A NOVEL CONVERTER TOPOLOGY FOR STAND-ALONE HYBRID PV/WIND/BATTERY POWER SYSTEM USING MATLAB / SIMULINK

A TECHNICAL SEMINAR REPORT

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In

ELECTRICAL AND ELECTRONICS ENGINEERING

By

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Under the Esteemed Guidance of

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DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

BALAJI INSTITUTE OF TECHNOLOGY AND SCIENCE

Accredited by NBA (UG-CE, ME, ECE &CSE),

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(Affiliated to JNTU, Hyderabad & Approved by AICTE, New Delhi) Narsampet, Warangal(R)-506331 (2020-2021)

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CERTIFICATE

This is to certify that the Technical seminar Report entitled with "**A NOVEL CONVERTER TOPOLOGY FOR STAND-ALONE HYBRID PV/WIND/BATTERY POWER SYSTEM USING MATLAB / SIMULINK**" is Bonafide record carried out by **GADHASU AKHIL** bearing Roll No. **18C35A0212** submitted in partial fulfilment of the requirements for the award of the degree of **Bachelor of Technology** in **ELECTRICAL ELECTRONICS ENGINEERING**, in the academic year of 2020-21 to the Jawaharlal Nehru Technological University, Hyderabad, and Telangana. The matter embodied in this report has not been submitted for the award of any other degree.

Co-Ordinator	**Head of the Department**
Mr. G.SRIDHAR	**Mr. S. MALLIKARJUN REDDY**
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I had the privilege to accomplish this Technical seminar presentation of **"A NOVEL CONVERTER TOPOLOGY FOR STAND-ALONE HYBRID PV/WIND/BATTERY POWER SYSTEM USING MATLAB / SIMULINK".**

I desire to convey my sincere thanks to all the Teaching and Non-Teaching staff members of **EEE** for their valuable corrections and comments.

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I am grateful to the management of Balaji Institute of Technology and science for providing all the facilities required for completing this project work.

By

GADHASU AKHIL (18C35A0212)

DECLARATION BY THE STUDENT

I **GADHASU AKHIL (18C35A0212)** hereby declare that the project entitled **"A NOVEL CONVERTER TOPOLOGY FOR STAND-ALONE HYBRID PV/WIND/BATTERY POWER SYSTEM USING MATLAB / SIMULINK"** has submitted in the partial fulfillment of the requirements for the award of Bachelor of Technology, in **Electrical and Electronics Engineering** to **Balaji Institute of Technology & Science**, Narsampet, affiliated to JNTU, Hyderabad is an authentic work and has not been submitted to any other university or institution for award of the degree.

By
GADHASU AKHIL (18C35A0212)

Place: Narsampet
Date:

CERTIFICATE BY THE SUPERVISOR/GUIDE

This is to certify that the above declaration made by the student is correct to the best of my knowledge and belief.

(Mr. G.SRIDHAR)
Assosiate Professor

Place: Narsampet
Date:

ABSTRACT

The objective of this project is to propose a multi-input power converter for the hybrid system that interfaces two unidirectional ports for input power sources, a bidirectional port for a storage element, and a port for output load in a unified structure. The two input ports for simultaneously converting two different input power sources with low voltages to a stable output power with a high voltage. According to various situations, the operational states of the proposed converter can be divided into three states based on battery utilization. In order to ensure that the system operates with high efficiency, this project proposes a power management control scheme, which controls the bidirectional converter operating under boost mode according to the operation condition of the PV/Wind , so that the battery can be charged or discharged. The integration of the hybrid renewable power system is implemented and simulated using MATLAB/SIMULINK.

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1.INTRODUCTION

The use of renewable energy sources as a promising path for replacement of fossil fuels and the development of Power Electronics systems for capitalizing such Energy sources have received renewed interest in the past decade. Many of such sources are mutually complementary in the sense that they can be utilized simultaneously to maintain continuous delivery of power to the load among available renewable energy technologies, Wind and Solar Energy are the most promising options. Although these technologies are improving in various aspects, the drawbacks associated with them, such as their intermittent nature and high capital cost, remain the main obstacles for their utilization. In order to obtain a more consistent energy flow for the user demand, there has been a growing trend to combine the renewable energy sources with Diesel generators, Battery bank, Ultra-capacitors, or Hydrogen production system. A common short-term solution for energy storage is a Battery bank, which offers advantages of high efficiency and fast charge/discharge capacity. Recently, the use of a Multiple-Input Converter (MIC)to replace several single-input converters for reducing complexity and cost of hybrid power systems has attracted increasing attention. MIC is capable of converting power from multiple power sources to a common load. In past literature, a variety of power converter topologies and control methods was proposed to interface hybrid sources to different load In the traditional structure, Multi Input converters based on buck, boost, and buck–boost topologies have been reported in. The main limitation of these configurations is the lack of a bidirectional port to interface storage device. Multiport converters are also constructed out of a multi winding transformer based on half-bridge or full bridge topologies. They can meet isolation requirement and also have bidirectional capabilities. However, the major problem is that they use too many active switches, in addition to the bulky transformer, which cannot justify the unique features of low component count and compact structure for the integrated multiport converter.

In this project, a new three-input DC–DC boost converter is proposed for PV/Wind/Battery power system. The proposed structure utilizes only four power switches that are independently controlled with four different duty ratios. Utilizing these duty ratios facilitates controlling the power flow among the input sources. In comparison with the conventional method of hybridizing three input sources with three-boost cell, the proposed converter can economize in the number of inductors, makes use of low-voltage batteries or super capacitors, works in high-stable-margin operating points and gain access to high-voltage boost factor. As another improvement in our proposed system in comparison with converter represented in, the battery can be charged and discharged through the both power sources individually and simultaneously. Also, four duty ratios of the converter are con-trolled independently, so the restriction of the duty ratios summation is eliminated which results in high level of the output voltage.

2.WIND ELECTRICITY GENERATION

Wind power technology dates back many centuries. There are historical claims that wind machines which harness the power of the wind date back beyond the time of the ancient Egyptians. Hero of Alexandria used a simple windmill to power an organ whilst the Babylonian emperor, Hammurabi, used windmills for an ambitious irrigation project as early as the 17th century BC. The Persians built windmills in the 7th century AD for milling and irrigation and rustic mills similar to these early vertical axis designs can still be found in the region today. In Europe the first windmills were seen much later, probably having been introduced by the English on their return from the crusades in the Middle East or possibly transferred to Southern Europe by the Muslims after their conquest of the Iberian Peninsula. It was in Europe that much of the subsequent technical development took place. By the late part of the 13th century the typical 'European windmill' had been developed and this became the norm until further developments were introduced during the 18th century. At the end of the 19th century there were more than 30,000 windmills in Europe, used primarily for the milling of grain and water pumping.

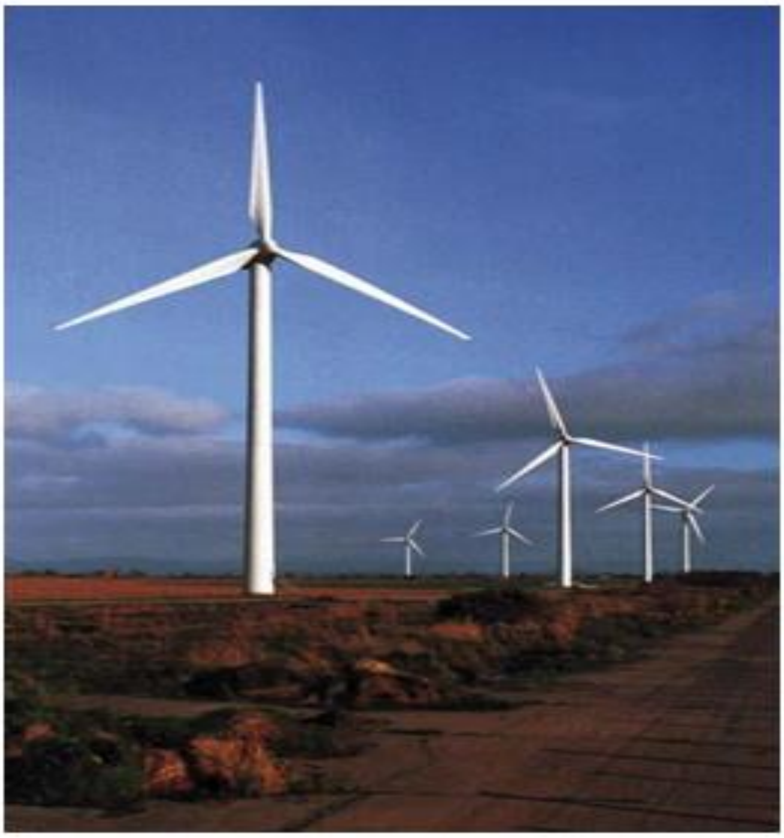

Fig 2.1 Wind Mill

2.1 MODERN WIND GENERATORS

The first wind powered electricity was produced by a machine built by Charles F. Brush in Cleveland, Ohio in 1888. It had a rated power of 12 kW (direct current - dc). Direct current electricity production continued in the form of small-scale, stand-alone (not connected to a grid) systems until the 1930's when the first large scale AC turbine was constructed in the USA. There was then a general lull in interest until the 1970's when the fuel crises sparked a revival in research and development work in North America (USA and Canada) and Europe (Denmark, Germany, The Netherlands, Spain, Sweden and the UK). Modern wind turbine generators are highly sophisticated machines, taking full advantage of state-of-the-art technology, led by improvements in aerodynamic and structural design, materials technology and mechanical, electrical and control engineering and capable of producing several megawatts of electricity. During the 1980's installed capacity costs dropped considerably and wind power has become an economically attractive option for commercial electricity generation. Large wind farms or wind power stations have become a common sight in many western countries. In 2001 Denmark alone had 2000 Megawatts of electricity generating capacity from more than 5,700 wind turbines, representing 14% of their national electricity consumption.

To a lesser degree, there has been a parallel development in small-scale wind generators for supplying electricity for battery charging, for stand-alone applications and for connection to small grids. Table 1 shows the classification system for wind turbines.

