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**Design And Analysis Of Home Application Hybrid Micro Grid (PV–  
Wind) Energy System In Hebron-Palestine**

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## **Abstract**

The Renewable energy becoming popular in the recent decade due to soaring fuel prices and due to technological advancements which reduce the cost of mentioned technology. As well known, the Palestinian energy sector totally depends on the Israeli sector, due to that reason, the cost of electricity is too much high than anywhere else in the world. Because of Solar and Wind sources are the most available once in Palestine they should be used in present project as Hybrid system.

The purpose of this project is to design a hybrid system that combines several energy systems (Photovoltaic and wind turbine) together with control system (PLC), so it can supply high reliable electricity rather than individual sources. This project describes the application of PV-wind hybrid with control system in domestic use, where the average consumption of the houses in domestic sector is found around 4045 Kwh/year. Based on the estimated energy consumption the designed PV system should cover the daily consumption, while the designed wind turbine should the cover night consumption. In addition to the excess or shortages of energy should be delivered to the grid or received from the grid in order to fulfill the required consumption mainly in night time and cloudy weather. The control of the energy exchange and estimation should be realized by PLC system.

The hybrid system will be studied economically in order to estimate its feasibility and the prospects to be applied in large scale in Hebron – Palestine.

Moreover, Unity pro , PV sys and Excel software will be used to analyses and design the hybrid system.

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# Abbreviation

PV	Photovoltaic
HPWS	Hybrid PV And Wind Electricity System
Mpp	Maximum Power Point
FF	Fill Factor
I-V	Current Vs. Voltage
P-V	Power Vs. Voltage
DC	Direct Current
AC	Alternating Current
Isc	Short Circuit Current
Voc	Open Circuit Voltage
VAWT	Vertical Axis Wind Turbines
HAWT	Horizontal Axis Wind Turbines
WS	Wind Speed
DG	Distributed Generation
P.D.F	Probability Density Functions
PMS	Power Management Strategy
P.C.U	Power Condition Unit
LD	Ladder language
ST	Structured Text language
SFC	Sequential Function Chart language
PLC	Programmable Logic Controller

## **Chapter 1**

### **Introduction**

**1.1** Renewable Energy

**1.2** Hybrid Renewable Energy Systems

**1.3** Problem Statement

**1.4** Project Importance

**1.5** Project Objects

**1.6** Motivation

**1.7** Related Previous Work

**1.8** Project Plan

## **Chapter 1:**

### **Introduction**

#### **1.1 Renewable Energy**

Renewable energy is any energy resource that is naturally regenerated over a short time scale and derived directly from the sun (such as thermal, photochemical, and photoelectric), indirectly from the sun (such as wind, hydropower, and photosynthetic energy stored in biomass), or from other natural movements and mechanisms of the environment (such as geothermal and tidal energy). Renewable energy does not include energy resources derived from fossil fuels, waste products from fossil sources, or waste products from inorganic sources. [3]

#### **1.2 Hybrid Renewable Energy Systems**

Hybrid power systems combine two or more energy conversion mechanisms, or two or more fuels for the same mechanism, that when integrated, overcome limitations inherent in either. Hybrid systems provide a high level of energy security and reliability through the integrated mix of complementary generation methods, and often will incorporate a storage system (battery, fuel cell) or fossil-fueled power generation to ensure consistent supply.[3]

#### **1.3 Problem Statement**

Our project has taken randomly house in Hebron as case study, the electrical company in Hebron don't pay for the energy which inject to the grid , most electrical company not allow to inject energy equal double energy load along the year , the importance of the control system (PLC) shown here which let the one of systems (solar or wind turbine system) or twice connect with grid to cover home load just and not inject exceed energy to the grid.

The people are still increase the consuming electricity and the fossil fuels cost are still increasing , also the electricity in Hebron is come from Alqutria Company which sell the electricity at expensive price .In the recently time the people start thinking about using renewable energy because the demand on electricity is increase , so the renewable energy will have a good future in the next century.

As in all renewable energy sources, solar energy has intermittency issues; not shining at night but also during daytime there may be cloudy or rainy weather, also , Solar panels efficiency levels are relatively low (between 14%-25%) compared to the efficiency levels of other renewable energy systems.[6]

Wind can never be predicted. In areas where large amount of wind is needed or winds strength is too low to support wind turbine, there solar or geothermal energy could prove to be great alternatives.[7]

## 1.4 Project Importance:

When we used hybrid system with our control system (PLC) we will solved intermittency issues in electricity which happened in daytime and night if we are used individual system, and we will cover almost all of home load in daytime and night without inject double of power load to the grid continuously along the year .

In general natural energy resources are unpredictable, intermittent, and seasonally unbalanced .Therefore, a combination of two renewable energy sources may satisfy bigger Share of electricity demand and offer reliable and consistent energy supply.

Design The Hybrid PV and Wind Electricity System is well suited to conditions where sun light and wind have seasonal shifts, for example, in summer the sun light is abundant but windless, while in winter wind resource increased that can complement the solar resource.[2]

## 1.5 Project Objects

The project main goals are:

- Using hybrid renewable sources wind and solar energy.
- Design hybrid system contain wind turbine , photovoltaic and grid for house in Hebron.
- The system will be used PLC system for controlled that mean more reliable ,economic , effective system.
- Write the program control by using Unity Pro software in language SFC .
- Cover almost all of home load during the year in daytime and night .
- Study economic feasibility for all system (PV, wind, hybrid) and see which one is the best .
- The system should be able to produce enough and reliable energy for all loads in the home.

## 1.6 Motivation

- The hybrid system which contain several energy sources can be supply reliable electricity rather than system which has individual source .[2]
- When the number of energy source in hybrid system will increase the storage requirement will decrease , that cause the cost of hybrid system will decrease .[4]

- Using more energy source in the hybrid system let the efficiency of the system increase and let the system produce electricity without or with lowest interrupt .[2]
- Due to the contradiction between gradual growth of the global energy demand and diminishing fossil fuel resources, renewable energy such as solar energy, wind energy, bioenergy, and hydropower might become a new manner in which we produce energy for sustainable development. Photovoltaic (PV) and wind energy systems are the most promising candidates of the future energy technologies, and it has been widely noticed that grid connected PV and wind energy markets have grown rapidly.[2]
- So for a safe globe and better life of all living beings on this planet new, clean and renewable sources of energy and related technologies are being sought, developed and implemented worldwide. These alternative sources of energy include wind, solar, geothermal, tidal, wave, and biofuels. The applications of these sources include the very small to large isolated, grid connected and hybrid power systems. Moreover, the hybrid power systems exhibit higher reliability and lower cost of generation than those that use only one source of energy .[4]

## 1.7 Related Previous Work

There are many references and paper talk about hybrid system and the benefit of this system for example :

- Performance Analysis of a Grid Connected Hybrid Photovoltaic and Wind Electricity Generation System in Cold Climate .This paper say a Hybrid Photovoltaic and Wind Electricity Generation System has been monitored and analyzed over a period of two years at Central Finland in order to examine the behavior of grid-connected hybrid system in cold climate. The monitoring results showed that the grid connected hybrid system is more reliable than the single renewable resource power system. [2]
- Feasibility study of a Wind-PV-Diesel hybrid power system for a village .This paper say the Wind-PV-Diesel hybrid system with 35% renewable energy penetration (26% wind and 9% solar) and 65% diesel power was found to be the most economical power with system only diesel . [4]
- Simulation of a Hybrid Power System Consisting of Wind Turbine, PV, Storage Battery and Diesel Generator with Compensation Network: Design, Optimization and Economical Evaluation .This paper say for wind, PV, diesel with a storage battery bank hybrid system the cost of energy (COE) equals to 1.28 NIS/kWh , for for wind-only system, the COE is 1.57 NIS/kWh , for PV-only system, the COE is 1.55 NIS/kWh . [8]

# 1.8 Project Plan

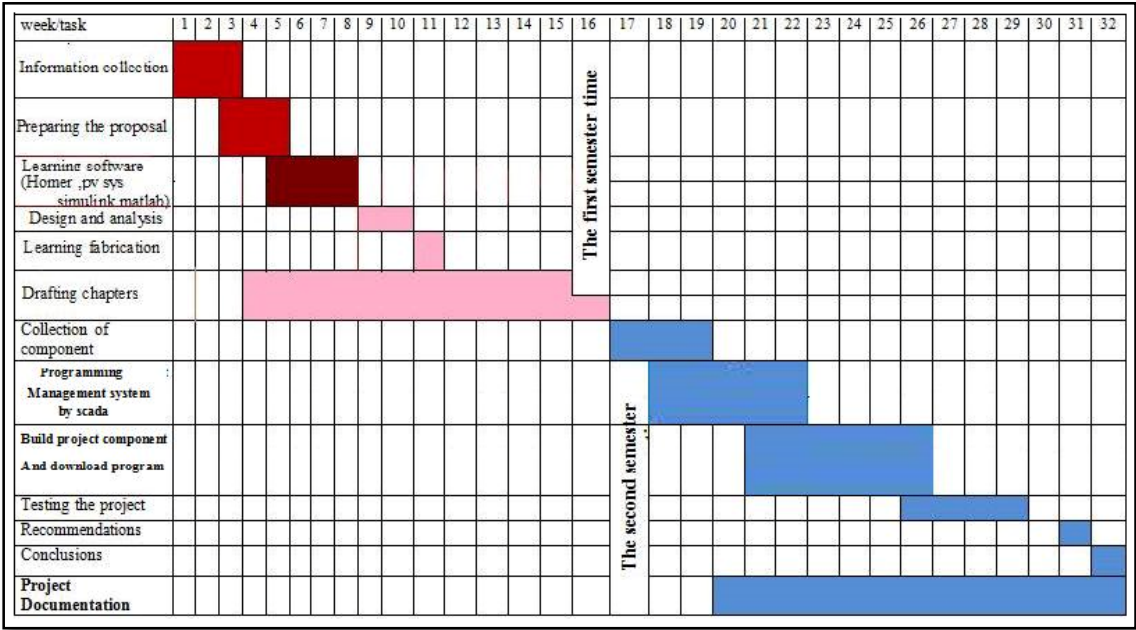


Figure 1.1:Project plan

## **Chapter 2:**

### **Description And Modeling Of Photovoltaic-Wind System**

#### **2.1 Description And Modeling Of Photovoltaic System**

#### **2.2 Description and Modeling of wind turbine system**

## Chapter 2:

### Description And Modeling Of Photovoltaic-Wind System

This chapter provides an overview of the main components and modeling of photovoltaic – wind system and also control system between them and also main grid such a system includes a source of power (PV), wind turbine ,in addition main grid. The system provides electrical energy continuously without interruption.

Photovoltaic, or PV is a solar power technology to convert energy directly from sunlight into electricity. Solar cells or PV cells are the devices to produce direct current electricity (DC) from the sun's rays.

Wind power is conversion of wind energy into more useful forms, usually to generate electricity by using wind turbines. A wind turbine is a machine for converting the kinetic energy in wind first into mechanical energy then to electricity by a generator.

