrolyte. The electrons coming back from the external circuit combines with protons and oxygen to produce water and heat. It can be said that the hydrogen fuel is combined with oxygen to produce electricity




Application circuit for Fuel cells

CONTROL OF FUEL CELL SYSTEM:

One of the main weak points of FC among others is its time constant dominated by fuel delivery systems (pumps, valves, compressors).As a consequent, fast load demand will cause a high voltage drop in a short time, which well known as fuel starvation phenomena and is evidently harmful for FC. Slope limitation to a maximum absolute value of some amperes per second enables safe operation of the FC, even during transient power demand. The output power thus obtained from the fuel cell is also fed to a dc•dc boost converter which is controlled using the slope limitation technique is shown in Figure.




Block diagram for FC application circuit

## RESULT

The working and features of a fuel cell model is studied.

# EXPERIMENT 4

**Aim -** To study production and storage of Hydrogen energy

**THEORY:**

Hydrogen can be produced from a variety of feedstocks. These include fossil resources, such as natural gas and coal, as well as renewable resources, such as biomass and water with input from renewable energy sources (e.g. sunlight, wind, wave or hydro•power). A variety of process technologies can be used, including chemical, biological, electrolytic, photolytic and thermo•chemical. Each technology is in a different stage of development, and each offers unique opportunities, benefits and challenges. Local availability of feedstock, the maturity of the technology, market applications and demand, policy issues, and costs will all influence the choice and timing of the various options for hydrogen production.Based on the form of hydrogen available it can be stored in different ways.

Methods of Hydrogen Production :

- Produced from fossil fuels:

Hydrogen can be produced from most fossil fuels.The complexity of the processes varies and feasibility of the processes will vary with respect to a centralised or distributed production plant.

- Production from natural gas :

Hydrogen can currently be produced from natural gas by means of three different chemical processes:

- Steam reforming (steam methane reforming – SMR).
- Partial oxidation (POX).
- Autothermal reforming (ATR)

Steam reforming involves the endothermic conversion of methane and water vapour into hydrogen and carbon monoxide. The heat is often supplied from the combustion of some of the methane feed gas.

Partial oxidation of natural gas is the process whereby hydrogen is produced through the partial combustion of methane with oxygen gas to yield carbon monoxide and hydrogen. In this process, heat is produced in an exothermic reaction, and hence a more compact design is possible as there is no need for any external heating of the reactor

Autothermal reforming is a combination of both steam reforming and partial oxidation.The total reaction is exothermic, and so it releases heat. Again, the CO produced is converted to H2 through the water•gas shift reaction. The need to purify the output gases adds significantly to plant costs and reduces the total efficiency.

- Production from coal :

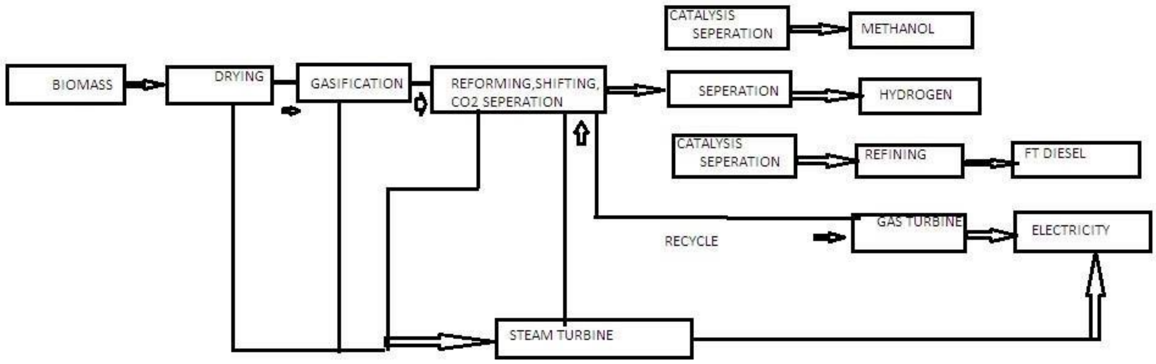
Hydrogen can be produced from coal through a variety of gasification processes (e.g. fixed bed, fluidised bed or entrained flow). Since this reaction is endothermic, additional heat is required, as with methane reforming. The CO is further converted to CO2 and H2 through the water•gas shift reaction. Hydrogen production from coal is commercially mature, but it is more complex than the production of hydrogen from natural gas. The cost of the resulting hydrogen is also higher. But since coal is plentiful in many parts of the world and will probably be used as an energy source regardless, it is worthwhile to explore the development of clean technologies for its use.