Scale	Rotor diameter	Power rating
Micro	Less than 3 m	50 W to 2 kW
Small	3 m to 12 m	2 kW to 40 kW
Medium	12 m to 45 m	40 kW to 999 kW
Large	46 m and larger	More than 1.0 MW

Table 2.1 The classification system for wind turbines

2.2 WIND GENERATION FOR DEVELOPING COUNTRIES

Unlike the trend toward large-scale grid connected wind turbines seen in the West, the more immediate demand for rural energy supply in developing countries is for smaller machines in the 5 - 100 kW range. These can be connected to small, localized micro-grid systems and used in conjunction with diesel generating sets and/or solar photovoltaic systems (see hybrid systems section later in this fact sheet). Currently, the use of wind power for electricity production in developing countries is limited, the main area of growth being for very small battery charging wind turbines (50 - 150 Watts). In Inner Mongolia there are over 30,000 such machines used by herders for providing power for lighting, televisions, radios, etc. (Spera

1994). Other applications for small wind machines include water pumping, telecommunications power supply and irrigation.

2.3 THE POWER IN THE WIND

The wind systems that exist over the earth's surface are a result of variations in air pressure. These are in turn due to the variations in solar heating. Warm air rises and cooler air rushes in to take its place. Wind is merely the movement of air from one place to another. There are global wind patterns related to large scale solar heating of different regions of the earth's surface and seasonal variations in solar incidence. There are also localized wind patterns due the effects of temperature differences between land and seas, or mountains and valleys. Wind speed generally increases with height above ground. This is because the roughness of ground features such as vegetation and houses cause the wind to be slowed.

Wind speed data can be obtained from wind maps or from the meteorology office. Unfortunately the general availability and reliability of wind speed data is extremely poor in many regions of the world. However, significant areas of the world have mean annual wind speeds of above 4-5 m/s (meters per second) which makes small-scale wind powered electricity generation an attractive option. It is important to obtain accurate wind speed data for the site in mind before any decision can be made as to its suitability. Methods for assessing the mean wind speed are found in the relevant texts (see the 'References and resources' section at the end of this fact sheet).

- The power in the wind is proportional to:
  the area of windmill being swept by the wind
  the cube of the wind speed
  the air density - which varies with altitude
  The formula used for calculating the power in the wind is shown below:

$$\text{Power} = \frac{\text{density of air x swept area x velocity cubed}}{2}$$

$$P = ½.\rho.A.V^3$$

where, P is power in watts (W)

ρ is the air density in kilograms per cubic metre (kg/m^3) A is the swept rotor area in square metres (m^2)

V is the windspeed in metres per second (m/s)

The fact that the power is proportional to the cube of the windspeed is very significant. This can be demonstrated by pointing out that if the wind speed doubles then the power in the wind increases by a factor of eight. It is therefore worthwhile finding a site which has a relatively high mean wind speed.

2.4 WIND INTO WATTS

Although the power equation above gives us the power in the wind, the actual power that we can extract from the wind is significantly less than this figure suggests. The actual power will depend on several factors, such as the type of machine and rotor used, the sophistication of blade design, friction losses, and the losses in the pump or other equipment connected to the wind machine. There are also physical limits to the amount of power that can be extracted realistically from the wind. It can been shown theoretically that any windmill can only possibly extract a maximum of 59.3% of the power from the wind (this is known as the Betz limit). In reality, this figure is usually around 45% (maximum) for a large electricity producing turbine and around 30% to 40% for a windpump, (see the section on coefficient of performance below). So, modifying the formula for 'Power in the wind' we can say that the power which is produced by the wind machine can be given by:

$$P_M = ½.Cp.\rho.A.V^3$$

Where, P_M is power (in watts) available from the machine

C_p is the coefficient of performance of the wind machine

It is also worth bearing in mind that a wind machine will only operate at its maximum efficiency for a fraction of the time it is running, due to variations in wind speed. A rough estimate of the output from a wind machine can be obtained using the following equation;

$$P_A = 0.2\ A\ V^3$$

where, P_A is the average power output in watts over the year

V is the mean annual windspeed in m/s

Principles of wind energy conversion

There are two primary physical principles by which energy can be extracted from the wind; these are through the creation of either lift or drag force (or through a combination of the two). The difference between drag and lift is illustrated by the difference between using a spinnaker sail, which fills like a parachute and pulls a sailing boat with the wind, and a Bermuda rig, the familiar triangular sail which deflects with wind and allows a sailing boat to travel across the wind or slightly into the wind.

Drag forces provide the most obvious means of propulsion, these being the forces felt by a person (or object) exposed to the wind. Lift forces are the most efficient means of propulsion but being more subtle than drag forces are not so well understood.

The basic features that characterize lift and drag are:

- drag is in the direction of air flow

- lift is perpendicular to the direction of air flow
- generation of lift always causes a certain amount of drag to be developed
- with a good aerofoil, the lift produced can be more than thirty times greater than the drag
- lift devices are generally more efficient than drag devices

Types and characteristics of rotor:

There are two types 1 .vertical axis machines
2. horizontal axis machines

These can in turn use either lift or drag forces to harness the wind. The horizontal axis lift device is the type most commonly used. In fact other than a few experimental machines virtually all windmills come under this category.

There are several technical parameters that are used to characterise windmill rotors. The *tip-speed ratio* is defined as the ratio of the speed of the extremities of a windmill rotor to the speed of the free wind. Drag devices always have tip-speed ratios less than one and hence turn slowly, whereas lift devices can have high tip-speed ratios (up to 13:1) and hence turn quickly relative to the wind.

The proportion of the power in the wind that the rotor can extract is termed the *coefficient of performance* (or power coefficient or efficiency; symbol C_p) and its variation as a function of tip-speed ratio is commonly used to characterise different types of rotor. As mentioned earlier there is an upper limit of C_p = 59.3%, although in practice real wind rotors have maximum C_p values in the range of 25%-45%.

Solidity is usually defined as the percentage of the area of the rotor, which contains material rather than air. Low-solidity machines run at higher speed and tend to be used for electricity generation. High-solidity machines carry a lot of material and have coarse blade angles. They generate much higher starting torque (torque is the twisting or rotary force produced by the rotor) than low-solidity machines but are inherently less efficient than low-solidity machines. The wind pump is generally of this type. High solidity machines will have a low tip-speed ratio and vice versa.

2.5 GRID CONNECTED OR BATTERY CHARGING

Depending on the circumstances, the distribution of electricity from a wind machine can be carried out in one of various ways. Commonly, larger machines are connected to a grid distribution network. This can be the main national network, in which case electricity can be sold to the electricity utility (providing an agreement can be made between the producer and the grid) when an excess is produced and purchased when the wind is low. Using the national grid helps provide flexibility to the system and does away with the need for a back-up system when wind speeds are low.

Micro-grids distribute electricity to smaller areas, typically a village or town. When wind is used for supplying electricity to such a grid, a diesel generator set is often used as a backup for the periods when wind speeds are low. Alternatively, electricity storage can be used but this is an expensive option. Hybrid systems use a combination of two or more energy sources to provide electricity in all weather conditions. The capital cost for such a system is high but subsequent running costs will be low compared with a pure diesel system.

In areas where households are widely dispersed or where grid costs are prohibitively expensive, battery charging is an option. For people in rural areas a few tens of watts of power are sufficient for providing lighting and a source of power for a radio or television. Batteries can be returned to the charging station occasionally for recharging. This reduces the inconvenience of an intermittent supply due to fluctuating wind speeds. 12 and 24 volt direct current wind generators are commercially available which are suitable for battery charging applications. Smaller turbines (50 -150 watt) are available for individual household connection.

3.PHOTOVOLTAIC SYSTEMS

3.1 SOLAR ENERGY

Fig 3.1 Solar Plates

Solar energy, radiant light and heat from the sun, is harnessed using a range of ever-evolving technologies such as solar heating, solar photovoltaic's, solar thermal electricity, solar architecture and artificial photosynthesis.

Solar technologies are broadly characterized as either passive solar or active solar depending on the way they capture, convert and distribute solar energy. Active solar techniques include the use of photovoltaic panels and solar thermal collectors to harness the energy. Passive solar techniques include orienting a building to the Sun, selecting materials with favorable thermal massor light dispersing properties, and designing spaces that naturally circulate air.

In 2011, the International Energy Agency said that "the development of affordable, inexhaustible and clean solar energy technologies will have huge longer-term benefits. It will increase countries' energy security through reliance on an indigenous, inexhaustible and mostly import-independent resource, enhance sustainability, reduce pollution, lower the costs of mitigating climate change, and keep fossil fuel prices lower than otherwise. These advantages are global. Hence the additional costs of the incentives for early deployment should be considered learning investments; they must be wisely spent and need to be widely shared. The Earth receives 174 petawatts (PW) of incoming solar radiation (insolation) at the upper atmosphere Approximately 30% is reflected back to space while the rest is absorbed by clouds, oceans and land masses. The spectrum of solar light at the Earth's surface is mostly spread across the visible and near-infrared ranges with a small part in the near-ultraviolet.

Earth's land surface, oceans and atmosphere absorb solar radiation, and this raises their temperature. Warm air containing evaporated water from the oceans rises, causingatmospheric circulation or convection. When the air reaches a high altitude, where the temperature is low, water vapor condenses into clouds, which rain onto the Earth's surface, completing the water cycle. The latent heat of water condensation amplifies convection, producing atmospheric phenomena such as wind, cyclones and anti-cyclones Sunlight absorbed by the oceans and land masses keeps the surface at an average temperature of 14 °C By photosynthesis green plants convert solar energy into chemical energy, which produces food, wood and the biomass from which fossil fuels are derived.

The total solar energy absorbed by Earth's atmosphere, oceans and land masses is approximately 3,850,000 hexajoules (EJ) per year. In 2002, this was more energy in one hour than the world used in one year. Photosynthesis captures approximately 3,000 EJ per year in biomass.[15] The technical potential available from biomass is from 100–300 EJ/year. The amount of solar energy reaching the surface of the planet is so vast that in one year it is about twice as much as will ever be obtained from all of the Earth's non-renewable resources of coal, oil, natural gas, and mined uranium combined, Solar energy can be harnessed at different levels around the world, mostly depending on distance from the equator.