Any power system that incorporates more than one generator is referred to as a hybrid power system. The electric generator could mean, for example, PV array, wind turbine, hydro generator, or diesel, gasoline generators. In our case, a Hybrid PV and Wind Electricity System (HPWS) is a power system that contains PV cells and wind turbine to generate electricity. [2]

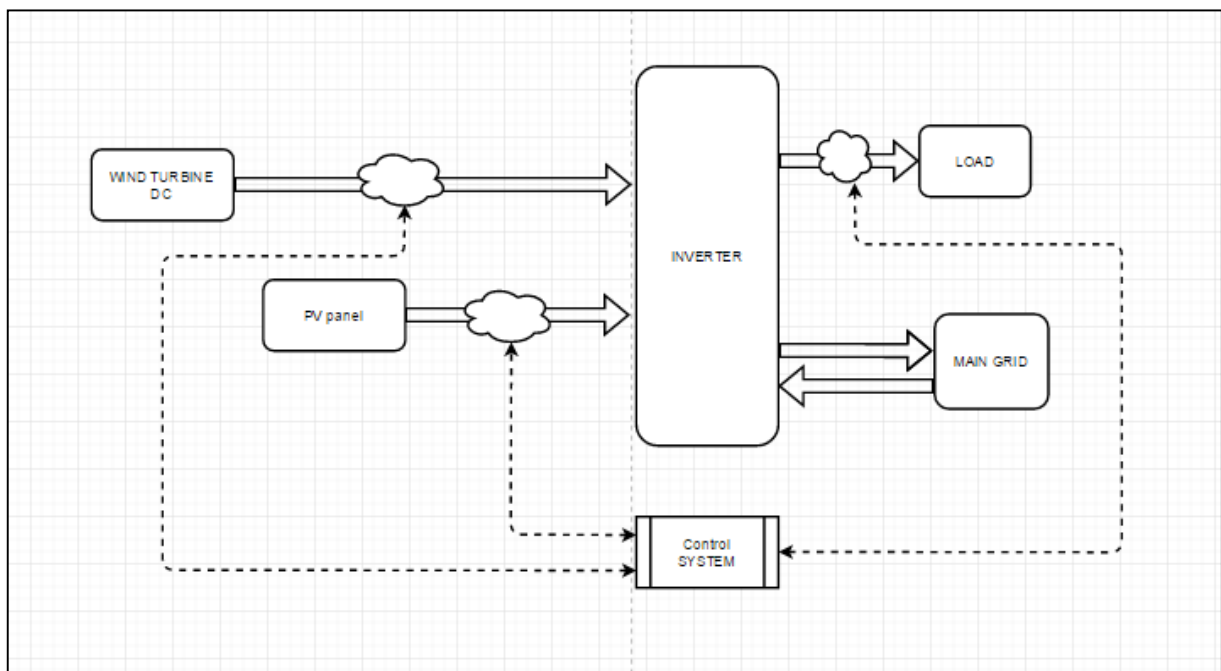


Figure 2.1 : Logical Block Diagram For Hybrid System

## 2.1 Description And Modeling Of Photovoltaic System

### 2.1.1 Photovoltaic

Photovoltaic cells are made of semi-conducting materials and the most commonly used material is silicon. When sunlight is absorbed by these materials, the solar energy knocks electrons loose from their atoms, allowing the electrons to flow through the material to produce electricity. [11]

A single PV cell typically produces a small amount of power and in order to increase the operating voltage, the cells are connected in series to form a PV module. A photovoltaic array consists of a number of electrically connected PV modules, which can be connected together in series to generate a higher voltage or in parallel to get a higher current. Fig 2.2 shows the conceptual relationship between the PV cell, module and array. [11]

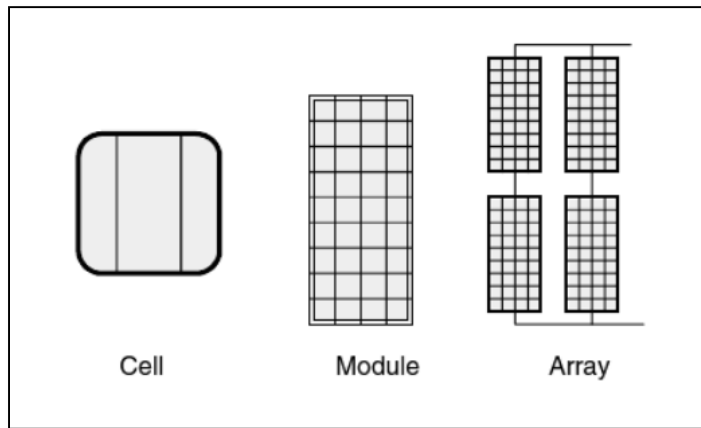


Figure 2.2: Conceptual relationship between the PV cell, module and array.[11]

### 2.1.2 Characteristics Of Photovoltaic Module

The performance of a photovoltaic module depends on manufacturing technology and operating conditions (solar radiation and temperature). The curve of current – voltage (I-V) which determines the behavior of a photovoltaic cell is represented in figure 2.3 .

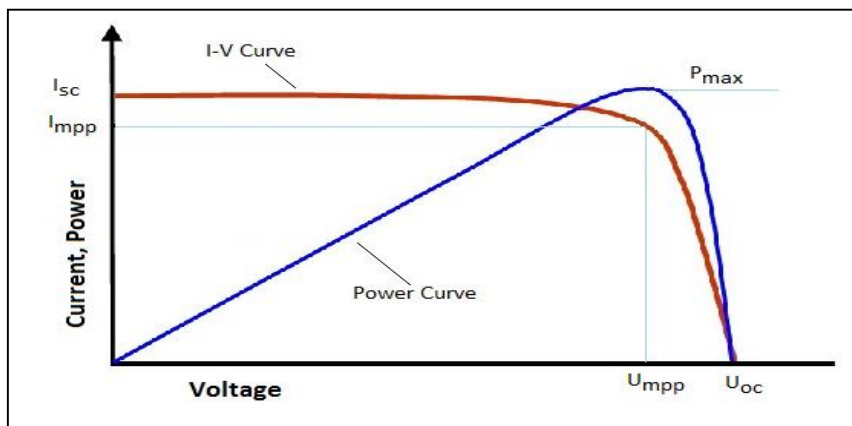


Figure 2.3: I-V and P-V characteristics of typical PV module.[13]

The main electrical parameters that describe the performance of a Photovoltaic cell are :

1. Short circuit current ( $I_{sc}$ )

The value of ( $I_{sc}$ ) can be obtained by connecting the terminals of a module via an ammeter and measuring the current .The value of  $I_{sc}$  changes in function of solar radiation and very little of temperature.

2. Open circuit voltage( $V_{oc}$ )

It's the voltage of a PV module measured at terminals at no load.

3. Maximum power point (Mpp)

The maximum power point of a photovoltaic is a unique point on the (I-V) or (P-V) Characteristics and the power supplied in this point is maximum , where measured in Watts (W). its value can be calculated by the product  $V_{max}$  and  $I_{max}$ .

4. Fill Factor (FF)

The ratio of output power at maximum power point to the power computed by multiplying  $I_{sc}$  by  $V_{oc}$  , as illustrated in figure 2.4.

The FF is obtained according the following equation:

$$FF = (V_{mpp} \cdot I_{mpp}) / V_{oc} \cdot I_{sc} \dots\dots\dots(2.1)$$

It is important performance indicator .

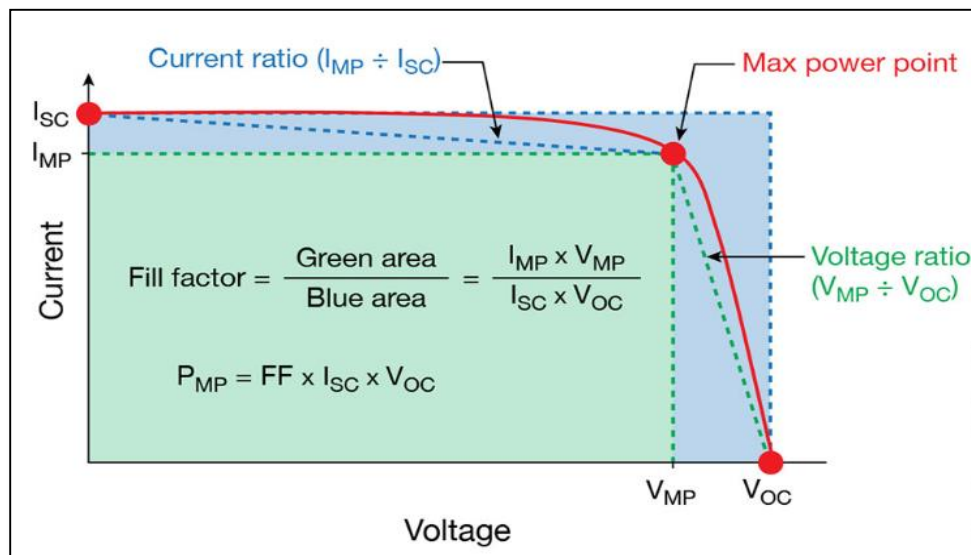


Figure 2.4: The I-V curve of a PV module for defining the FF .[12]

Typically , crystalline silicon photovoltaic FF module is between 0.67 and 0.74. If the I-V curves of two individual PV modules have the same values of  $I_{sc}$  and  $V_{oc}$  , the array with the higher fill factor (squarer I-V curve) will produce more power. Also , any impairment that reduces the fill factor will reduce the output power [12].

### 2.1.3 Modeling Of Photovoltaic Cell

The equivalent electrical circuit of one-diode model consists of a real diode in parallel with a current source. The current source produces the current ( $I_{ph}$ ) and the current ( $I_d$ ) flows through diode. The current ( $I_c$ ) which flows to the load is the difference between ( $I_{ph}$ ) and ( $I_d$ ) and it is reduced by the resistances ( $R_s$ ) and  $R_p$ . [13].

Two resistances ( $R_s$ ) and ( $R_p$ ), are included to model the contact resistances and the internal PV cell resistance respectively.

The value of these two resistances can be obtained from measurements or by using curve fitting methods based on the I-V characteristic of PV.

The equivalent electrical circuit for a PV cell or module is illustrated in figure 2.5.

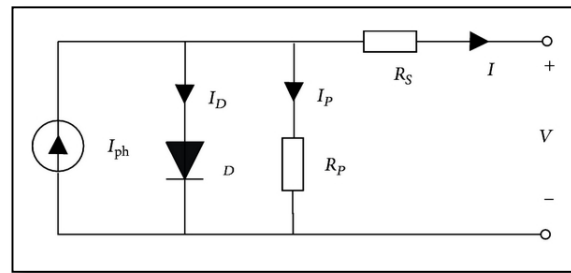


Figure 2.5: Equivalent circuit of PV. [13]

The current source ( $I_{ph}$ ) depended on the solar radiation and the ambient temperature. The (I-V) characteristics of photovoltaic cell can be determined by the following equations. The terminal current of the model ( $I_L$ ) is given by:

$$I_L = I_{ph} - I_d - I_p \dots\dots\dots(2.2)$$

Where

$I_{ph}$  : photocurrent from photovoltaic cell (A)

$I_d$ : is the current passing through none linear diode (A)

$I_p$ : current through shunt resistance (A)

The photocurrent  $I_{ph}$  is a function of solar radiation and temperature, it is determined from equation:

$$I_{ph} = [I_{sc} + k_i(T_c - T_r)]G/G_n \dots\dots\dots(2.3)$$

Where

$I_{sc}$  : is the short-circuit of the cell at standard test condition (STC:  $G_n = 1000W/m$  and  $T_r = 298.15K$ ) [A].

$K_i$  : is the short-circuit temperature co- efficient of the cell [A/K]

$T_c$  and  $T_r$  : are the working temperatures of the cell and reference temperature respectively[k]

$G$  and  $G_n$  : are the working solar radiation and nominal solar radiation respectively [w/m]

The diode saturation current  $I_d$  of the cell varies with the cell temperature which is expressed in equation:

$$I_d = I_o[e(q(V_L + I_L R_s) A k T_c)] \dots\dots\dots(2.4)$$

Where

$I_o$ : reverse saturation current of the diode [A]

$q$ : is the electron charge [ $1.6021 \times 10^{-19}$  C]

$V_L$ : output voltage of the photovoltaic cell [V]

$R_s$ : series resistance of cell [ $\Omega$ ]

$A$ : is the ideality constant of diode depend on the PV technology

$K$ : boltzman constant [ $1.38 \times 10^{-23}$  j/k]

The shunt current  $I_p$  is given by equation:

$$I_p = (V_L + I_L R_s) / R_p \dots\dots\dots(2.5)$$

Where  $R_p$  is parallel resistance [ $\Omega$ ]

## 2.1.4 Modeling Of Photovoltaic Module

A PV module is the result of connecting several PV cell in series in order to increase the output voltage . the characteristic has the same shape except for changes in the magnitude of the open circuit voltage . as shown in figure (2.6).

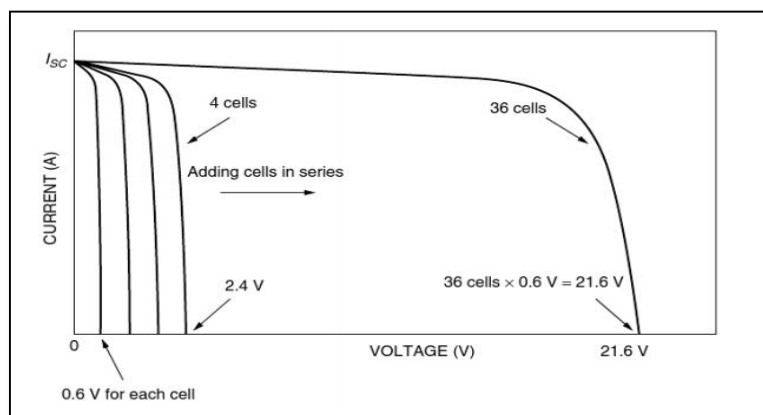


Figure 2.6: The I-V characteristics of a typical PV module consisting of 36 cells connected in series.[12]

The output voltage of a PV module is calculated by :

$$V_{\text{module}} = n(V_d - I L R_s) \dots\dots\dots (2.6)$$

Where

$n$ : is the number pf PV cells connected in series in module

$V_d$ : is the voltage of the diode of the equivalent circuit of the cell [V].