- Hydrogen From Splitting Of Water:

Hydrogen can be produced from the splitting of water through various processes. Few to mention are water electrolysis, photo•electrolysis, photo•biological production and high•temperature water decomposition.

- Biomass To Hydrogen :

In biomass conversion processes, a hydrogen•containing gas is normally produced in a manner similar to the gasification of coal. However, no commercial plants exist to produce hydrogen from biomass. Currently, the pathways followed are steam gasification (direct or indirect), entrained flow gasification, and more advanced concepts such as gasification in supercritical water, application of thermo•chemical cycles, or the conversion of intermediates




Hydrogen STORAGE

An overview of the three principal forms of hydrogen storage (gas, liquid, and solid), with various approaches is as follows.

- Gaseous Hydrogen

The most common method to store hydrogen in gaseous form is in steel tanks,

Although lightweight composite tanks designed to endure higher pressures are also becoming more and more common. Cryogas, gaseous hydrogen cooled to near cryogenic temperatures, is another alternative that can be used to increase the

volumetric energy density of gaseous hydrogen. A more novel method to store hydrogen gas at high pressures is to use glass microspheres.

- Liquid Hydrogen The most common way to store hydrogen in a liquid form is to cool it down to cryogenic temperatures (–253 °C). Other options include storing hydrogen as a constituent in other liquids, such as $NaBH_4$ solutions, rechargeable organic liquids, or anhydrous ammonia $NH_3$.

- Solid Hydrogen

Storage of hydrogen in solid materials has the potential to become a safe and efficient way to store energy, both for stationary and mobile applications. There are four main groups of suitable materials: carbon and other high surface area materials; $H_2O$-reactive chemical hydrides; thermal chemical hydrides; and rechargeable hydrides.

Comparisons between the three basic storage options shows that the potential advantages of solid $H_2$•storage are more compared to gaseous and liquid hydrogen storage in terms of Lower volume, Lower pressure (greater energy efficiency)& Higher purity $H_2$ output. Compressed gas and liquid storage are the most commercially viable options today, but completely cost•effective storage systems have yet to be developed.

**RESULT:** Study of methods of Production and Storage of Hydrogen Energy has been made.

# EXPERIMENT 5

**Aim**: FAMILIARIZATION WITH RENEWABLE ENERGY GADGETS

## Theory:

### RENEWABLE ENERGY

Renewable energy sources also called non-conventional energy, are sources that are continuously replenished by natural processes. For example, solar energy, wind energy, bioenergy bio-fuels grown sustain ably), hydropower etc., are some of the examples of renewable energy sources A renewable energy system converts the energy found in sunlight, wind, fallingwater, sea waves, geothermal heat, or biomass into a form, we can use such as heat or electricity. Most of the renewable energy comes either directly or indirectly from sun and wind and can never be exhausted, and therefore they are called renewable.

### Various forms of renewable energy

1. Solar energy
2. Wind energy
3. Bio energy and Biofuel
4. Hydro energy
5. Geothermal energy
6. Wave and tidal energy

### 1. Solar energy

Solar energy is the most readily available and free source of energy since prehistoric times. India receives solar energy in the region of 5 to 7 $kWh/m^2$ for 300 to 330 days in a year. This energy is sufficient to set up 20 MW solar power plant per square kilometre land area.

Solar energy can be utilised through two different routes, as solar thermal route and solar electric (solar photovoltaic) routes. Solar thermal route uses the sun's heat to produce hot water or air, cook food, drying materials etc. Solar photovoltaic uses sun's heat to produce electricity for lighting home and building, running motors, pumps, electric appliances, and lighting.

### 2. Wind energy

Wind energy is basically harnessing of wind power to produce electricity. The kinetic energy of the wind is converted to electrical energy. When solar radiation enters the earth's atmosphere, different regions of the atmosphere are heated to different degrees because of earth curvature. This heating is higher at the equator and lowest at the poles. Since air tends to flow from warmer to cooler regions, this causes what we call winds, and it is these airflows that are harnessed in windmills and wind turbines to produce power.