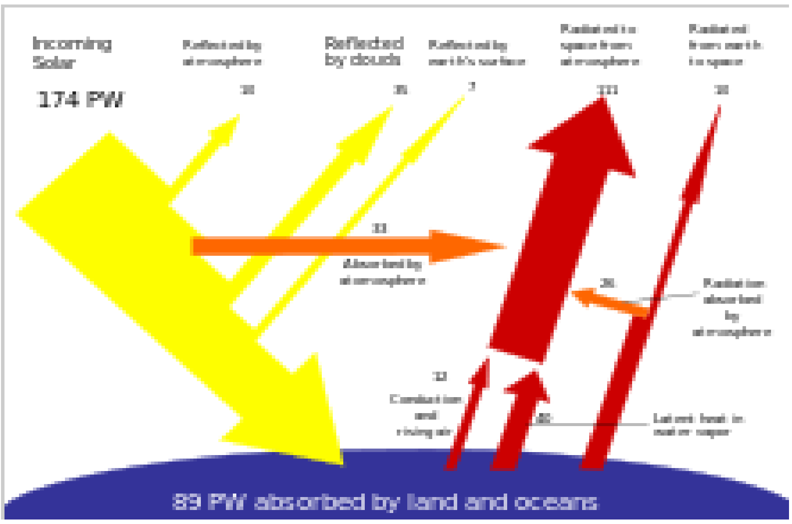

Fig. 3.2 Figure showing how solar energy reached the earth's surface

Solar energy refers primarily to the use of solar radiation for practical ends. However, all renewable energies, other than geothermal and tidal, derive their energy from the sun.

Solar technologies are broadly characterized as either passive or active depending on the way they capture, convert and distribute sunlight. Active solar techniques use photovoltaic panels, pumps, and fans to convert sunlight into useful outputs. Passive solar techniques include selecting materials with favorable thermal properties, designing spaces that naturally circulate air, and referencing the position of a building to the Sun. Active solar technologies increase the supply of energy and are considered supply side technologies, while passive solar technologies reduce the need for alternate resources and are generally considered demand side technologies.

Sunlight has influenced building design since the beginning of architectural history. Advanced solar architecture and urban planning methods were first employed by the Greeksand Chinese, who oriented their buildings toward the south to provide light and warmth.

The common features of passive solar architecture are orientation relative to the Sun, compact proportion (a low surface area to volume ratio), selective shading (overhangs) and thermal mass. When these features are tailored to the local climate and environment they can produce well-lit spaces that stay in a comfortable temperature range. Socrates' Megaron House is a classic example of passive solar design. The most recent approaches to solar design use computer modeling tying together solar lighting, heating and ventilation systems in an integrated solar design package. Active solar equipment such as pumps, fans and switchable windows can complement passive design and improve system performance.

Urban heat islands (UHI) are metropolitan areas with higher temperatures than that of the surrounding environment. The higher temperatures are a result of increased absorption of the Solar light by urban materials such as asphalt and concrete, which have lower albedos and higher heat capacities than those in the natural environment. A straightforward method of counteracting the UHI effect is to paint buildings and roads white and plant trees. Using these methods, a hypothetical "cool communities" program in Los Angeles has projected that urban temperatures could be reduced by approximately 3 °C at an estimated cost of US$1 billion, giving estimated total annual benefits of US$530 million from reduced air-conditioning costs and healthcare savings.

3.2 WATER HEATING

Solar hot water systems use sunlight to heat water. In low geographical latitudes (below 40 degrees) from 60 to 70% of the domestic hot water use with temperatures up to 60 °C can be provided by solar heating systems. The most common types of solar water heaters are evacuated tube collectors (44%) and glazed flat plate collectors (34%) generally used for domestic hot water; and unglazed plastic collectors (21%) used mainly to heat swimming pools.

Fig 3.3 Solar water heaters

As of 2007, the total installed capacity of solar hot water systems is approximately 154 GW. China is the world leader in their deployment with 70 GW installed as of 2006 and a long term goal of 210 GW by 2020. Israel and Cyprus are the per capita leaders in the use of solar hot water systems with over 90% of homes using them. In the United States, Canada and Australia heating swimming pools is the dominant application of solar hot water with an installed capacity of 18 GW as of 2005.

3.3 HEATING, COOLING AND VENTILATION

In the United States, heating, ventilation and air conditioning (HVAC) systems account for 30% (4.65 EJ) of the energy used in commercial buildings and nearly 50% (10.1 EJ) of the energy used in residential buildings Solar heating, cooling and ventilation technologies can be used to offset a portion of this energy.

Thermal mass is any material that can be used to store heat—heat from the Sun in the case of solar energy. Common thermal mass materials include stone, cement and water. Historically they have been used in arid climates or warm temperate regions to keep buildings cool by absorbing solar energy during the day and radiating stored heat to the cooler atmosphere at night. However they can be used in cold temperate areas to maintain warmth as well. The size and placement of thermal mass depend on several factors such as climate, day lighting and shading conditions. When properly incorporated, thermal mass maintains space temperatures in a comfortable range and reduces the need for auxiliary heating and cooling equipment

A solar chimney (or thermal chimney, in this context) is a passive solar ventilation system composed of a vertical shaft connecting the interior and exterior of a building. As the chimney warms, the air inside is heated causing an updraft that pulls air through the building. Performance can be improved by using glazing and thermal mass materials in a way that mimics greenhouses.

Deciduous trees and plants have been promoted as a means of controlling solar heating and cooling. When planted on the southern side of a building, their leaves provide shade during the summer, while the bare limbs allow light to pass during the winter. Since bare, leafless trees shade 1/3 to 1/2 of incident solar radiation, there is a balance between the benefits of summer shading and the corresponding loss of winter heating. In climates with significant heating loads, deciduous trees should not be planted on the southern side of a building because they will interfere with winter solar availability. They can, however, be used on the east and west sides to provide a degree of summer shading without appreciably affecting winter solar gain.

3.4 ABOUT DC-DC CONVERTERS:

Several methods exist to achieve DC-DC voltage conversion. Each of these meth-ods has its specific benefits and disadvantages, depending on a number of operating conditions and specifications. Examples of such specifications are the voltage con-version ratio range, the maximal output power, power conversion efficiency, num-ber of components, power density, galvanic separation of in- and output, etc. When designing fully-integrated DC-DC converters these specifications generally remain relevant, nevertheless some of them will gain weight, as more restrictions emerge. For instance the used IC technology, the IC technology options and the available chip area will be dominant for the production cost, limiting the value and quality factor of the passive components. These limited values will in-turn have a signifi-cant impact upon the choice of the conversion method.

In order for the designer to obtain a clear view of the DC-DC voltage conversion methods and their individual advantages and disadvantages, with respect to mono-lithic integration, the three fundamental methods are discussed in this chapter. The first and oldest method of performing DC-DC voltage conversion is by means of linear voltage converters (resistive dividers), which are explained in Sect. The second method, which also has an interesting potential for the purpose of mono-lithic voltage conversion, is by means of capacitor charge-pumps, as explained in Sect. The latter two methods are explained more briefly as this work will mainly concentrate on inductive type DC-DC converters, which are discussed in Sect.

Power conversion efficiency is in most cases a primary specification for any given energy converter. Therefore, a formal method for the fair comparison of DC-DC step-down voltage converters, in terms of power conversion efficiency, is introduced in Sect.. This method is referred to as the Efficiency Enhancement Factor (EEF). The chapter is concluded with the conclusions in Sect.

Linear Voltage Converters

The most elementary DC-DC converters are linear voltage converters. They achieve DC-DC voltage conversion by dissipating the excess power into a resistor, making

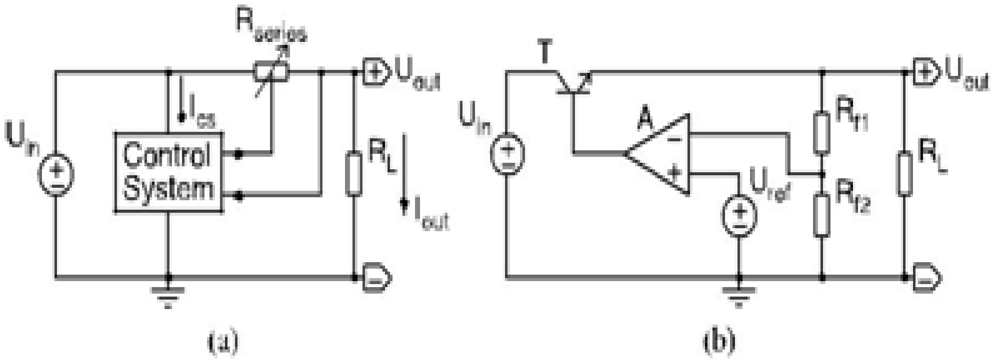

Fig 3.4 The principle of a linear series voltage converter and a simple practical implementation

them resistive dividers. Clearly, this is not quite ideal for the power conversion efficiency η_{lin}. Another implication of their operating principle is the fact that they can only convert a certain input voltage U_{in} into a lower output voltage U_{out} , having the same polarity. In other words, the value of their voltage conversion ratio k_{lin}, given by (1.1), is always between zero and one.A permanent magnet synchronous generator is a generator where the excitation field is provided by a permanent magnet instead of a coil.