### 2.1.5 Modeling Of Photovoltaic Array

The PV array are composed of some combination of series and parallel of PV modules. The modeling of pv arrays is the same as modeling of the PV module from the PV cells. Modules in series, the (I-V) curves are simply added along the voltage axis. The total voltage is just the sum of the individual module voltages. [14]

For PV modules connected in parallel the total current is the sum of the currents of the modules whereby the total output voltage is equal to the voltage of the module, as shown in figure 2.7:

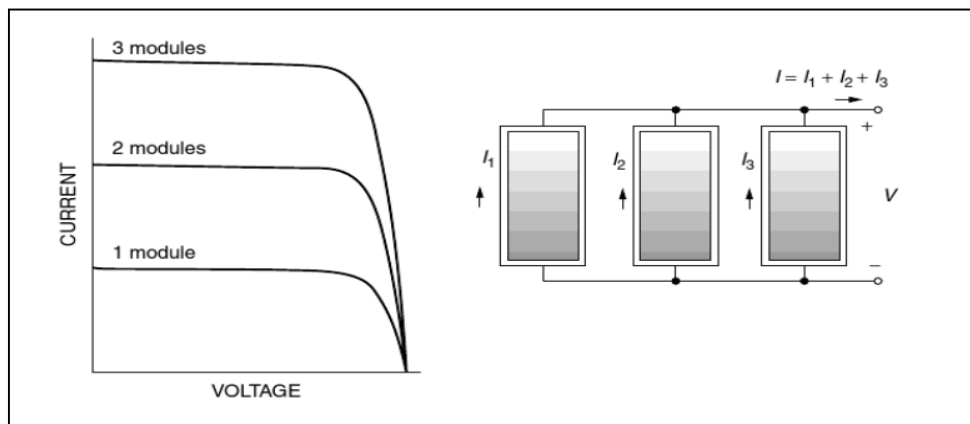


Figure 2.7: The I-V curve for 3 PV modules connected in parallel.[14]

For PV modules connected in series the total voltage is just the sum of the individual module voltages whereby the total output current is equal to the voltage of the module, as shown in figure 2.8:

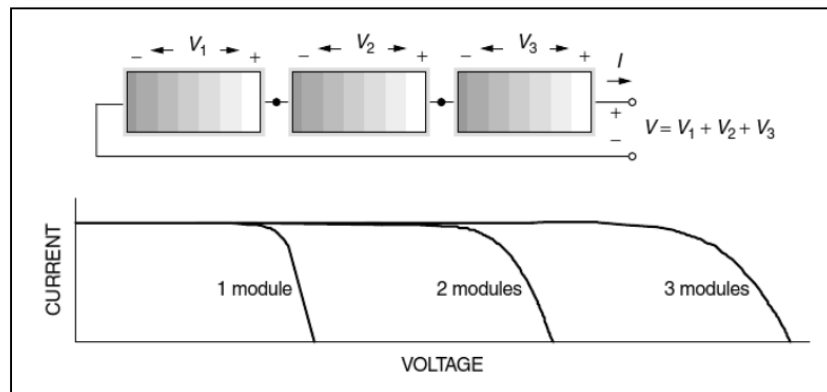


Figure 2.8: The I-V curve for 3 PV modules connected in series. [14]

Practically the PV array will consist of a combination of series and parallel modules depending on the needed output power of the system is needed.

### 2.1.6 Converter DC/DC

DC-to-DC converter is an electronic circuit which converts a source of direct current (DC) from one voltage level to another. So the converter use to conversion raises or lowers the incoming PV voltage and adjust the output to greatest efficiency.[2]

### 2.1.7 Inverter DC/AC

An inverter is a circuit for converting direct current (DC) to alternating current (AC), which acts as the interface between the PV arrays and the utility grid.[15]

In general, the inverters can be classified as in figure (2.9) :

- Central inverters
- String inverters
- Module integrated inverters (AC modules)
- Multi-string inverters

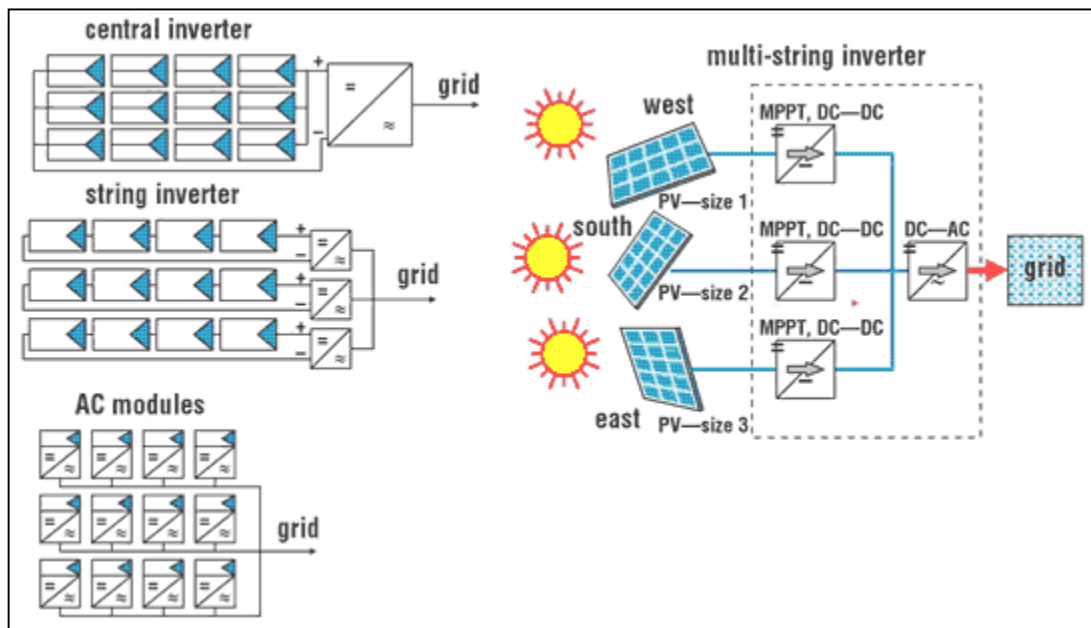


Figure 2.9: Basic design concepts for PV installations: central, string, multistring or AC module inverters.[15]

### 2.1.8 The Important Equations Which Use In PV System Design

1. power parameters:

$$P_{ac} = E_{tot} / (H_{peak \text{ sun hour}} * 365) \dots\dots\dots(2.7)$$

$$P_{dc} = P_{ac} / \mu_{conventional} \dots\dots\dots(2.8)$$

2. PV sizing :

$$Area = P_{dc} / (1kwh * \mu_{pv}) \dots\dots\dots(2.9)$$

$$Area \text{ of the roof that we need} = Area / 0.4 \dots\dots\dots(2.10)$$

$$Number \text{ of panel} = area / area \text{ of } 1 \text{ panel} \dots\dots\dots(2.11)$$

3. fuse parameters:

$$Combiner \text{ fuse} \geq 1.25 * 1.25 * I_{sc} \dots\dots\dots(2.12)$$

$$Array \text{ disconnecter fuse} \geq \# \text{ of string} * I_{combiner \text{ fuse}} \dots\dots\dots(2.13)$$

$$Inverter \text{ fuse} \geq 1.25 * (inverter \text{ output power} / inverter \text{ output voltage}) \dots\dots\dots(2.14)$$

## 5. Diode Parameter:

$$I_{diode} = I_{sc} * 1.25 \dots\dots\dots(2.15)$$

$$V_{diode} = V_{oc} * 1.25 \dots\dots\dots(2.16)$$

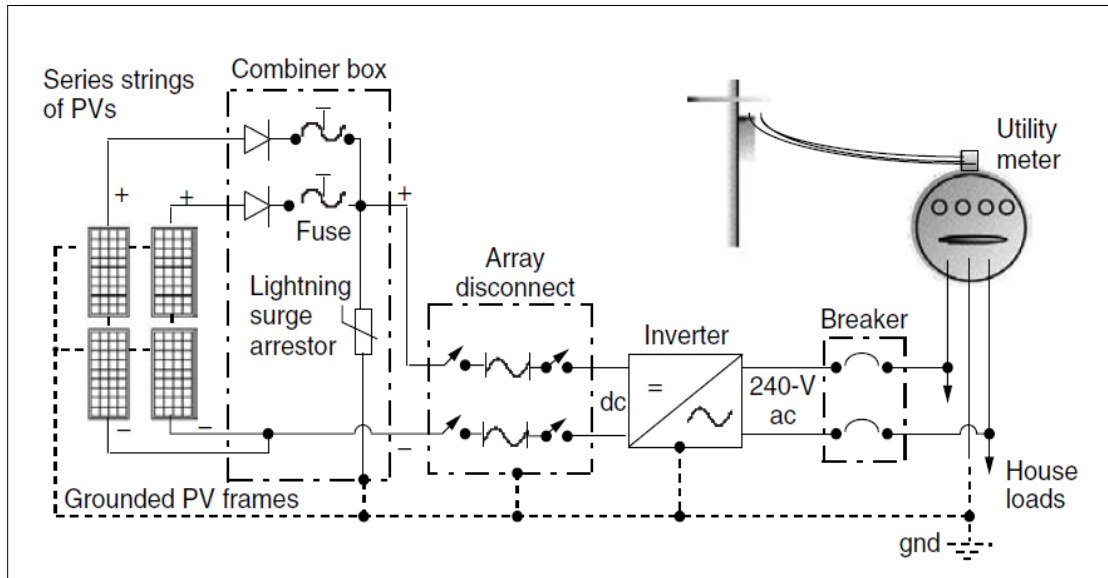


Figure 2.10: Principal components in a grid-connected PV system using a single inverter.[1]

## 2.2 Description and Modeling of wind turbine system

### 2.2.1 Wind turbine

A wind turbine is a machine for converting the kinetic energy in wind into mechanical energy. Wind turbine's working principle is the opposite of a fan. Instead of using electricity to make wind like a fan, wind turbines use wind to generate electricity. When the wind blows, the combination of lift and drag forces on turbine blades causes the rotor to spin, and the turning shaft spins a generator to generate electricity. [3]

### 2.2.2 Parts of a Wind Turbine

The wind turbine contains:

- The nacelle ,including the gearbox, and the electrical generator.
- The tower of the wind turbine carries the nacelle and the rotor. Generally, it is an advantage to have a high tower, since wind speeds increase farther away from the ground.
- The rotor blades capture wind energy and transfer its power to the rotor hub.
- The generator converts the mechanical energy of the rotating shaft to electrical energy.
- The gearbox, increases the rotational speed of the shaft for the generator.