## 3. Bio energy

Biomass is a renewable energy resource derived from the carbonaceous waste of various human and natural activities. It is derived from numerous sources, including the by-products from the wood industry, agricultural crops, raw material from the forest, household wastes etc.

**Biofuel:** Unlike other renewable energy sources, biomass can be converted directly into liquid fuels—biofuels—for our transportation needs (cars, trucks, buses, airplanes, and trains). The two most common types of biofuels are ethanol and biodiesel.

Ethanol is an alcohol, similar to that used in beer and wine. It is made by fermenting any biomass high in carbohydrates (starches, sugars, or celluloses) through a process similar to brewing beer. Ethanol is mostly used as a fuel additive to cut down a vehicle's carbon monoxide and other smog-causing emissions. Flexible-fuel vehicles, which run on mixtures of gasoline and up to 85% ethanol, are now available.

Biodiesel, produced by plants such as rapeseed (canola), sunflowers and soybeans, can be extracted and refined into fuel, which can be burned in diesel engines and buses. Biodiesel can also made by combining alcohol with vegetable oil, or recycled cooking greases. It can be used as an additive to reduce vehicle emissions (typically 20%) or in its pure form as a renewable alternative fuel for diesel engines.

## 4. Hydro energy

The potential energy of falling water, captured and converted to mechanical energy by waterwheels, powered the start of the industrial revolution. Wherever sufficient head, or change in elevation, could be found, rivers and streams were dammed and mills were built. Water under pressure flows through a turbine causing it to spin. The Turbine is connected to a generator, which produces electricity.

## 5. Geothermal energy

Geothermal energy is heat derived within the sub-surface of the earth. Water and/or steam carry the geothermal energy to the Earth's surface. Depending on its characteristics, geothermal energy can be used for heating and cooling purposes or be harnessed to generate clean electricity. However, for electricity, generation high or medium temperature resources are needed, which are usually located close to tectonically active regions.

## 6. Tidal and Ocean Energy

Tidal electricity generation involves the construction of a barrage across an estuary to block the incoming and outgoing tide. The head of water is then used to drive turbines to generate electricity from the elevated water in the basin as in hydroelectric dams.

Oceans cover more than 70% of Earth's surface, making them the world's largest solar collectors. Ocean energy draws on the energy of ocean waves, tides, or on the thermal energy (heat) stored in the ocean. The sun warms the surface water a lot more than the deep ocean water, and this temperature difference stores thermal energy.

# EXPERIMENT 6

**Aim:** To study about solar lighting

## Theory:

Solar photo-voltaic powered lights called lanterns fig are considered to be alternative solution to village lighting needs. A typical solar lantern consists of small photovoltaic module, alighting device, a high frequency investor, battery charge controller and appropriate housing. During day time, module is placed under the sun and is connected to lantern through cable for charging a typical lantern uses a 10 watt lamp. The expected life of the lamp is 3 to 5 years.

Storage battery is one crucial component in lantern, Recombinant maintenance free absorbed electrotype batteries are being used. The battery has a life of 3 to 5 years. Sealed nickel Cadmium battery is a good option considering their deep discharge characteristics.

It is important to have reliable electronics to operate the lamp and provide suitable protection. A high frequency investor is being used to excite compact fluorescent lamp and a charge controller which protect battery from over charging.

## Solar Street Light

It consists of two photo-voltaic modules, mounting frame, 4m long pole, battery box, tubular type lead-acid battery, charge controller, investor and day light senses fig. Time module sensing is used to switch on lights on the evening. It works for one fluorescent tube lights of 20 watts for whole night.

# EXPERIMENT 7

**Aim:** TO STUDY THE PRODUCTION PROCESS OF BIODIESEL

## Theory:

**Biodiesel**: Biodiesel is a liquid biofuel obtained by chemical processes from vegetable oils or animal fats and an alcohol that can be used in diesel engines, alone or blended with diesel oil. ASTM International (originally known as the American Society for Testing and Materials) defines biodiesel as a mixture of long-chain mono-alkylic esters from fatty acids obtained from renewable resources, to be used in diesel engines.