Synchronous generators are the majority source of commercial electrical energy. They are commonly used to convert the mechanical power output of steam turbines, gas turbines, reciprocating engines, hydro turbines and wind turbines into electrical power for the grid. In the majority of designs the rotating assembly in the center of the generator—the "rotor"—contains the magnet, and the "stator" is the stationary armature that is electrically connected to a load. A set of three conductors make up the armature winding in standard utility equipment, constituting three phases of a power circuit—that correspond to the three wires we are accustomed to see on transmission lines. The phases are wound such that they are 120 degrees apart spatially on the stator, providing for a uniform force or torque on the generator rotor. The uniformity of the torque arises because the magnetic fields resulting from the induced currents in the three conductors of the armature winding combine spatially in such a way as to resemble the magnetic field of a single, rotating magnet. This stator magnetic field or "stator field" appears as a steady rotating field and spins at the same frequency as the rotor when the rotor contains a single dipole magnetic field. The two fields move in "synchronicity" and maintain a fixed position relative to each other as they spin.[1]

They are known as synchronous generators because f, the frequency of the induced voltage in the stator (armature conductors) conventionally measured in hertz, is directly proportional to RPM, the rotation rate of the rotor usually given in revolutions per minute (or angular speed). If the rotor windings are arranged in such a way as to produce the effect of more than two magnetic poles, then each physical revolution of the rotor results in more magnetic poles moving past the armature windings. Each passing of a north and south pole corresponds to a complete "cycle" of a magnet field oscillation. Therefore, the constant of proportionality is $\frac{\mathrm{P}}{120}$, where P is the number of magnetic rotor poles (almost always an even number), and the factor of 120 comes from 60 seconds per minute and two poles in a single magnet; $f\,(\mathrm{Hz}) = RPM\frac{\mathrm{P}}{120}$

In a permanent magnet generator, the magnetic field of the rotor is produced by permanent magnets. Other types of generator use electromagnets to produce a magnetic field in a rotor winding. The direct current in the rotor field winding is fed through a slip-ring assembly or provided by a brushless exciter on the same shaft.Permanent magnet generators do not require a DC supply for the excitation circuit, nor do they have slip rings and contact brushes. However, large permanent magnets are costly which restricts the economic rating of the machine. The flux density of high performance permanent magnets is limited. The air gap flux is not controllable, so the voltage of the machine cannot be easily regulated. A persistent magnetic field imposes safety issues during assembly, field service or repair. High performance permanent magnets, themselves, have structural and thermal issues. Torque current MMF vectorially combines with the persistent flux of permanent magnets, which leads to higher air-gap flux density and eventually, core saturation. In this permanent magnet alternators the speed is directly proportional to the output voltage of the alternator.

Direct connected DC generator

This method of excitation consists of a smaller direct-current (DC) generator fixed on the same shaft with the alternator. The DC generator generates a small amount of electricity just enough to *excite* the field coils of the connected alternator to generate electricity. A variation of this system is a type of alternator which uses direct current from the battery for excitation, after which the alternator is self-excited.[8]

Transformation and rectification

This method depends on residual magnetism retained in the iron core to generate weak magnetic field which would allow weak voltage to be generated. The voltage is used to excite the field coils for the alternator to generate stronger voltage as part of its *build up* process. After the initial AC voltage buildup, the field is supplied with rectified voltage from the alternator.[8]

Brushless alternators

A brushless alternator is composed of two alternators built end-to-end on one shaft. Smaller brushless alternators may look like one unit but the two parts are readily identifiable on the large versions. The larger of the two sections is the main alternator and the smaller one is the exciter. The exciter has stationary field coils and a rotating armature (power coils). The main alternator uses the opposite configuration with a rotating field and stationary armature. A bridge rectifier, called the rotating rectifier assembly, is mounted on a plate attached to the rotor. Neither brushes nor slip rings are used, which reduces the number of wearing parts. The main alternator has a rotating field as described above and a stationary armature (power generation windings).

Varying the amount of current through the stationary exciter field coils varies the 3-phase output from the exciter. This output is rectified by a rotating rectifier assembly, mounted on the rotor, and the resultant DC supplies the rotating field of the main alternator and hence alternator output. The result of all this is that a small DC exciter current indirectly controls the output of the main alternator.

Number of phases

Another way to classify alternators is by the number of phases of their output voltage. The output can be single phase, or polyphase. Three-phase alternators are the most common, but polyphase alternators can be two phase, six phase, or more.[8]

Armature or Field Rotation

Another type of classification is based on which part of the alternators is being rotated. The revolving part of alternators can be armature or magnetic field. The revolving armature type has armature on the rotor to rotate through a stationary magnetic field. The revolving armature type is found only in alternators of low power rating and generally is not used. On the other hand, the revolving field type has magnetic field on the rotor to rotate through a stationary armature winding.

Alternators are used in modern automobiles to charge the battery and to power the electrical system when its engine is running. Until the 1960s, automobiles used DC dynamo generators with commutators. With the availability of affordable silicon diode rectifiers, alternators were used instead.

Diesel electric locomotive alternators

In diesel electric locomotives, and in diesel electric multiple units, the prime mover turns an alternator which in turn provides electricity for the traction motors (ac or dc) and, optionally, the head end power (HEP), however, the HEP option requires a constant engine speed, 900 rpm for a 480 volt 60 Hz HEP application, even when the locomotive is not moving.The traction alternator usually incorporates integral silicon diode rectifiers to provide the traction motors with up to 1200 volts dc (dc traction, which is used directly) or the common inverter bus (ac traction, which is first inverted from dc to three-phase ac).

Although ac traction motors are emerging for very heavy drag service, particularly in western North America, and its supply of Powder River Basin coal to other areas of the U.S., the simpler dc traction motor system remains the most popular, with Union Pacific alone having over 1,500 current model SD70Ms with dc traction motors (plus an additional 1,000SD70MACs with ac traction motors). Both of these models share an ac traction alternator with integral rectification, as the common bus is 1200 volts dc, from which dc traction motors may be directly powered, or ac traction motors may be powered through inverters.

Marine alternators

Marine alternators used in yachts are similar to automotive alternators, with appropriate adaptations to the salt-water environment. Marine alternators are designed to be explosion proof so that brush sparking will not ignite explosive gas mixtures in an engine room environment. They may be 12 or 24 volt depending on the type of system installed. Larger marine diesels may have two or more alternators to cope with the heavy electrical demand of a modern yacht. On single alternator circuits, the power is split between the engine starting battery and the domestic or house battery (or batteries) by use of a split-charge diode (battery isolator) or a mechanical switch. Because the alternator only produces power when running, engine control panels are typically fed directly from the alternator by means of an auxiliary terminal. Other typical connections are for charge control circuits.

Radio alternators

High frequency alternators of the variable-reluctance type were applied commercially to radio transmission in the low-frequency radio bands. These were used for transmission of Morse code and, experimentally, for transmission of voice and music.

3.5 PROPOSED SYSTEM

In this project, combining the Photovoltaic generation with Wind power generation, the instability of an output characteristic each other was compensated. The proposed system is shown in Fig.1.The Input Power source1 is Photovoltaic (PV) cell, Power source2 is the Wind and the storage element is the Battery. Both Wind generators through AC/DC converter and Photovoltaic (PV) array is connected to DC/DC converter and common DC link. The feedback is taken from both power generator and also from common DC-link as an input to the power management algorithm block. The PV array and Wind turbine work together to satisfy the load demand. When energy sources (solar and wind energy) are abundant ,the generated power, after satisfying the load demand, will be supplied to feed the battery until it is fully charged.

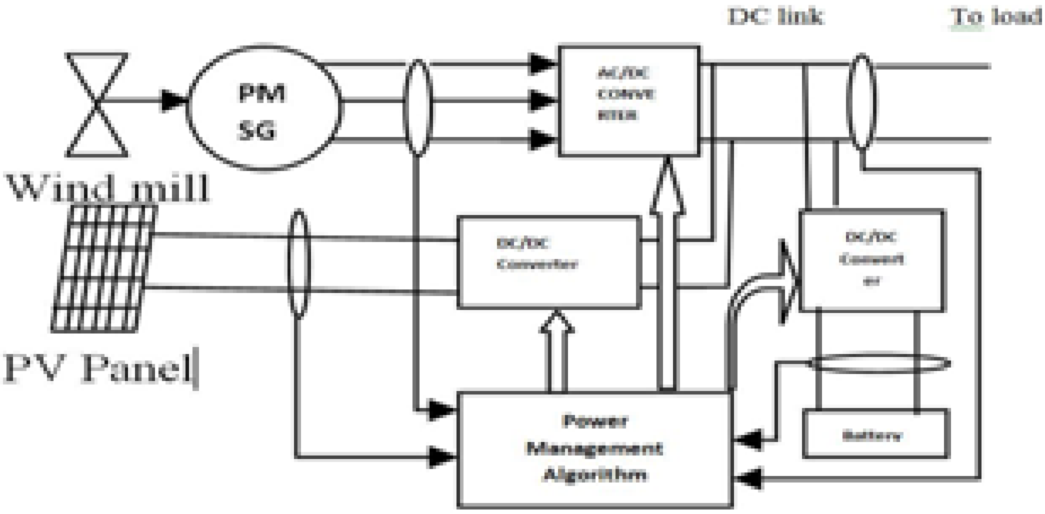

Fig 3.5 Proposed system overview

On the contrary, when energy sources are poor, the battery will release energy to assist the PV array and wind turbine to cover the load requirements until the storage is depleted.

3.6 TOPOLOGY OF THE PROPOSED CONVERTER:

The proposed Multi – Input power converter is shown in Fig.

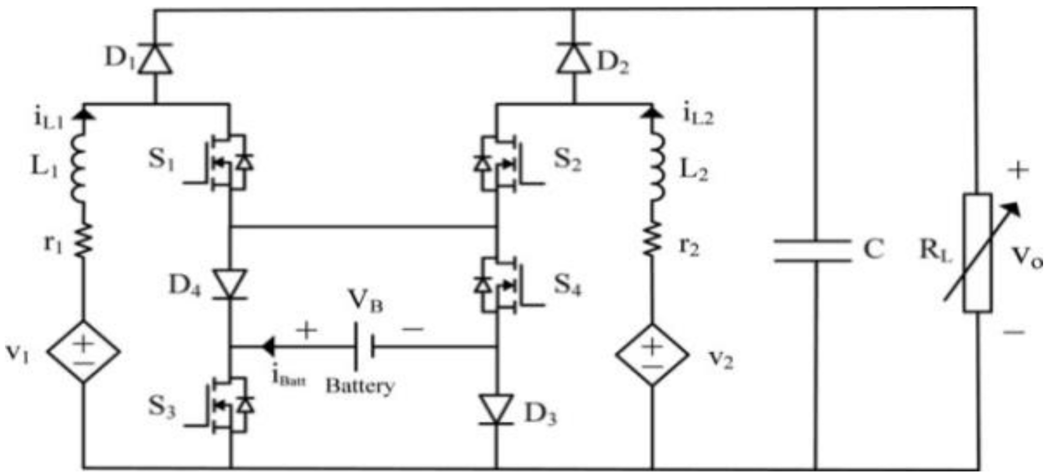

Fig 3.6 Multi input power converter

The proposed converter Interfaces two independent power sources,v_1 and v_2 and a Battery as the storage element. The Input power ports are made as two current type sources by two inductors L_1 and $L_{2,}$ in the proposed circuit which results in drawing smooth currents from the sources. The main controllable elements that control the power flow of the hybrid power system are the load resistance, R_L and the switches $S_1 – S_4$. The duty ratios controlling the switches $S_1 – S_4$ are $d_1 – d_4$ respectively

The diodes D_1 and D_2 conduct in complementary manner with switches S_1 and S . The diodes D_3 and D_4 are reverse biased by the . when S_3 and S_4 are turned ON. Similarly, turning OFF of these switches results in the diodes D_3 and D_4 to conduct Input currents i_{L1} and i_{L2}. The dynamic behavior and steady state of the converter is observed in Continuous Current Mode (CCM)

4. PRINCIPLE OF OPERATION

Three power operation modes of the converter can be defined based on the utilization of the battery. The following assumptions are considered for the operation modes: saw tooth carrier waveform utilization for $S_1 - S_4$ and considering d_3, $d_4 <$ min (d_1,d_2) in Battery Charge or Discharge mode. d_1 is assumed to be less than d_2 for simplification of operation mode investigation. By assuming $S_1 - S_4$ to be ideal , the steady – state equations are obtained in each operation mode.