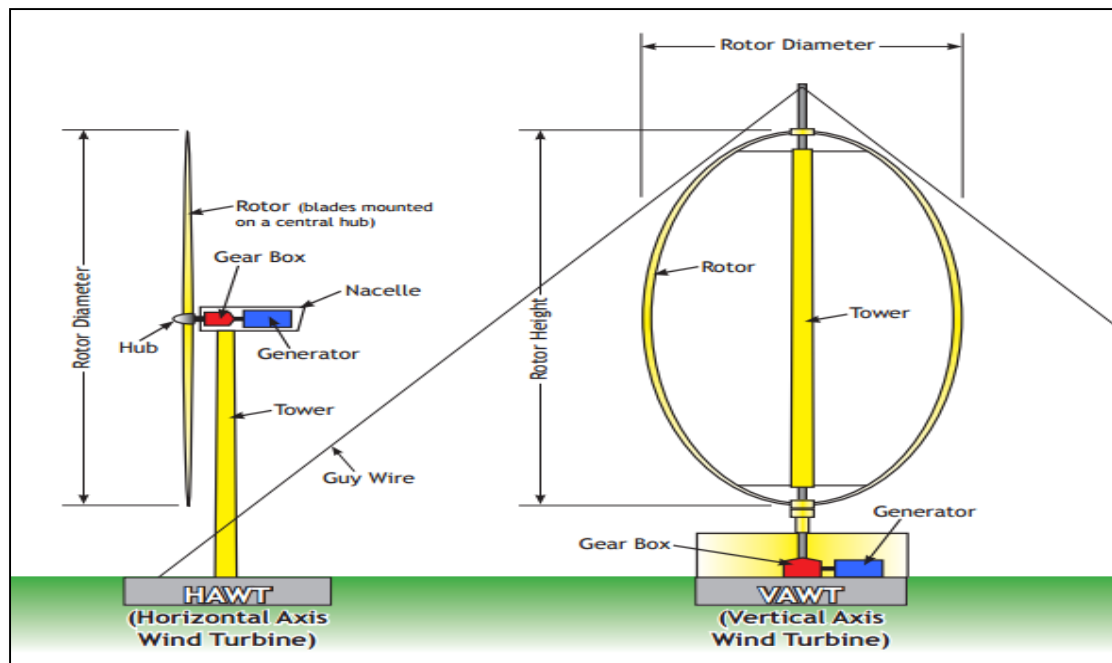


Figure 2.11: Parts of a Wind Turbine.[16]

### 2.2.3 Types of Wind Turbines

Wind turbines are classified into two general types: Horizontal axis and Vertical axis.. There are a number of available designs for both and each type has certain advantages and disadvantages. However, compared with the horizontal axis type, very few vertical axis machines are available commercially.[16]

#### a. Vertical Axis Wind Turbines (VAWT)

Machine has blades rotating on an axis perpendicular to the ground. Although vertical axis wind turbines have existed for centuries, they are not as common as their horizontal counterparts. The main reason for this is that they do not take advantage of the higher wind speeds at higher elevations above the ground as well as horizontal axis turbines.[3]

Example for Vertical Axis Wind Turbines (VAWT):

##### 1. Savonius Wind Turbine

The Savonius turbine is S-shaped if viewed from above. This drag-type VAWT turns relatively slowly, but yields a high torque. It is useful for grinding grain, pumping water, and many other tasks, but its slow rotational speeds make it unsuitable for generating electricity on a large-scale.

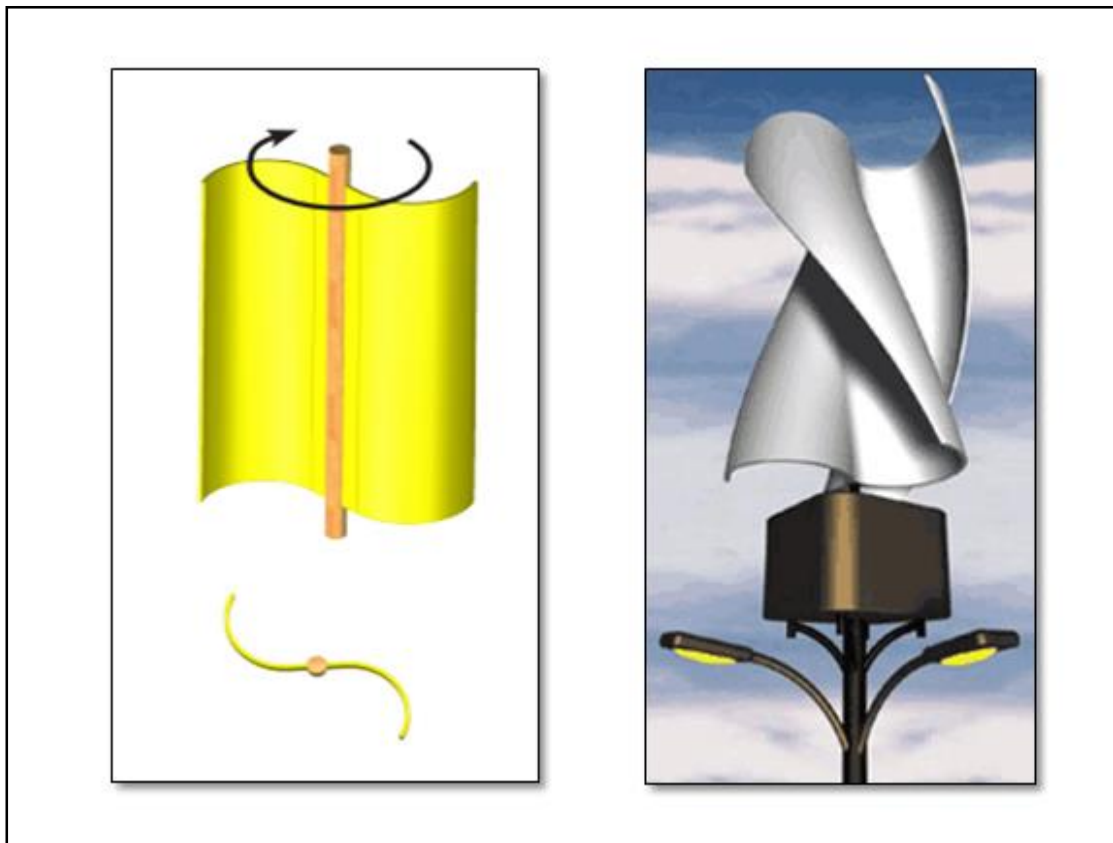


Figure 2.12: Savonius Wind Turbine

## 2. Darrieus Wind Turbine

The Darrieus turbine is the most famous vertical axis wind turbine. It is characterised by its C-shaped rotor blades which give it its eggbeater appearance. It is normally built with two or three blades.

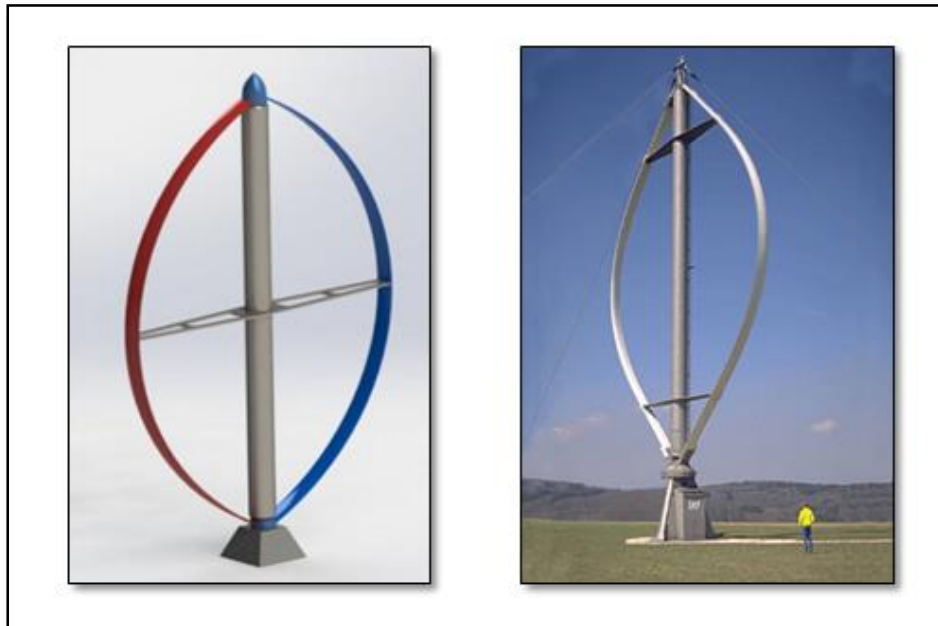


Figure 2.13: Darrieus Wind Turbine

## 3. Giromill Wind Turbine

The giromill is typically powered by two or three vertical aerofoils attached to the central mast by horizontal supports. Giromill turbines work well in turbulent wind conditions and are an affordable option where a standard horizontal axis windmill type turbine is unsuitable.



Figure 2.14: Giromill Wind Turbine

## b. Horizontal Axis Wind Turbines (HAWT)

Machine has its blades rotating on an axis parallel to the ground. It is the most common wind turbine design. In addition to being parallel to the ground, the axis of blade rotation is parallel to the wind flow.[3]

Example for Horizontal Axis Wind Turbines (HAWT):

### 1. Up-Wind Turbines

Some wind turbines are designed to operate in an upwind mode (with the blades upwind of the tower). Large wind turbines use a motor-driven mechanism that turns the machine in response to a wind direction. Smaller wind turbines use a tail vane to keep the blades facing into the wind.

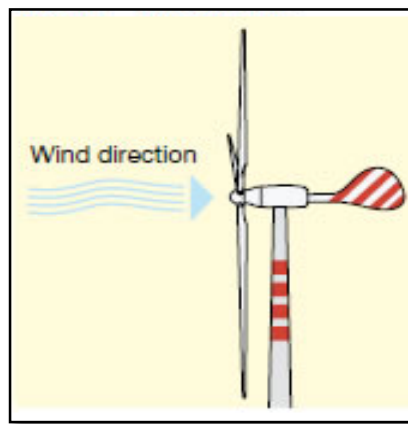


Figure 2.15: Up-Wind Turbine.[16]

### 2. Down-Wind Turbines

Other wind turbines operate in a downwind mode so that the wind passes the tower before striking the blades. Without a tail vane, the machine rotor naturally tracks the wind in a downwind mode.

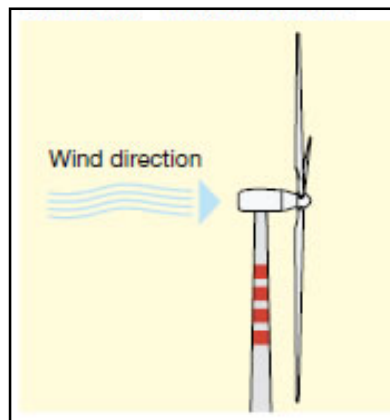


Figure 2.16: Down-Wind Turbine[16]

### 3. Shrouded Wind Turbines

Some turbines have an added structural design feature called an augmentor. The augmentor is intended to increase the amount of wind passing through the blades.

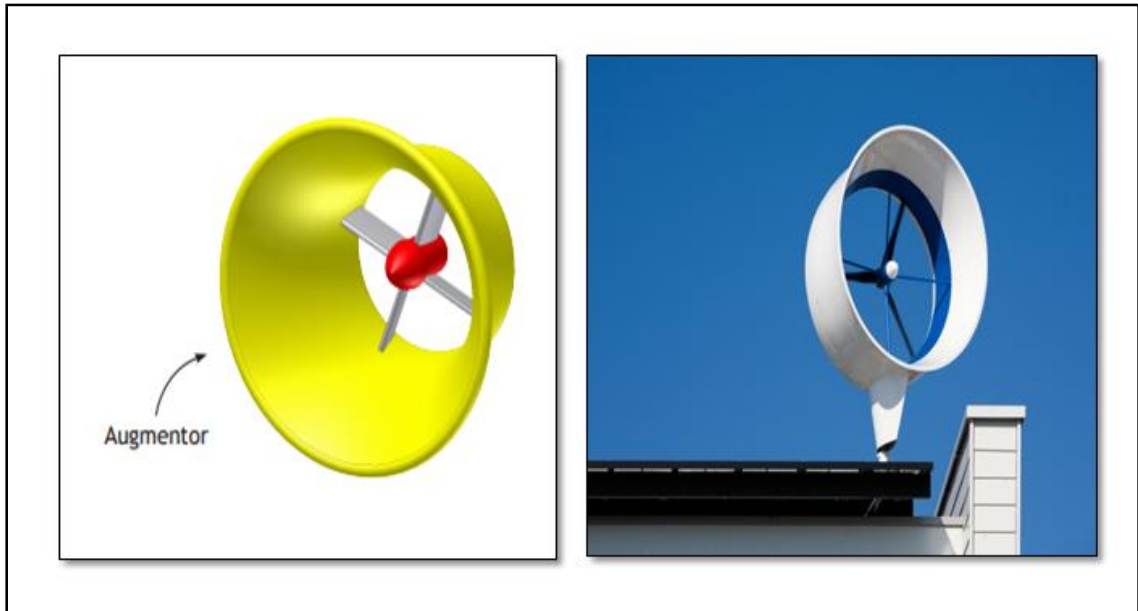


Figure 2.17: Shrouded Wind Turbine

## 2.2.4 Indirect Grid Connection Systems

The wind turbine is allowed to spin at whatever speed that is needed to deliver the maximum amount of power. When attached to a synchronous or induction generator, the electrical output will have variable frequency depending on whatever speed the wind turbine happens to have at the moment. This means that the generator cannot be directly connected to the utility grid, which of course requires fixed 50- or 60-Hz current.

Figure 2.18 shows the basic concept of these indirect systems. Variable frequency ac from the generator is rectified and converted into dc using high power transistors. This dc is then sent to an inverter that converts it back to ac, but this time with a steady 50- or 60-Hz frequency.