Blends with diesel fuel are indicated as ‘‘Bx’’, where ‘‘x’’ is the percentage of biodiesel in the blend. For instance, ‘‘B5’’ indicates a blend with 5% biodiesel and 95% diesel fuel; in consequence, B100 indicates pure biodiesel.

**Feedstocks Used in Biodiesel Production**

The primary raw materials used in the production of biodiesel are vegetable oils, animal fats, and recycled greases. These materials contain triglycerides, free fatty acids, and other contaminants depending on the degree of pre-treatment they have received prior to delivery. Since biodiesel is a mono-alkyl fatty acid ester, the primary alcohol used to form the ester is the other major feedstock. Most processes for making biodiesel use a catalyst to initiate the esterification reaction. The catalyst is required because the alcohol is sparingly soluble in the oil phase. The catalyst promotes an increase in solubility to allow the reaction to proceed at a reasonable rate. The most common catalysts used are strong mineral bases such as sodium hydroxide and potassium hydroxide. After the reaction, the base catalyst must be neutralized with a strong mineral acid.

**Typical proportions for the chemicals used to make biodiesel are:**

| | |
|---|---|
| Reactants: | Fat or oil (e.g. 100 kg soybean oil) |
| | Primary alcohol (e.g. 10 kg methanol) |
| Catalyst: | Mineral base (e.g. 0.3 kg sodium hydroxide) |
| Neutralizer: | Mineral acid (e.g. 0.25 kg sulfuric acid) |

**Advantages of the Use of Biodiesel**

1. Renewable fuel, obtained from vegetable oils or animal fats.

2. Low toxicity, in comparison with diesel fuel.
3. Degrades more rapidly than diesel fuel, minimizing the environmental consequences of biofuel spills.
4. Lower emissions of contaminants: carbon monoxide, particulate matter, polycyclic aromatic hydrocarbons, aldehydes.
5. Lower health risk, due to reduced emissions of carcinogenic substances.
6. No sulfur dioxide ($SO_2$) emissions.
7. Higher flash point.
8. May be blended with diesel fuel at any proportion; both fuels may be mixed during the fuel supply to vehicles.
9. Excellent properties as a lubricant.
10. It is the only alternative fuel that can be used in a conventional diesel engine, without modifications.
11. Used cooking oils and fat residues from meat processing may be used as raw materials.

**Disadvantages of the Use of Biodiesel**

1. Slightly higher fuel consumption due to the lower calorific value of biodiesel.
2. Slightly higher nitrous oxide (NOx) emissions than diesel fuel.
3. Higher freezing point than diesel fuel. This may be inconvenient in cold climates.
4. It is less stable than diesel fuel, and therefore long-term storage (more than six months) of biodiesel is not recommended.
5. May degrade plastic and natural rubber gaskets and hoses when used in pure form, in which case replacement with Teflon components is recommended.
6. It dissolves the deposits of sediments and other contaminants from diesel fuel in storage tanks and fuel lines, which then are flushed away by the biofuel into the engine, where they can cause problems in the valves and injection systems. In consequence, the cleaning of tanks prior to filling with biodiesel is recommended.

**It must be noted that these disadvantages are significantly reduced when biodiesel is used in blends with diesel fuel.**

# EXPERIMENT 8

**Aim:** To Study solar Pond

## Theory:

### Principle of operation of solar ponds

A solar pond is a solar energy collector, generally fairly large in size, that looks like a pond. This type of solar energy collector uses a large, salty lake as a kind of a flat plate collector that absorbs and stores energy from the Sun in the warm, lower layers of the pond. These ponds can be natural or man-made, but generally speaking the solar ponds that are in operation today are artificial.

### How they Work

The key characteristic of solar ponds that allow them to function effectively as a solar energy collector is a salt-concentration gradient of the water. This gradient results in water that is heavily salinated collecting at the bottom of the pond, with concentration decreasing towards the surface resulting in cool, fresh water on top of the pond. This collection of salty water at the bottom of the lake is known as the "storage zone", while the freshwater top layer is known as the "surface zone". The overall pond is several meters deep, with the "storage zone" being one or two meters thick.