4.1 First Operation Mode (Existence of Sources v_1 and v_2, without Battery)

In this operation mode, the supply to the load without Battery is given by sources v_1 and v_2 which is the Basic Operation mode of the converter.

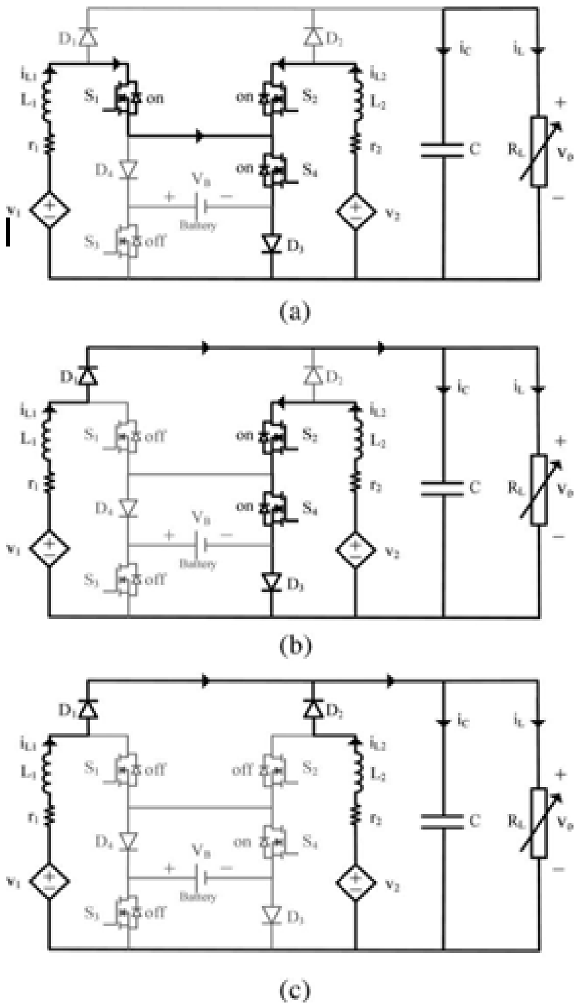

Fig 4.1 First operation mode

From the converter structure it is possible to conduct Input power sources currents i_{L1} and i_{L2} by two ways without passing along the battery, path1: $S_4 - D_3$, path2: $S_3 - D_4$. In this operation mode first path is chosen. Therefore in the entire switching period (d_4=1 and d_3=0) switch S_3 is turned OFF and Switch S_4 is turned ON. Therefore, in one switching period, three different switching states of the converter can be achieved.

Switching state 1 ($0 < t < d_1 T$): At $t = 0$,S_1 and S_2 are turned ON and L_1 and L_2 are charged with voltages across v_1 and v_2 , respectively [see Fig. 3(a)].

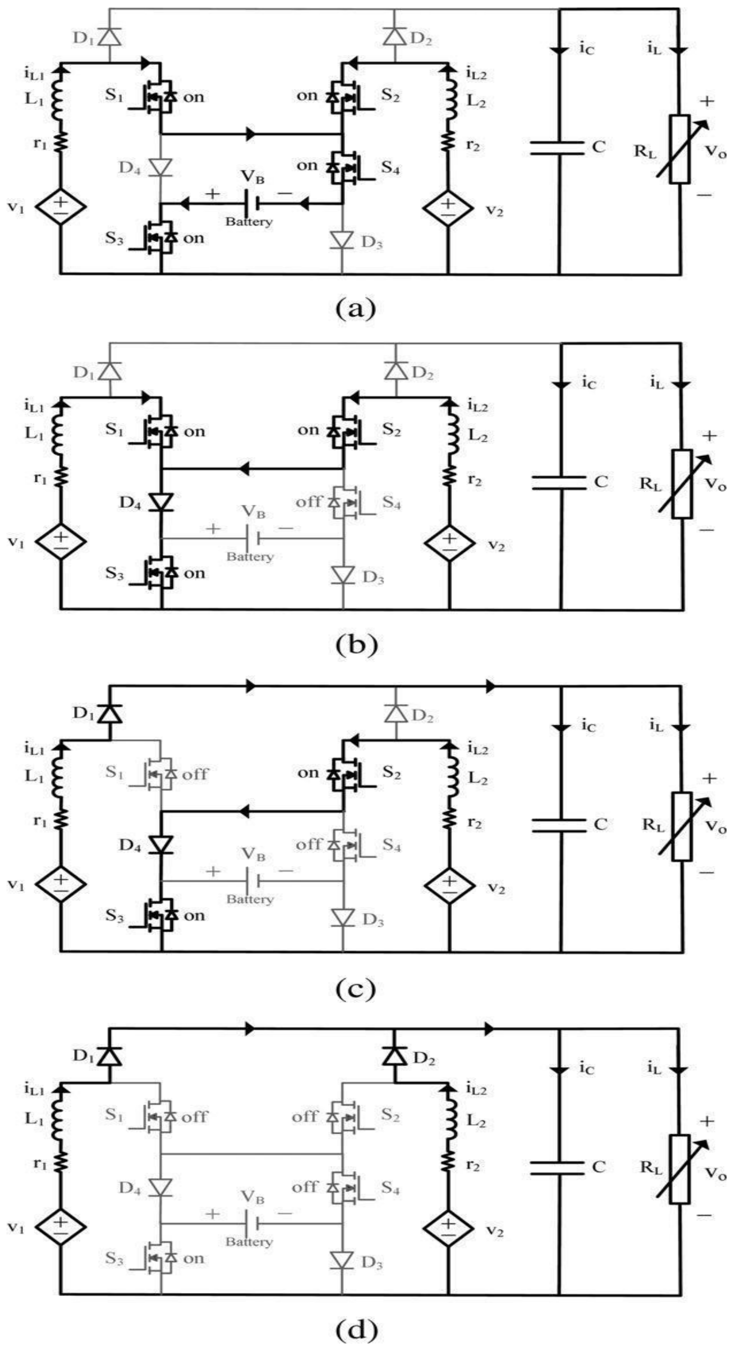

Fig. 4.2 Second operation mode. (a) Switching state 1: $0 < t < d4\ T$. (b)Switching state 2: $d4\ T< t < d1\ T$. (c) Switching state 3: $d1\ T < t < d2\ T$.(d) Switching state 4: $d2\ T < t < T$.

Switching state 2 ($d1\ T < t < d2T$): At $t = d1\ T$, $S1$ is turned OFF, while $S2$ is still ON (according to the assumption $d1< d_2$). Therefore, L_1 is discharged with voltage across $v_1 - v_o$ into the output load and the capacitor through D_1, while L_2 is still charged by voltage across v_2 [see Fig. 3(b)].

Switching state 3 (d2 T < t < T): At $t = d2\ T$, $S2$ is turned OFF and $L2$ is discharged with voltage across $v2 - v\mathrm{o}$, as like an $L1$ [see Fig. 3(c)].:

Equations based on balance theory are,

$$L_1 : d_1 T(v_1 - r_1 i_{L1}) + (1 - d_1)T(v_1 - r_1 i_{L1} - v_o)$$
$$= 0 \rightarrow v_o = \frac{v_1 - r_1 i L_1}{1 - d_1} \qquad (1)$$

$$L_2 : d_2 T(v_2 - r_2 i_{L2}) + (1 - d_2)T(v_2 - r_2 i_{L2} - v_o)$$
$$= 0 \rightarrow v_o = \frac{v_2 - r_2 i_{L2}}{1-2} \qquad (2)$$

$$C: (1 - d_1) T i_{L1} + (1 - d_2) T i_{L2} = T \frac{v_O}{R_L} \qquad (3)$$

$$i_{Batt} = 0 \rightarrow P_{Batt} = 0 \qquad (4)$$

With the corresponding duty ratios one of the Input sources is regulated in this mode, while the other power sources are utilized with its duty ratio to regulate output voltage.

4.2 Second Operation Mode (Existence of Sources v_1 and v_2 and Battery)

The supply to the load with the battery discharging state is given by the sources v_1 and v_2 in this operation mode. The converter structure depicts that the turning ON of switches S_3 and S_4 simultaneously results in i_{L1} and i_{L2} to conduct through the path S_4 of the battery and S_3,results in discharging of the battery. However, only when S_1 and/or S_2 are conducting discharging operations of the battery can hold. Therefore the maximum discharge state of the battery depends on d_1 and d_2 and currents i_{L1} and i_{L2}

$$P_{bat.dis}^{max} = v_B[d_1 i_{L1} + d_2 i_{L2}], \ S_3 = \mathrm{ON},\ S_4 = \mathrm{ON}. \quad (5)$$

By changing the state of any one of the switches $S3$ and $S4$ before turning OFF of the switches $S1$ and $S2$ the discharging power of the battery can be made below while controlling $d3$ which regulates the discharging power of the battery. The currents of power sources flows through the battery when $S4$ is turned ON, which results in the battery discharge mode, and turns OFF state, starts $D4$ to conduct and stops discharging mode of the battery. The switching states are shown in Fig. 4(a)–(d).

Switching state 1: *(0 < t < d4 T):* At $t = 0$, S_1, S_2, and S_4 are turned ON, so L_1 and L_2 are charged with voltages across $v_1 + v_B$ and $v_2 + v_B$, respectively [see Fig. 4(a)].