Notice in our project we will replace the wind turbine ac and rectifier with wind turbine dc because that is lower cost.

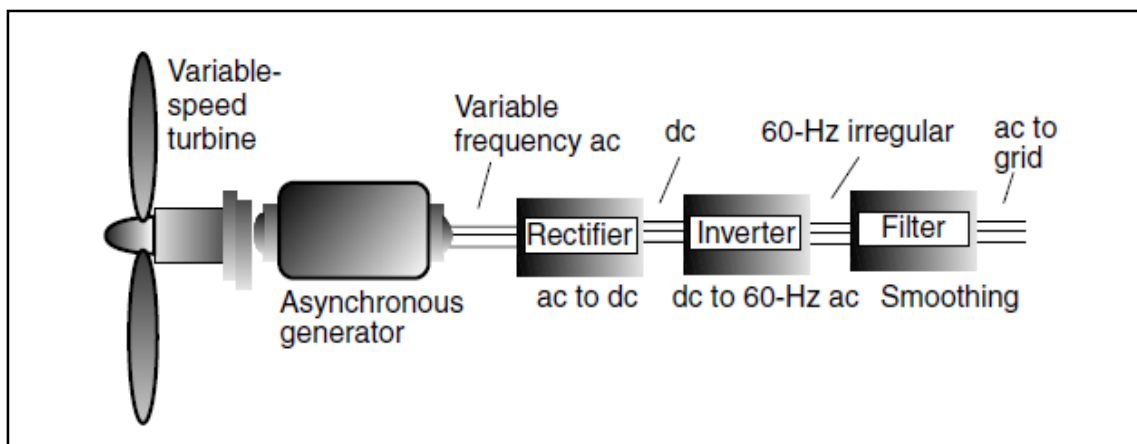


Figure 2.18: Variable-frequency output of the asynchronous generator is rectified, inverted, and filtered to produce acceptable 60-Hz power to the grid.[1]

### 2.2.5 Power In The Wind

The wind has kinetic energy , we can use this kinetic energy to generate power by using Wind turbine . We can determine the power in the wind from this equation :

$$P_w = \frac{1}{2} * \rho * A * v^3 \dots\dots\dots (2.17)$$

Where :

$\rho$  : Air density (kg/m<sup>3</sup>)

A : is the cross-sectional area through which the wind passes (m<sup>2</sup>)

V : Wind speed normal to A (m/s)

Notice the power per square meter of cross section , this quantity is called the Specific power or Power density.

### 2.2.6 Air Density

When wind power data are presented, it is often assumed that the air density is 1.225 kg/m<sup>3</sup>; that is, it is assumed that air temperature is 15°C and pressure is 1 atmosphere. Using the ideal gas law, we can easily determine the air density under other conditions from this equation :

$$\rho = \frac{n * MW * 10^{-3}}{R * T} \dots\dots\dots (2.18)$$

Where :

$\rho$  : air density (kg/m<sup>3</sup>)

n : is the mass (mol)

R : is the ideal gas constant = 8.2056 \* 10<sup>-5</sup>( m<sup>3</sup> \* atm \* mol<sup>-1</sup> \* K<sup>-1</sup>)

T : is the absolute temperature , where K= C + 273.15 (K)

MW: molecular weigh of air = 28.97 (g/mol)

### 2.2.7 Impact Of Tower Height

Power in the wind speed is proportional to the cube of the wind speed. the wind speed is proportional to the Tower height . So we can determine the wind speed at any height from this equation :

$$\left(\frac{v}{v_0}\right) = \left(\frac{H}{H_0}\right)^\alpha \dots\dots\dots (2.19)$$

Where :

$V$  : is the wind speed (m/s) at height  $H$  (m)

$V_0$  : is the wind speed (m/s) at height  $H_0$  (m)

$\alpha$  : is the friction coefficient.

## 2.2.8 Wind Power Probability Density Functions

The type of information displayed in the discrete windspeed is very often presented as a continuous function, called a probability density function (p.d.f.). The defining features of a p.d.f., such as that shown in Fig. 2.19, are that the area under the curve is equal to unity, and the area under the curve between any two windspeeds equals the probability that the wind is between those two speeds. Expressed mathematically.

$f(v)$  = windspeed probability density function

$$\text{probability } (v_1 \leq v \leq v_2) = \int_{v_1}^{v_2} f(v) dv \dots\dots\dots(2.20)$$

$$\text{probability } (0 \leq v \leq \infty) = \int_{v_1}^{\infty} f(v) dv = 1 \dots\dots\dots(2.21)$$

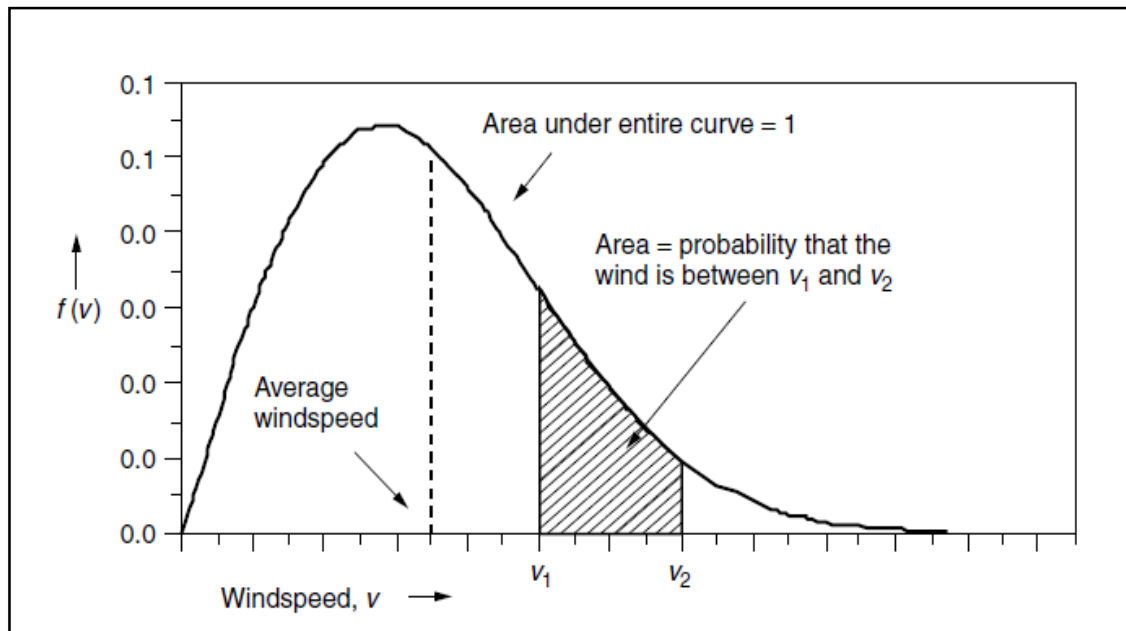


Figure 2.19: A windspeed probability density function (p.d.f.).[1]

### 2.2.9 Weibull And Rayleigh Statistics

A very general expression that is often used as the starting point for characterizing the statistics of windspeeds is called the Weibull probability density function :

$$f(v) = \frac{k}{c} * \left(\frac{v}{c}\right)^{k-1} * e^{-\left(\frac{v}{c}\right)^k} \dots\dots\dots (2.22)$$

Where :

K : shape parameter

C : scale parameter

V : wind speed

When the shape parameter k is equal to 2 , the p.d.f is called Rayleigh probability density function:

$$f(v) = \frac{2v}{c^2} * e^{-\left(\frac{v}{c}\right)^2} \dots\dots\dots (2.23)$$

Also

$$c = \frac{2}{\sqrt{\pi}} * \bar{v} \dots\dots\dots (2.24)$$

K = 2

The average value of the cube of windspeed in case Rayleigh p.d.f :

$$(v^3)_{avg} = \frac{3}{4} * \sqrt{\pi} * \left(\frac{2\bar{v}}{\sqrt{\pi}}\right)^3 = \frac{6}{\pi} * \bar{v}^3 = 1.91 \bar{v}^3 \dots\dots\dots (2.25)$$

The avarege power in the wind in case Rayleigh p.d.f

$$\bar{P} = \frac{6}{\pi} * \frac{1}{2} * \rho * A * \bar{v}^3 \dots\dots\dots (2.26)$$

### 2.2.10 Cumulative Distribution Function

The probability that the wind is less than some specified wind speed  $V$  is given by :

$$F(V) = \text{prob}(v < V) = \int_0^V f(v)dv \dots\dots\dots(2.27)$$

The probability that the wind speed is below cut-in speed :

$$F(V_c) = \text{prob}(v < V_c) = 1 - e^{-\frac{\pi}{4} \left(\frac{V_c}{\bar{v}}\right)^2} \dots\dots\dots(2.28)$$

The number of hours per year the wind will be less than cut-in speed :

$$\text{Hours}(v < V_c) = 8760 \times F(V_c) \dots\dots\dots(2.29)$$

The probability that the wind speed is above rated speed :

$$F(V_R) = \text{prob}(v > V_R) = e^{-\frac{\pi}{4} \left(\frac{V_R}{\bar{v}}\right)^2} \dots\dots\dots(2.30)$$

The number of hours per year the wind will be less than rated speed :

$$\text{Hours}(v > V_R) = 8760 \times F(V_R) \dots\dots\dots(2.31)$$

The probability that the wind speed is above cut-out speed :

$$F(V_f) = \text{prob}(v > V_f) = e^{-\frac{\pi}{4} \left(\frac{V_f}{\bar{v}}\right)^2} \dots\dots\dots(2.32)$$

The number of hours per year the wind will be less than cut-out speed :

$$\text{Hours}(v > V_f) = 8760 \times F(V_f) \dots\dots\dots(2.33)$$

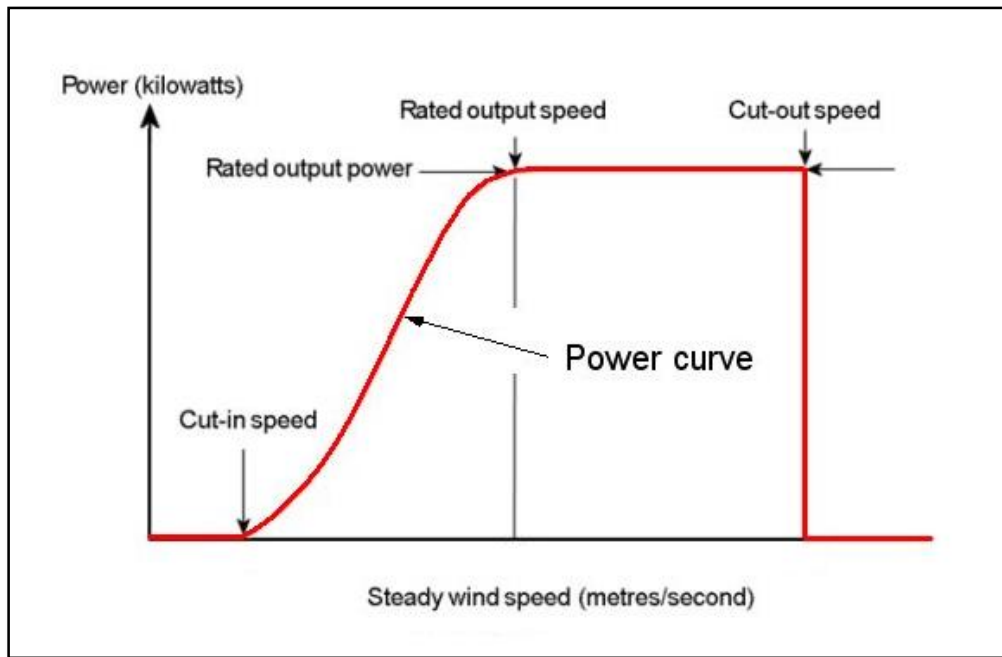


Figure 2.20: Power curve for wind turbine.[1]

### 2.2.11 Additional Equations Which Use In Wind Turbine System Design

$$\rho = 1.225 \cdot K_T \cdot K_A \dots\dots\dots (2.34)$$

$$K_A = \frac{p(\text{Elevation})}{p(\text{at sea level})} \dots\dots\dots (2.35)$$

$$p(\text{Elevation}) = 1 \text{ atm } e^{-(1.185 \times 10^{-4} \times \text{Elevation})} \dots\dots\dots (2.36)$$

$$K_T = \frac{\rho(T \text{ C}^\circ)}{\rho(15 \text{ C}^\circ)} \dots\dots\dots (2.37)$$

$$D^2 = \frac{A \cdot 4}{\pi} \dots\dots\dots (2.38)$$

## **Chapter 3**

### **System Design And Analysis**

3.1 load Analysis

3.2 Design Of Hybrid System

3.3 Plan For Next Semester

## Chapter 3

### System Design And Analysis

#### 3.1 load Analysis

We are take load for house in Hebron /AL-HARAS . The load consumption in 2014 as shown in table (3.1)