These ponds must be clear for them to operate properly, as sunlight cannot penetrate to the bottom of the pond if the water is murky. When sunlight is incident on these ponds, most of the incoming sunlight reaches the bottom and thus the "storage zone" heats up. However, this newly heated water cannot rise and thus heat loss upwards is prevented. The salty water cannot rise because it is heavier than the fresh water that is on top of the pond, and thus the upper layer prevents convection currents from forming. Because of this, the top layer of the pond acts as a type of insulating blanket, and the main heat loss process from the storage zone is stopped. Without a loss of heat, the bottom of the pond is warmed to extremely high temperatures - it can reach about 90°C. If the pond is being used to generate electricity this temperature is high enough to initiate and run an organic Rankine cycle engine.

It is vital that the salt concentrations and cool temperature of the top layer are maintained in order for these ponds to work. The surface zone is mixed and kept cool by winds and heat loss by evaporation. This top zone must also be flushed continuously with fresh water to ensure that there is no accumulation of salt in the top layer, since the salt from the bottom layer diffuses through the saline gradient over time. Additionally, a solid salt or brine mixture must be added to the pond frequently to make up for any upwards salt loses.

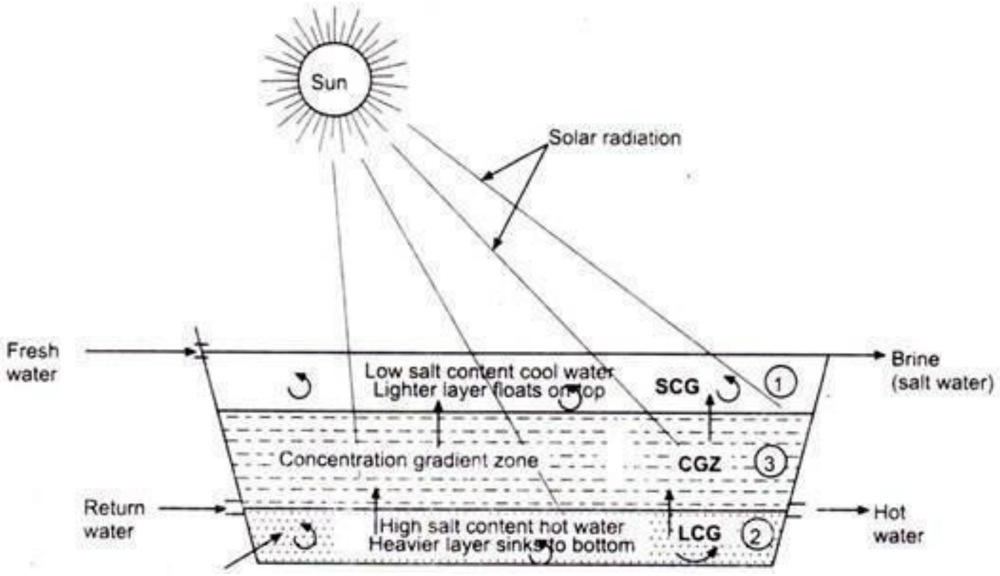
## Applications

The heat from solar ponds can be used in a variety of different ways. First, since the heat storing abilities of solar ponds are so great they are ideal for use in heating and cooling buildings as they can maintain a fairly stable temperature. These ponds can also be used to generate electricity either by driving a thermo-electric device or some organic Rankine engine cycle - simply a turbine powered by evaporating a fluid (in this case a fluid with a lower boiling point). Finally, solar ponds can be used for desalination purposes as the low cost of this thermal energy can be used to remove the salt from water for drinking or irrigation purposes.

## Benefits and Drawbacks

One benefit of using these ponds is that they have an extremely large thermal mass. Since these ponds can store heat energy very well, they can generate electricity during the day when the Sun is shining as well as at night.

Despite being a source of energy, there are numerous thermodynamic limitations as a result of the relatively low temperatures achieved in these ponds. Because of this, the solar-to-electricity conversion is fairly inefficient - generally less than 2%. As well, large amounts of fresh water are necessary to maintain the right salt concentrations all through the pond. This is an issue in places where fresh water is hard to come by, especially in desert environments. These ponds also do not work well at high latitudes as the collection surface is horizontal and cannot be tilted to collect more sunlight.




Solar Pond