Switching state 2: *(d4 T < t < d1 T):* At $t = d_4\ T$, S_4 is turned OFF, while S_1 and S_2 are still ON. Therefore, L_1 and L_2 are charged with voltages across, v_1 and v_2 respectively [see Fig. 4(b)].

Switching state 3: *(d_1 T < t < d_2 T):* At $t = d_1 T$, S_1 is turned OFF, so L_1 is discharged with voltage across v_1- v_o , while i L_2 is still charged with voltages across v_2 [see Fig. 4(c)].

Switching state 4: *(d_2 T < t < T):* At $t = d_2 T$, S_2 is also turned OFF and L_1 and L_2 are discharged with voltage across $v_1 - v_o$ and $v_2 - v_o$, respectively [see Fig. 4(d)]

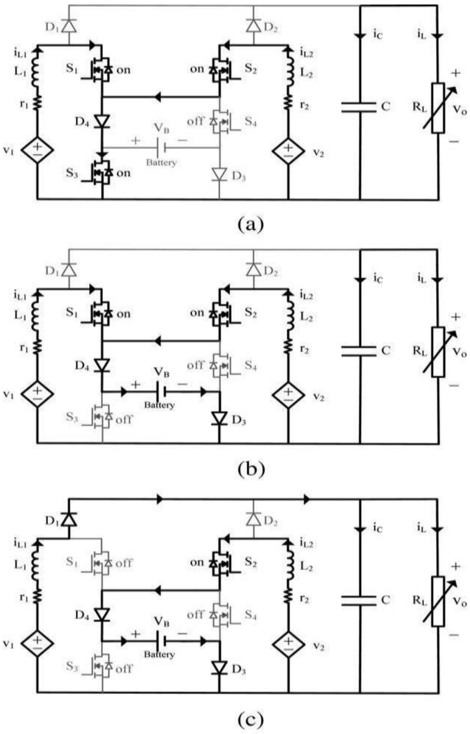

Fig. 4.3 . Third operation mode. (a) Switching state 1: $0<t<d_3T$ (b) Switching state 2: $d_3T< t<d_1T$. (c) Switching state 3: $d_1T<t <d_2T$. (d) Switching state 4: $d_2T <t<T$.

Equations based on the balance theory are,

$$L_1 : \; d_4T(v_1 - r_1 i_{L1} + v_B) + (d_1 - d_4)T(v_1 - r_1 i_{L1})$$

$$+ (1 - d_1)T(v_1 - r_1 i_{L1} - v_o) = 0$$

$$= 0 \;\; \rightarrow v_o = \frac{v_1 - r_1 i L_1 + d_4 v_B}{1 - d_1} \qquad (6)$$

$$L_2 : \; d_4T(v_2 - r_2 i_{L2} + v_B) + (d_2 - d_4)T(v_2 -$$

$$r_2 i_{L2}) + (1 - d_2)T(v_2 - r_2 i_{L2} - v_o) = 0$$

$$= 0 \rightarrow v_o = \frac{v_1 - r_1 i_{L2} + d_4 v_B}{1 - d_2} \qquad (7)$$

$$C: \; (1 - d_1)Ti_{L1} + (1 - d_2)Ti_{L2} = T\frac{v_O}{R_L} \qquad (8)$$

$$Battery \begin{cases} i_{Batt} = d_4(i_{L1} + i_{L2}) \\ P_{Batt} = -v_B[d_4(i_{L1} + i_{L2}) \end{cases} \qquad (9)$$

Duty Ratio,$d4$ is utilized to regulate output voltage through battery discharging in this mode, while $d1$ and $d2$ regulates powers of the input sources.

4.3 Third Operation Mode (Existence of Sources v_1 and v_2 with Battery Charging)

In this operation mode, the supply to the load while the Battery is in charging state is given by the Sources v_1 and v_2. Switches S_3 and S_4 are turned OFF from the converter structure, by turning ON S_1 and S_2, and the currents i_{L1} and i_{L2} are conducted through the path of the battery, D_4 and D_3. Therefore the battery charging condition is provided.

However, until S_1 and/or S_2 conduct the charging mode of the battery exists. Hence, the maximum charging of the battery depends on d_1, d_2 and i_{L1}, i_{L2}.

$$P_{bat.ch}^{max} = -v_B[d_1 i_{\mathrm{L1}} + d_2 i_{\mathrm{L2}}],\ \ \mathrm{S_3} = \mathrm{OFF},\ \mathrm{S_4} = \mathrm{OFF}.$$

By changing the state of the switches $S3$ and $S4$ before turning OFF of the switches $S1$ and $S2$ (Assuming that $d3$, $d4<\min(d1, d2)$)charging power of the battery can be made below. $S3$ is controlled in order to regulate the charging state of the battery and when $S3$ is turned ON the battery charging is not accomplished. In one switching period, Four different switching states are obtained which are shown in Fig. 5(a)–(d).

Switching state 1: *($0 < t < d_3 T$):* At $t = 0$, S_1 , S_2 , and S_3 are turned ON, so L_1 and L_2 are charged with voltages across v_1 and v_2 , respectively [see Fig. 5(a)].

Switching state 2: *($d_3 T < t < d_1 T$):* At $t = d_3 T$, S_3 is turned OFF while S_1 and S_2 are still ON (according to the assumption). Therefore, L_1 and L_2 are charged with voltages across $v_1 - v_B$ and $v_2 - v_B$, respectively [see Fig. 5(b)].

Switching state 3: *($d_1 T < t < d_2 T$):* At $t = d_1 T$, S_1 is turned OFF, so L_1 is discharged with voltage across v_1 - v_o , while L_2 is still charged with voltage across v_2- v_B [see Fig. 5(c)].

Switching state 4: *($d_2 T < t < T$):* At $t = d_2 T$, S_2 is also turned OFF and L_2 as like as L_1 is discharges.

5. MATLAB

Matlab is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. Typical uses include Math and computation Algorithm development Data acquisition Modeling, simulation, and prototyping Data analysis, exploration, and visualization Scientific and engineering graphics Application development, including graphical user interface building.

Matlab is an interactive system whose basic data element is an array that does not require dimensioning. This allows you to solve many technical computing problems, especially those with matrix and vector formulations, in a fraction of the time it would take to write a program in a scalar no interactive language such as C or Fortran.

The name matlab stands for matrix laboratory. Matlab was originally written to provide easy access to matrix software developed by the linpack and eispack projects. Today, matlab engines incorporate the lapack and blas libraries, embedding the state of the art in software for matrix computation.

Matlab has evolved over a period of years with input from many users. In university environments, it is the standard instructional tool for introductory and advanced courses in mathematics, engineering, and science. In industry, matlab is the tool of choice for high-productivity research, development, and analysis.

Matlab features a family of add-on application-specific solutions called toolboxes. Very important to most users of matlab, toolboxes allow you to learn and apply specialized technology. Toolboxes are comprehensive collections of matlab functions (M-files) that extend the matlab environment to solve particular classes of problems. Areas in which toolboxes are available include signal processing, control systems, neural networks, fuzzy logic, wavelets, simulation, and many others.

The matlab system consists of five main parts:

Development Environment**.** This is the set of tools and facilities that help you use matlab functions and files. Many of these tools are graphical user interfaces. It includes the matlab desktop and Command Window, a command history, an editor and debugger, and browsers for viewing help, the workspace, files, and the search path.

The matlab Mathematical Function Library. This is a vast collection of computational algorithms ranging from elementary functions, like sum, sine, cosine, and complex arithmetic, to more sophisticated functions like matrix inverse, matrix eigenvalues, Bessel functions, and fast Fourier transforms.

The matlab Language**.** This is a high-level matrix/array language with control flow statements, functions, data structures, input/output, and object-oriented programming features. It allows both "programming in the small" to rapidly create quick and dirty throw-away programs, and "programming in the large" to create large and complex application programs.

Matlab has extensive facilities for displaying vectors and matrices as graphs, as well as annotating and printing these graphs. It includes high-level functions for two-dimensional and three-dimensional data visualization, image processing, animation, and presentation graphics. It also includes low-level functions that allow you to fully customize the appearance of graphics as well as to build complete graphical user interfaces on your matlab applications.

The matlab Application Program Interface (API). This is a library that allows you to write C and Fortran programs that interact with matlab. It includes facilities for calling routines from matlab (dynamic linking), calling matlab as a computational engine, and for reading and writing MAT-files.

6.SIMULINK

6.1 INTRODUCTION

Simulink is a software add-on to matlab which is a mathematical tool developed by The Math works,(http://www.mathworks.com) a company based in Natick. Matlab is powered by extensive numerical analysis capability. Simulink is a tool used to visually program a dynamic system (those governed by Differential equations) and look at results. Any logic circuit, or control system for a dynamic system can be built by using standard building blocks available in Simulink Libraries. Various toolboxes for different techniques, such as Fuzzy Logic, Neural Networks, dsp, Statistics etc. are available with Simulink, which enhance the processing power of the tool. The main advantage is the availability of templates / building blocks, which avoid the necessity of typing code for small mathematical processes.

6.2 CONCEPT OF SIGNAL AND LOGIC FLOW

In Simulink, data/information from various blocks are sent to another block by lines connecting the relevant blocks. Signals can be generated and fed into blocks dynamic / static).Data can be fed into functions. Data can then be dumped into sinks, which could be scopes, displays or could be saved to a file. Data can be connected from one block to another, can be branched, multiplexed etc. In simulation, data is processed and transferred only at Discrete times, since all computers are discrete systems. Thus, a simulation time step (otherwise called an integration time step) is essential, and the selection of that step is determined by the fastest dynamics in the simulated system.