Month	Total Consumption (kwh)
January	429
February	450
March	257
April	234
May	281
Jun	230
July	289
Augest	284
September	304
October	270
November	232
December	785
Total	4045

Table 3.1: load consumption in 2014

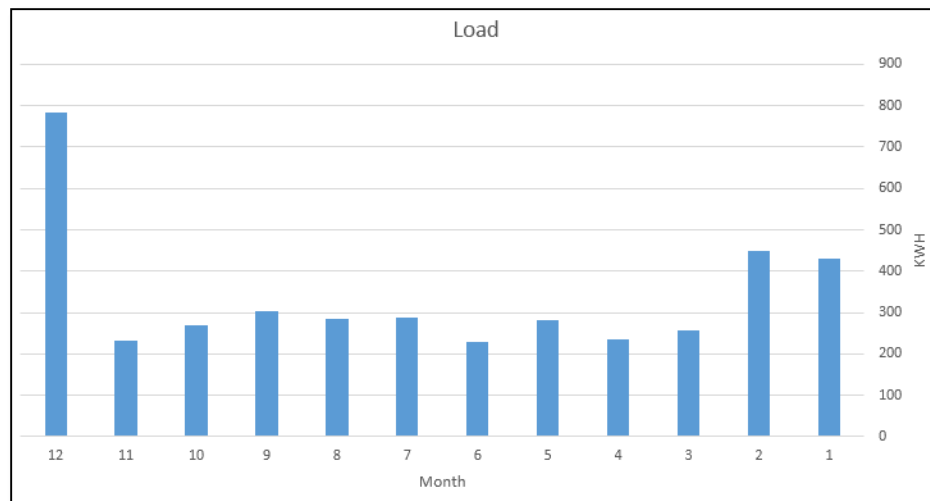


Figure 3.1 : The Monthly Load Consumption In 2014

Figure (3.1), Shown the load consumption per month for year 2014, as we see the highest power consumption in December and the lowest power consumption in Jun.

## 3.2 Design Of Hybrid System

### 3.2.1 Solar System Design

Givens:-

- The total energy consumption Is 4045 Kwh/year
- We are live in Hebron so tilt angle is (31deg) & Peak hour sun is 5.40kwh/m2.day [9].
- $\mu$ Conventional = 75%
- Datasheet in the appendix

Lat 31 Lon 35	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
SSE HRZ	2.85	3.54	4.76	6.08	6.98	7.77	7.53	6.67	5.70	4.17	3.17	2.63	5.16
K	0.49	0.50	0.54	0.59	0.62	0.67	0.66	0.63	0.61	0.55	0.52	0.49	0.57
Diffuse	1.07	1.35	1.66	1.88	2.01	1.87	1.86	1.81	1.56	1.38	1.10	0.98	1.54
Direct	4.00	4.23	5.23	6.43	7.32	8.63	8.32	7.30	6.68	5.13	4.45	3.88	5.98
Tilt 0	2.79	3.51	4.71	5.95	6.95	7.73	7.49	6.64	5.62	4.14	3.09	2.59	5.11
Tilt 16	3.43	4.08	5.15	6.15	6.82	7.42	7.26	6.70	6.05	4.75	3.77	3.24	5.41
Tilt 31	3.84	4.39	5.29	6.01	6.34	6.73	6.65	6.39	6.12	5.06	4.19	3.68	5.40
Tilt 46	4.05	4.48	5.16	5.56	5.55	5.70	5.71	5.75	5.86	5.11	4.39	3.92	5.11
Tilt 90	3.40	3.42	3.37	2.87	2.36	2.10	2.22	2.70	3.49	3.74	3.60	3.38	3.05
OPT	4.07	4.48	5.29	6.15	6.96	7.73	7.49	6.72	6.13	5.12	4.40	3.96	5.71
OPT ANG	52.0	44.0	31.0	17.0	3.00	0.00	0.00	10.0	27.0	41.0	51.0	55.0	27.4

Table 3.2: Monthly Averaged Radiation Incident On Earth (kWh/m2.day)

#### ☒ Power Parameters

From eq (2.7) :

$$P_{ac} = E_{tot} / (H_{peak\ sun\ hour} * 365) = 4045 / (5.40 * 365) = 2052.2577w$$

From eq (2.8) :

$$P_{dc} = P_{ac} / \mu_{conventional} = 2052.2577 / 0.75 = 2736.3436w$$

#### ☒ PV Sizing

From eq (2.9) :

$$Area = P_{dc} / (1kwh * \mu_{pv}) = 2736.3436 / (1000 * 14.9\%) = 18.364\ m^2$$

From eq (2.10) :

$$Area\ of\ the\ roof\ that\ we\ need = Area / 0.4 = 18.364 / 0.4 = 45.911\ m^2$$

$$Area\ PV\ panel\ (from\ data\ sheet) = 1.652 * 0.994 = 1.65\ m^2$$

From eq (2.11) :

$$Number\ of\ panel = area / area\ of\ 1\ panel = 18.36 / 1.65 = 12\ panel$$

$$= P_{ac} / P_{1panel} = 2736.3436 / 245 = 12\ panel$$

- ☒ The max  $V_{in}$  of an inverter (600)volt .so we can connect all- panel in series per string

$$V_{rated} = \# \text{ of panel in series} * V_{mpp} = 12 * 30.5 = 366 \text{ volt/string}$$

$$\# \text{ of string} = 12/12 = 1 \text{ string}$$

- ☒ Fuse Parameters:

From eq (2.13) :

$$\text{Array disconnecter fuse} \geq \# \text{ of string} * I_{\text{combiner fuse}} = 1 * 13.64 = 13.64 \text{ A}$$

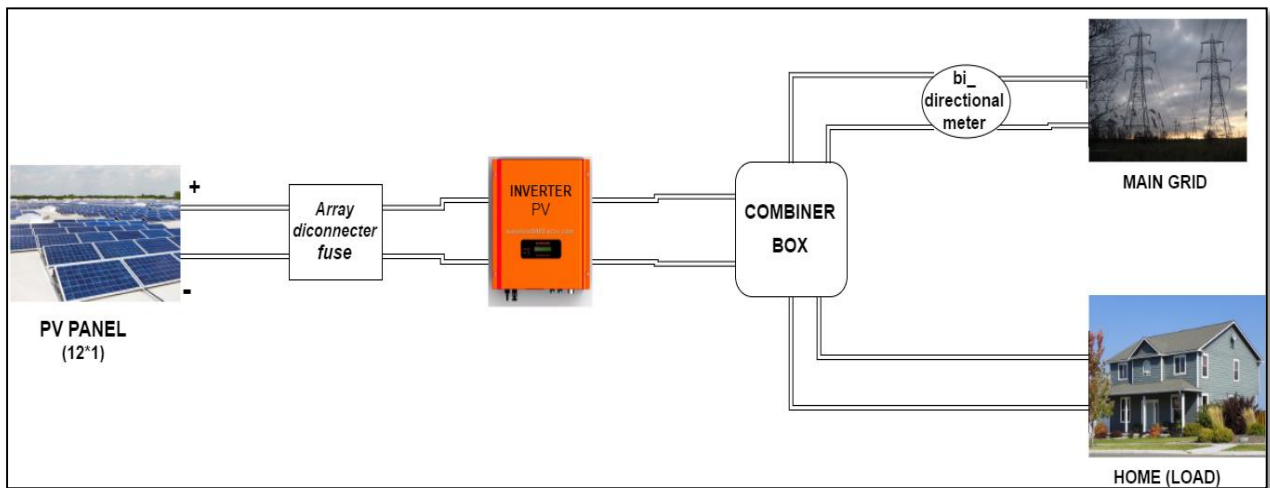


Figure 3.2 : PV System Model

### 3.2.2. Wind Turbine System Design

Givens:-

- Load power = 4045 kwh /year
- Elevation = 1015 meter above the sea level
- Average temperature (from Nasa site [10])  
Tavg= 22.5c °
- Wind speeds for Hebron for full year (2010).

Lat 31 Lon 35	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Amplitude
Minimum	5.14	5.23	7.73	12.0	15.3	18.3	20.9	21.7	20.0	16.5	11.5	6.89	
Maximum	22.4	25.6	31.1	39.7	44.4	47.0	50.1	50.1	47.1	39.3	30.9	24.2	
Amplitude	8.67	10.1	11.7	13.8	14.5	14.3	14.5	14.1	13.5	11.3	9.67	8.65	22.5

Table 3.3: Average Minimum, Maximum and Amplitude Of The Daily Mean Earth Temperature (C)

☒ Air Density ( $\rho$ ) :

From eq (2.34) :

$$\rho = 1.225 \cdot K_T \cdot K_A$$

From eq (2.35) :

$$K_A = \frac{p(\text{Elevation 1015 meter})}{p(\text{at sea level})}$$

From eq (2.36) :

$$p(\text{Elevation 1015 meter}) = 1 \text{ atm} e^{-(1.185 \times 10^{-4} \times 1015)} = 0.886 \text{ atm}$$

$$K_A = \frac{p(\text{Elevation 1015 meter})}{p(\text{at sea level})} = \frac{0.886 \text{ atm}}{1 \text{ atm}} = 0.886$$

From eq (2.37) :

$$KT = \frac{\rho(T=22.5\text{ C}^\circ)}{\rho(15\text{ C}^\circ)}$$

From eq (2.18) :

$$\rho(T = 22.5\text{ C}^\circ) = \frac{P * MW * 10^{-3}}{T * R}$$

$$\rho(T = 22.5\text{ C}^\circ) = \frac{1\text{ atm} \times 28.97 \times 10^{-3}}{8.2056 \times 10^{-5} \times (22.5 + 273.15)} = 1.194 \frac{\text{kg}}{\text{m}^3}$$

$$KT = \frac{\rho(T = 22.5\text{ C}^\circ)}{\rho(15\text{ C}^\circ)} = \frac{1.194}{1.225} = 0.974$$

$$\rho = 1.225 \times 0.974 \times 0.886 = 1.057 \frac{\text{kg}}{\text{m}^3}$$

#### ☒ Average Wind Speed

Annual average wind speed in Hebron for 10 years (from Nasa site [9] )

$$V_{\text{avg}} = 4.12 \text{ m/s}$$

Average wind speed in Hebron at 2010 (From excel sheet)

$$V_{\text{avg}} = 4.45 \text{ m/s}$$

we will use average wind speed from Nasa site because it is more reliable than other

Lat 31 Lon 35	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
10-year Average	4.45	4.59	4.72	4.36	4.09	4.13	4.13	3.92	3.64	3.65	3.65	4.13	4.12

Table 3.4: Monthly average wind speed (at lat 31 , lon 35)

## Rayleigh Distribution With

From eq (2.24)

$$c = \frac{2*V_{avg}}{\sqrt{\pi}} = 4.6 \quad , \quad K = 2$$

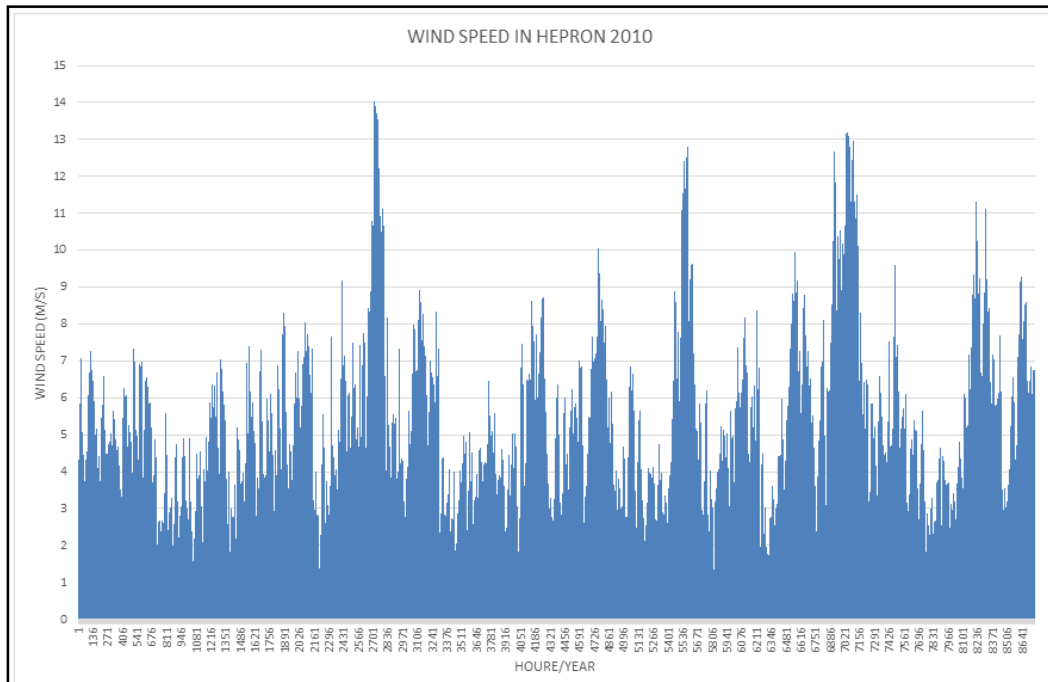


Figure 3.3 : Wind Speeds for Hebron for Full Year (2010)

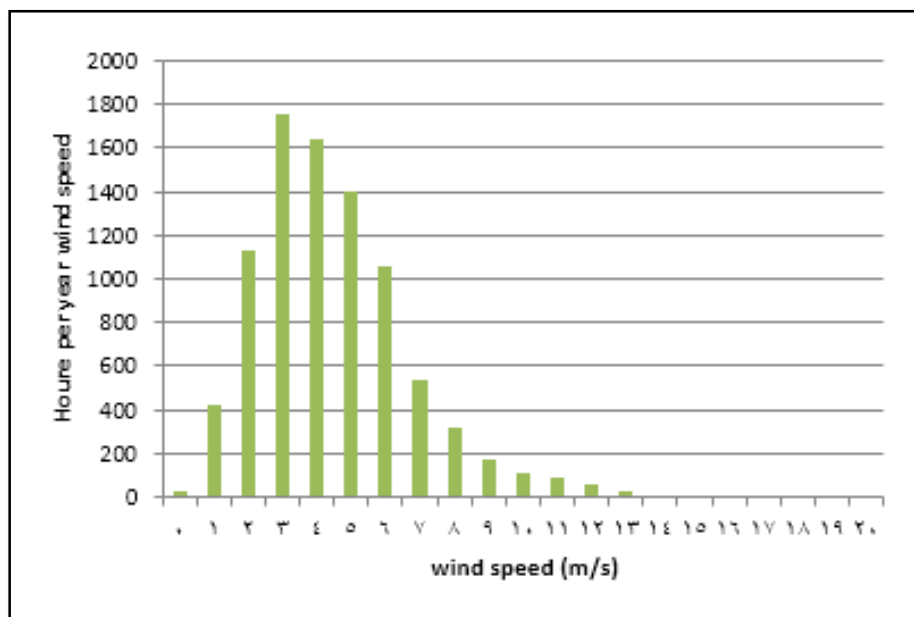


Figure 3.4 : Relation Between Hours Per Year And Wind Speed

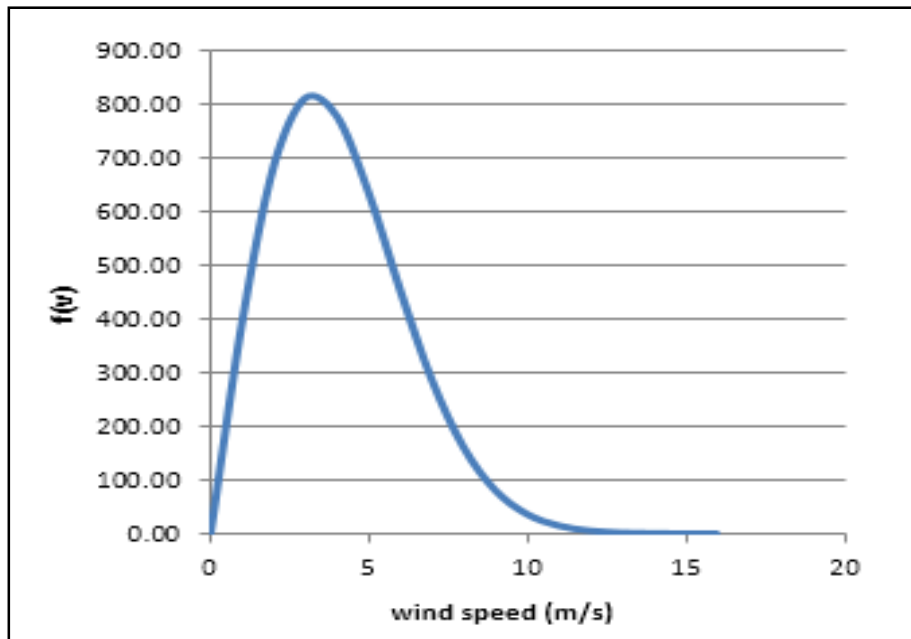


Figure 3.5 : Relation Between Probability( $f(v)$ ) And Wind Speed

#### ☒ Impact of Tower High

$H_0 = 10 \text{ m}$  ,  $H = 20 \text{ m}$  ,  $\alpha = 0.25$

From eq (2.19)

$$v_{20m} = v_0 \left( \frac{H}{H_0} \right)^\alpha = 4.12 \left( \frac{20}{10} \right)^{0.25} = 4.89 \text{ m/s}$$

#### ☒ Diameter For Rotor:

From eq (2.25)

$$V_{avg}^3 = \frac{3}{4} C^3 \sqrt{\pi} = \frac{3}{4} (4.6^3) \sqrt{\pi} = 129.4 \text{ m/s}$$

$$p = \frac{4045 \frac{kwh}{yr}}{8760 \frac{h}{yr}} = 461.75 \text{ W}$$

From eq (2.26)

$$A = \frac{p\pi}{3\rho V_{avg}^3} = \frac{461.75 \cdot \pi}{3 \cdot 1.057 \cdot 129.4} = 3.5 \text{ m}^2$$

From eq (2.38)

$$D^2 = \frac{A \cdot 4}{\pi} = \frac{3.5 \cdot 4}{\pi} = 4.5 \text{ m}$$

$$D = \sqrt{4.5} = 2.12 \text{ m}$$

☒ The probability that the windspeed is below cut-in speed :

From eq (2.28)

$$F(Vc) = \text{prob}(v < Vc) = 1 - e^{-\frac{\pi}{4} \left(\frac{Vc}{\bar{v}}\right)^2}$$

$$F\left(v < 1 \frac{m}{s}\right) = 1 - e^{-\frac{\pi}{4} \left(\frac{v}{\bar{v}}\right)^2} = 0.04521$$

☒ The number of hours per year the wind will be less than cut-in speed :

From eq (2.29)

$$\text{Hours}(v < Vc) = 8760 \times F(Vc)$$

$$\text{Hours}\left(v < 1 \frac{m}{s}\right) = 8760 \times 0.04521 = 396.039 \text{ hours}$$

☒ The probability that the windspeed is above rated speed :

From eq (2.30)

$$F(VR) = \text{prob}(v > VR) = e^{-\frac{\pi}{4} \left(\frac{VR}{\bar{v}}\right)^2}$$

$$F\left(v > 4 \frac{m}{s}\right) = e^{-\frac{\pi}{4} \left(\frac{v}{\bar{v}}\right)^2} = 0.4771$$

☒ The number of hours per year the wind will be less than rated speed :

From eq (2.31)

$$\text{Hours}(v > VR) = 8760 \times F(VR)$$

$$\text{Hours}\left(v > 4 \frac{m}{s}\right) = 8760 \times 0.4771 = 4179.77 \text{ hours}$$

☒ The probability that the windspeed is above cut-out speed :

From eq (2.32)

$$F(V_f) = \text{prob}(v > V_f) = e^{-\frac{\pi}{4} \left( \frac{V_f}{v} \right)^2}$$

$$F\left(v > 14 \frac{m}{s}\right) = e^{-\frac{\pi}{4} \left( \frac{v}{v} \right)^2} = 1.1520 * 10^{-4}$$

☒ The number of hours per year the wind will be less than cut-out speed :

From eq (2.33)

$$\text{Hours } (v > V_f) = 8760 \times F(V_f)$$

$$\text{Hours } \left(v > 14 \frac{m}{s}\right) = 8760 \times 1.1520 * 10^{-4} = 1.0091 \text{ hours}$$

$$\text{Hours } \left(4 < v < 14 \frac{m}{s}\right) = 4179.77 - 1.0091 = 4178 \text{ hours /yr}$$

$$P_w * 4178 \text{ h/yr} = 4045 \text{ kwh/yr}$$

$$\text{## } P_w = 968 \text{ w}$$

$$\approx 1 \text{ kw}$$

## Then

$$\text{Cut-in speed} = 1 \text{ m/s}$$

$$\text{Rated speed} = 4 \text{ m/s}$$

$$\text{Cut out speed} = 14 \text{ m/s}$$

From Wind turbine data sheet:

specifications following :

Wind turbine DC

Output voltage : 48VDC

Cut-in wind speed : 3m/s

Rated wind speed : 10m/s

Cut out wind speed : 16m/s

Rotor diameter : 2.18 m

Hub high : 10 m

Rated output power = 1kw

☒ The probability that the windspeed is above cut-in speed and above rated speed :

From eq (2.32)

$$F(Vf) = \text{prob}(v > Vf) = e^{-\frac{\pi}{4} \left( \frac{Vf}{v} \right)^2}$$

$$F\left(v > 3 \frac{m}{s}\right) = e^{-\frac{\pi}{4} \left( \frac{v}{3} \right)^2} = 0.6595$$

$$F\left(v > 10 \frac{m}{s}\right) = e^{-\frac{\pi}{4} \left( \frac{v}{10} \right)^2} = 9.807 * 10^{-3}$$

☒ The number of hours per year the wind will be above cut-in speed and above rated speed :

From eq (2.33)

$$\text{Hours } (v > Vf) = 8760 \times F(Vf)$$

$$\text{Hours } \left(v > 3 \frac{m}{s}\right) = 8760 \times 0.6595 = 5777.22 \text{ hours}$$

$$\text{Hours } \left(v > 10 \frac{m}{s}\right) = 8760 \times 9.807 * 10^{-3} = 85.91 \text{ hours}$$

$$\text{Hours } \left(3 < v < 10 \frac{m}{s}\right) = 5777.22 - 85.91 = 5691.31 \text{ hours /yr}$$

$$P_w * 5691.31 \text{ h/yr} = 4045 \text{ kwh/yr}$$

$$\text{## } P_w = 710.7 \text{ w}$$

$$\approx 1 \text{ kw}$$

\*\* But we are depend on the wind speed that below rated speed so we need to used excel sheet and Weibull for each month to know how much wind turbine I need .

## By using excel sheet and Weibull for each month show for us we should use two wind turbine 1kw in parallel.

☒ Fuse Parameters:

From eq (2.13) :

$$\text{disconnecter fuse} \geq \# \text{ of string} * I_{\text{combiner fuse}} = 2 * 21 = 42 \text{ A}$$

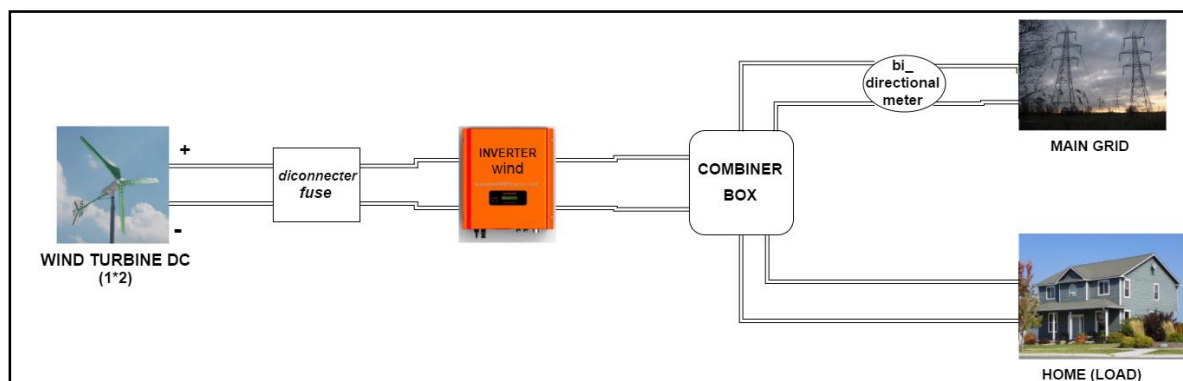


Figure 3.6 : Wind Turbine System Model

### 3.2.3 Power Management Strategy

The performance of hybrid system will be strongly when it depend on the power management strategy (PMS) ,so the main aim for applied power management strategy in this system to satisfy the load requirement and increase reliability for the system .Usually in long hybrid system the power production from the system is monitored by engineer after that he will collect the data and process the data to reach to the right decision for the system.