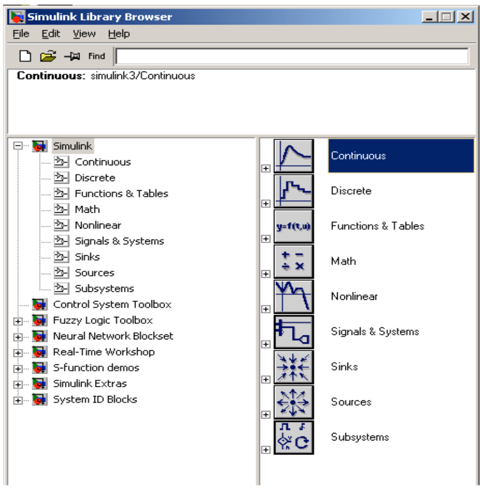

Fig 6.1 Simulink library browser

6.3 CONNECTING BLOCKS

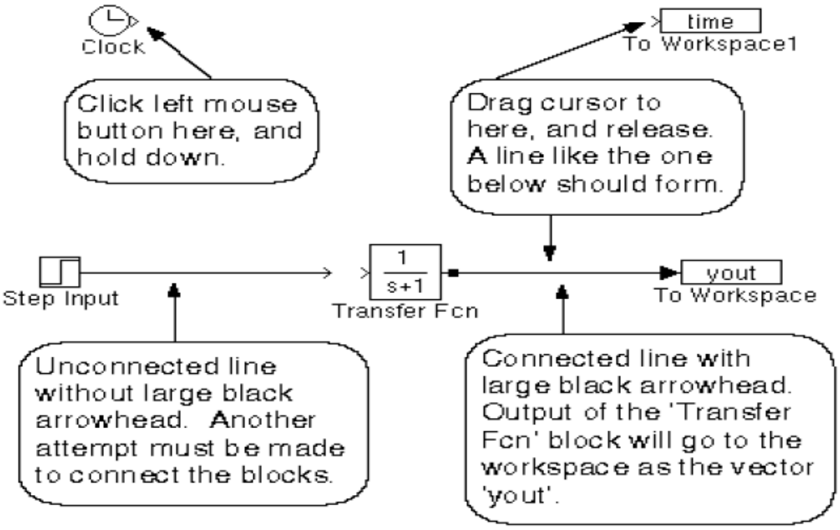

Fig 6.2 Connecting blocks

To connect blocks, left-click and drag the mouse from the output of one block to the input of another block.

6.4 SOURCES AND SINKS

The sources library contains the sources of data/signals that one would use in a dynamic system simulation. One may want to use a constant input, a sinusoidal wave, a step, a repeating sequence such as a pulse train, a ramp etc. One may want to test disturbance effects, and can use the random signal generator to simulate noise. The clock may be used to create a time index for plotting purposes. The ground could be used to connect to any unused port, to avoid warning messages indicating unconnected ports.

The sinks are blocks where signals are terminated or ultimately used. In most cases, we would want to store the resulting data in a file, or a matrix of variables. The data could be displayed or even stored to a file. the stop block could be used to stop the simulation if the input to that block (the signal being sunk) is non-zero. Figure 3 shows the available blocks in the sources and sinks libraries. Unused signals must be terminated, to prevent warnings about unconnected signals.

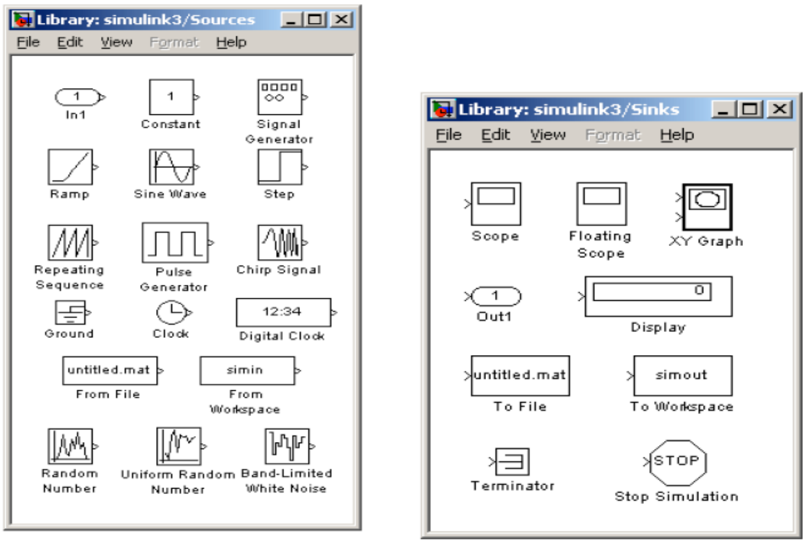

Fig 6.3 Sources and sinks

6.5 CONTINUOUS AND DISCRETE SYSTEMS

All dynamic systems can be analyzed as continuous or discrete time systems. Simulink allows you to represent these systems using transfer functions, integration blocks, delay blocks etc.

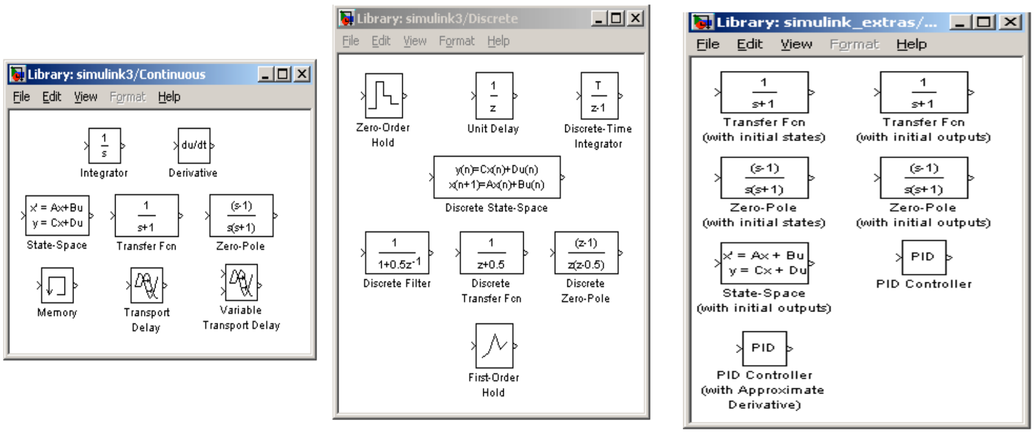

Fig 6.4 continous and descrete systems

6.6 NON-LINEAR OPERATORS

A main advantage of using tools such as Simulink is the ability to simulate non-linear systems and arrive at results without having to solve analytically. It is very difficult to arrive at an analytical solution for a system having non-linearities such as saturation, signup function, limited slew rates etc. In Simulation, since systems are analyzed using iterations, non-linearities are not a hindrance. One such could be a saturation block, to indicate a physical limitation on a parameter, such as a voltage signal to a motor etc. Manual switches are useful when trying simulations with different cases. Switches are the logical equivalent of if-then statements in programming.

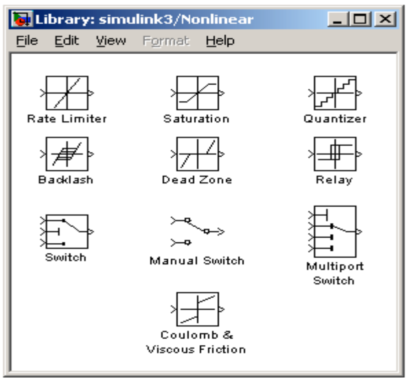

Fig 6.5 simulink blocks

6.7 MATHEMATICAL OPERATIONS

Mathematical operators such as products, sum, logical operations such as and, or, etc. .can be programmed along with the signal flow. Matrix multiplication becomes easy with the matrix gain block. Trigonometric functions such as sin or tan inverse (at an) are also available. Relational operators such as ‘equal to’, ‘greater than’ etc. can also be used in logic circuits

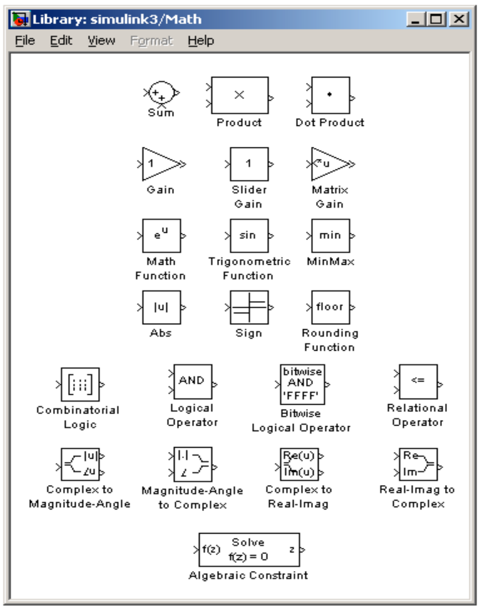

Fig 6.6 Simulink math blocks

6.8 SIGNALS & DATA TRANSFER

In complicated block diagrams, there may arise the need to transfer data from one portion to another portion of the block. They may be in different subsystems. That signal could be dumped into a goto block, which is used to send signals from one subsystem to another.

Multiplexing helps us remove clutter due to excessive connectors, and makes matrix(column/row) visualization easier.

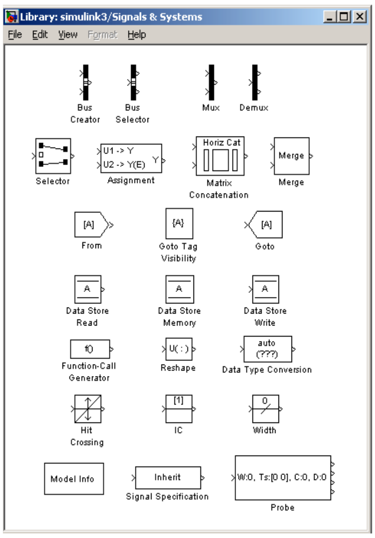

Fig 6.7 signals and systems

6.9 MAKING SUBSYSTEMS

Drag a subsystem from the Simulink Library Browser and place it in the parent block where you would like to hide the code. The type of subsystem depends on the purpose of the block. In general one will use the standard subsystem but other subsystems can be chosen. For instance, the subsystem can be a triggered block, which is enabled only when a trigger signal is received.

Open (double click) the subsystem and create input / output PORTS, which transfer signals into and out of the subsystem. The input and output ports are created by dragging them from the Sources and Sinks directories respectively. When ports are created in the subsystem, they automatically create ports on the external (parent) block. This allows for connecting the appropriate signals from the parent block to the subsystem.

Running a simulation in the computer always requires a numerical technique to solve a differential equation. The system can be simulated as a continuous system or a discrete system based on the blocks inside. The simulation start and stop time can be specified. In case of variable step size, the smallest and largest step size can be specified. A Fixed step size is recommended and it allows for indexing time to a precise number of points, thus controlling the size of the data vector. Simulation step size must be decided based on the dynamics of the system. A thermal process may warrant a step size of a few seconds, but a DC motor in the system may be quite fast and may require a step size of a few milliseconds.

7. SIMULATION RESULTS

The Evaluation of the performance of the proposed converter is done by simulating all the three operation modes by MATLAB/SIMULINK software. The simulation is done setting 0.4 Ω , 6,C=200μF20KHZ with average power of 2.5KW is supplied at the dc link in the proposed system. The dc-link voltage of the converter is regulated at=350V which is a desired condition. In this paper, P & O algorithm has been used to track and . Power of input sources and Load characteristics are discussed below for three modes.

A.First Operation Mode:

In this stage (S=750Wm) square the load power required is =2.5KW (50 ohms) where the maximum available PV power = 1.7KW. There is no need to charge/ discharge the battery. The wind current is set on =4.5A by duty ratio d2=0.75 to regulate on zero value output voltage, while the maximum power of the PV is elicited with the current of = 11.45A and adjusting the first duty ratio at $d1 = 0.7$,So that third and fourth duty ratios are set on $d3 = 0$ and $d4 = 1$, which result the battery power to be set on zero value.

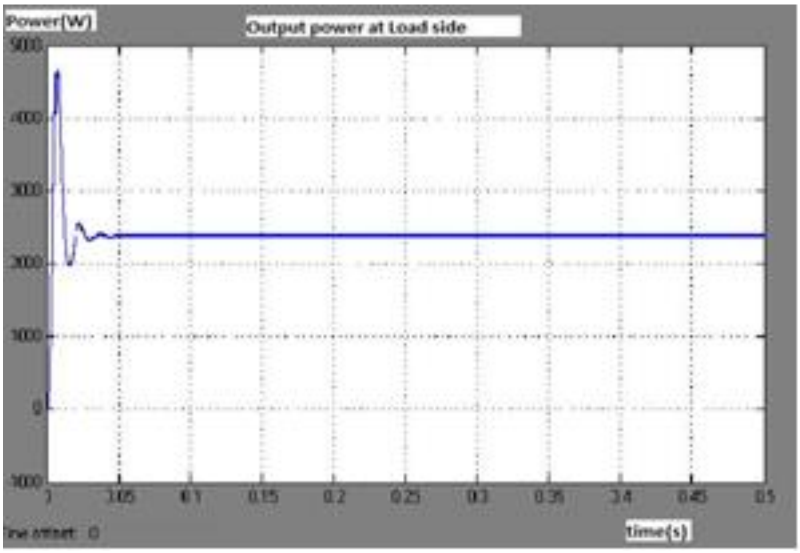

Fig 7.1 Output power at load side for mode 1

B.Second Operation Mode:

This stage occurs in a condition that solar power decreased certain value(S= 500W/m^2) in which the load requires = 2.5 KW and the PV power is simultaneously decreased into =0.45KW.From the maximum deliverable power of the PV, it is obviously understood that the PV is not able to completely supply the power deficiency. Thus, the remaining power should be supplied by the battery. Regulating its current at = 5.3A and adjusting the first duty ratio at d1 = 0.71, maximum power of the wind is delivered at = 15.72A. Adjusting the second duty ratio at d2 = 0.73 and controlling the third and fourth duty ratios at d3 = 1 and d4 = 0.4 results in discharging the battery

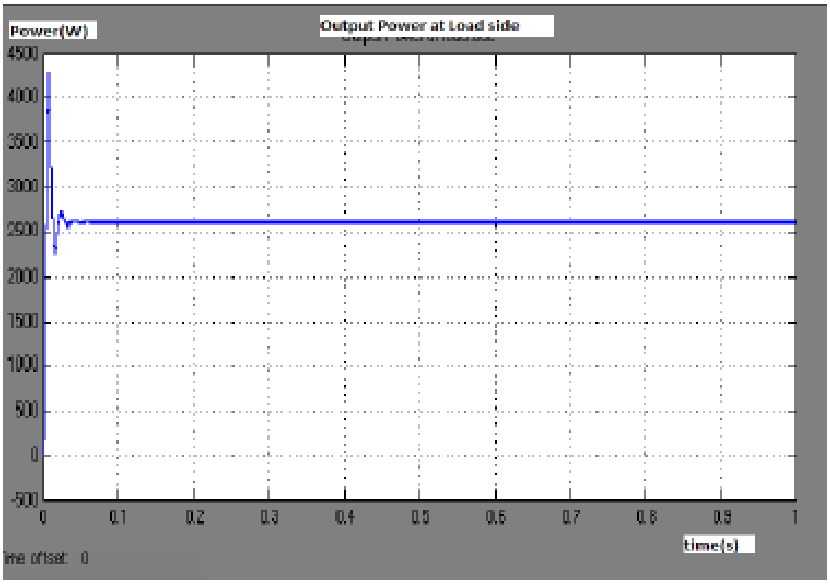

Fig 7.2 Output power at load side for mode 2

C.Third Operation Mode:

In this stage, a step change in the sun irradiation level (S=1000W/m^2), which results to increase the available maximum PV power into =1.7KWwhile the load power remains constant at = 2.5 kW. In this condition, providing charging power of the battery in addition to power deficiency between the PV and the load can be accomplished. The Wind current is regulated with duty ratio d2 = 0.79, while the maximum power of the PV source is tracked with regulating the PV current at = 4.4A and adjusting the first duty ratio at d1 = 0.73. Moreover, controlling the third and fourth duty ratios at d3 = 0.45 and d4 = 0, respectively, results in providing the charging power of the battery in addition to regulating the output voltage.

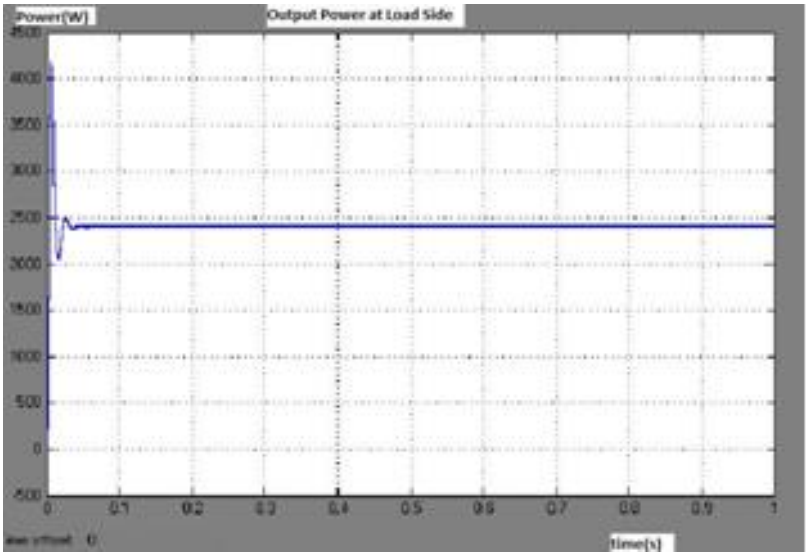

Fig 7.3 Output power at load side for mode 3

Table 7.1 Indicates the analysis of simulation results for the three states based on battery utilization. The values obtained from simulation results are given below

ANALYSIS OF SIMULATION RESULTS FOR THREE MODES

Parameters (Unit)	Simulation Results for Operation Modes		
	Mode1	*Mode2*	*Mode3*
Insolation(W/m^2)	**750**	**500**	**1000**
Load Voltage(V)	346	326.5	350.1
Load Current(A)	6.59	8.1	6.57
Wind Voltage(V)	56.98	55.5	55.8
PV Voltage(V)	45.1	42.8	46.3
Battery State	No operation	Discharge	Charge
Wind Current(A)	11.9	14.5	13.5
PV Current(A)	5.98	1.58	4.4
Battery Power(W)	0	350	300
Wind Power(W)	635	780	665
PV Power(W)	902.5	858	923
Load Power(W)	2384	2635	2462

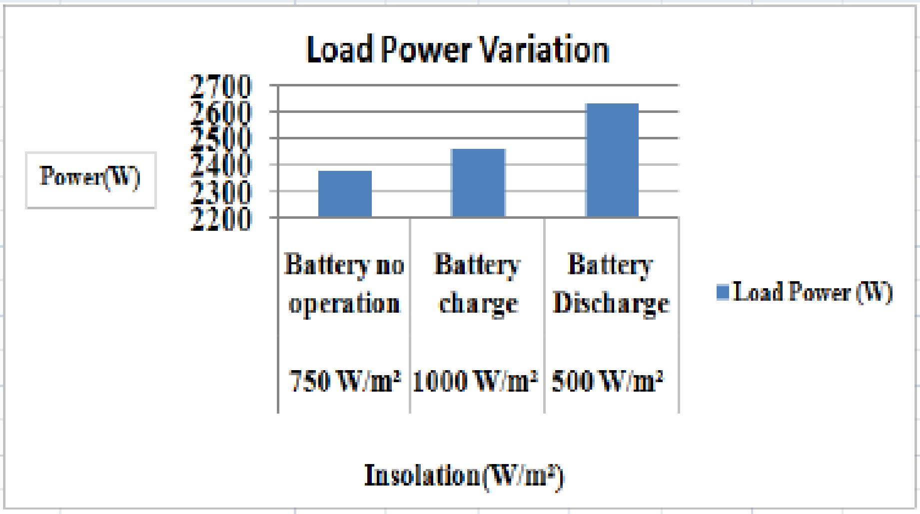

Fig.9. Comparison of output power at load side for three modes

CONCLUSION

This project describes renewable energy hybrid Wind-PV with battery energy storage system. The Analysis of the power converter along with its operational modes has been presented with simulation results which showed that Photovoltaic- Wind hybrid system can perform well to meet the external load using energy storage mechanism. It defies the downside of other types of hybrid power resources. Thus the system has been designed, optimized and control strategy has been considered for DC load that showed satisfactory performance. Due to low power components and bidirectional power flow it has simple structure .In addition, the Proposed Converter can be extended to have *n* input ports although it has only two input ports The other advantages are 1)DC input voltages can be of different magnitudes;2) DC sources can deliver power individually and simultaneously to load. The future work is to extend the system to higher ratings and solve for the synchronization issues.

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