Power condition unit (P.C.U) designed for small hybrid system , it can be applied to remote site applications where grid may or may not be available. The (P.C.U) contain inverter , solar charger , wind charger, grid charger , battery bank ,control system and net metering.

Distributed Generation (DG) systems are small-scale, on-site power sources located at or near customers' homes or businesses. Some common examples include rooftop solar panels, energy storage devices, fuel cells, microturbines, small wind, and combined heat and power systems.

Net metering is a billing system that allows electric customers to sell to their electric company any excess electricity generated by their DG systems. While many different DG sources may be eligible for net metering credits, solar rooftop installations are by far the most common type of DG promoted with net metering.

Power management strategy principle in fig 3.7 that the photovoltaic generator and wind turbine generator will produce during the day enough electric power cover requirments of the home load while the excess power will send to grid.

Firstly the PLC read the power which measured by power meter for PV , Wind Turbine and load consumed ; after the reading power the PIC will compare between them , if power load less than power PV then the relay of PV will connect , else if power load less than power Wind turbine then the relay of Wind Turbine will connect , else if power load less than sum of power PV and power Wind turbine and in the same time power load larger than power Wind turbine and power load larger than power PV then the relay of Wind Turbine and PV will connect and the extra power will inject to the grid , else if power load larger than sum of power PV and power Wind turbine then the relay of Wind Turbine and PV will connect and the remaining power will take form grid .

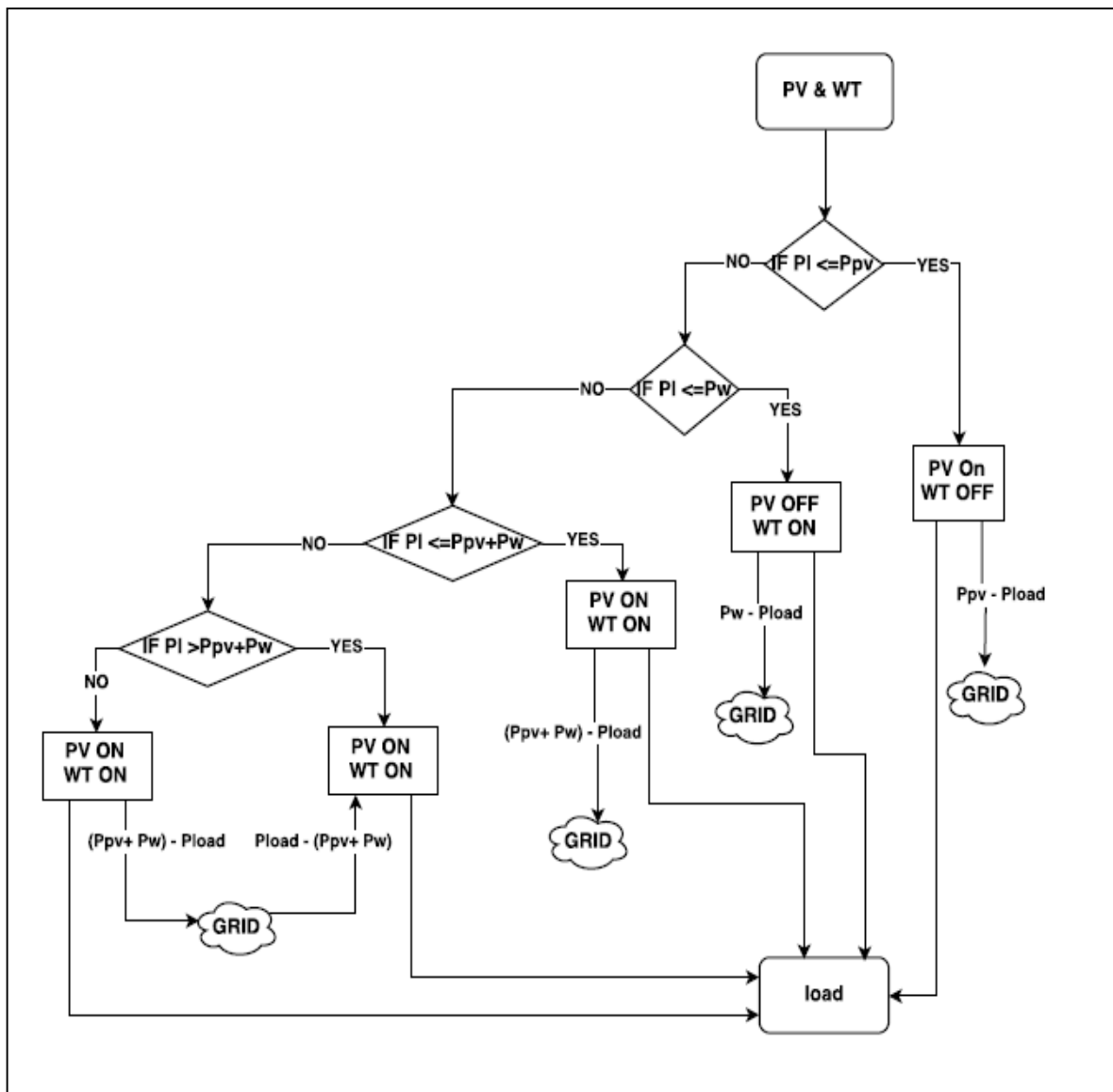


Figure 3.7 : Power Management Strategy (PMS)

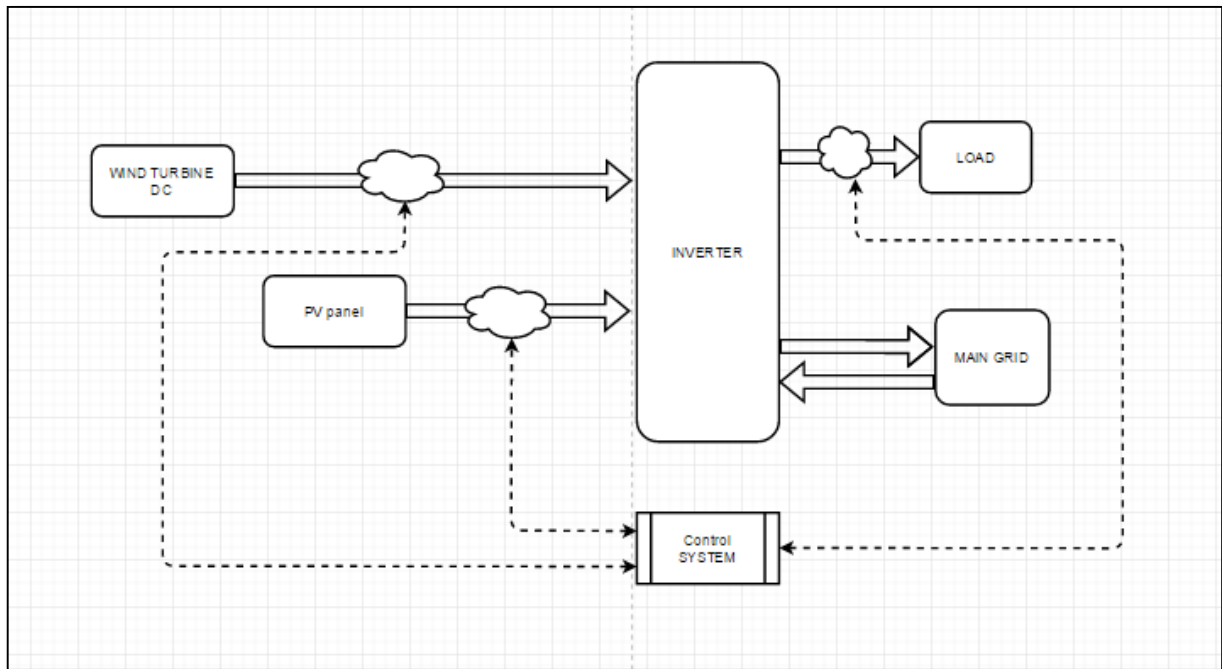


Figure 3.8 : Logical Block Diagram For Hybrid System

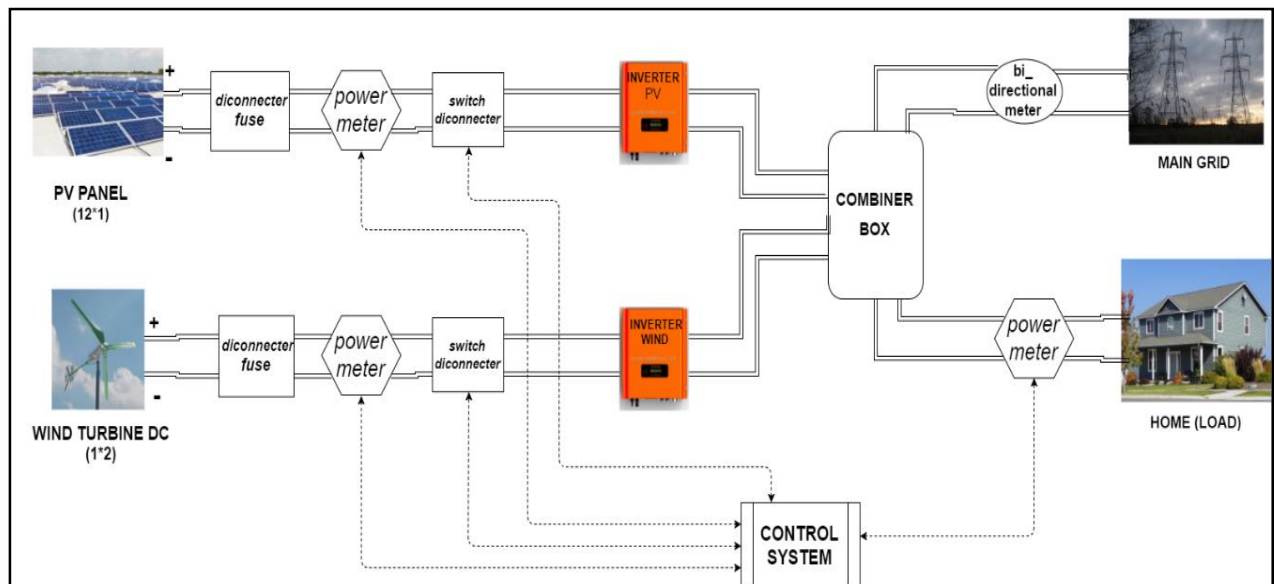


Figure 3.9 : Hybrid (PV & Wind Turbine) System Model

## **Chapter 4**

### **Control System**

**4.1** Specification Of The Control System

**4.2** Operator Screen For The System

**4.3** Table Digital And Analog Input / Output For The Control System

**4.4** Hardware Configuration

**4.5** Program Of Control System

## **Chapter 4**

### **Control System (PLC System)**

This chapter show the control system which used in the hybrid system , in this project we are used PLC System for control , and we are used Unity Pro software to build the program for the control.

A Programmable Logic Controller, PLC, or programmable controller is a digital computer used for automation of typically industrial electromechanical processes, such as control of machinery on factory assembly lines, amusement rides, or light fixtures. PLCs are used in many machines and in many functions.

Unity pro is Schneider software used to write and simulate the program that will download on PLC.

#### **4.1 Specification Of The Control System**

In this control system we have three Power Meter and two DC Relay, the control system will measure the power produced from PV , Wind Turbine and the power consumed after that connect and disconnect the rely depend on power which measured .

Firstly the PLC read the power which measured by power meter for PV , Wind Turbine and load consumed ; after the reading power the PIC will compare between them , if power load less than power PV then the relay of PV will connect , else if power load less than power Wind turbine then the relay of Wind Turbine will connect , else if power load less than sum of power PV and power Wind turbine and in the same time power load larger than power Wind turbine and power load larger than power PV then the relay of Wind Turbine and PV will connect and the extra power will inject to the grid , else if power load larger than sum of power PV and power Wind turbine then the relay of Wind Turbine and PV will connect and the remaining power will take form grid .

## 4.2 Operator Screen For The System

In figure (4.1), shown operator screen for the system in Unity Pro software , on this screen we can simulate the program to see if the program is working well .

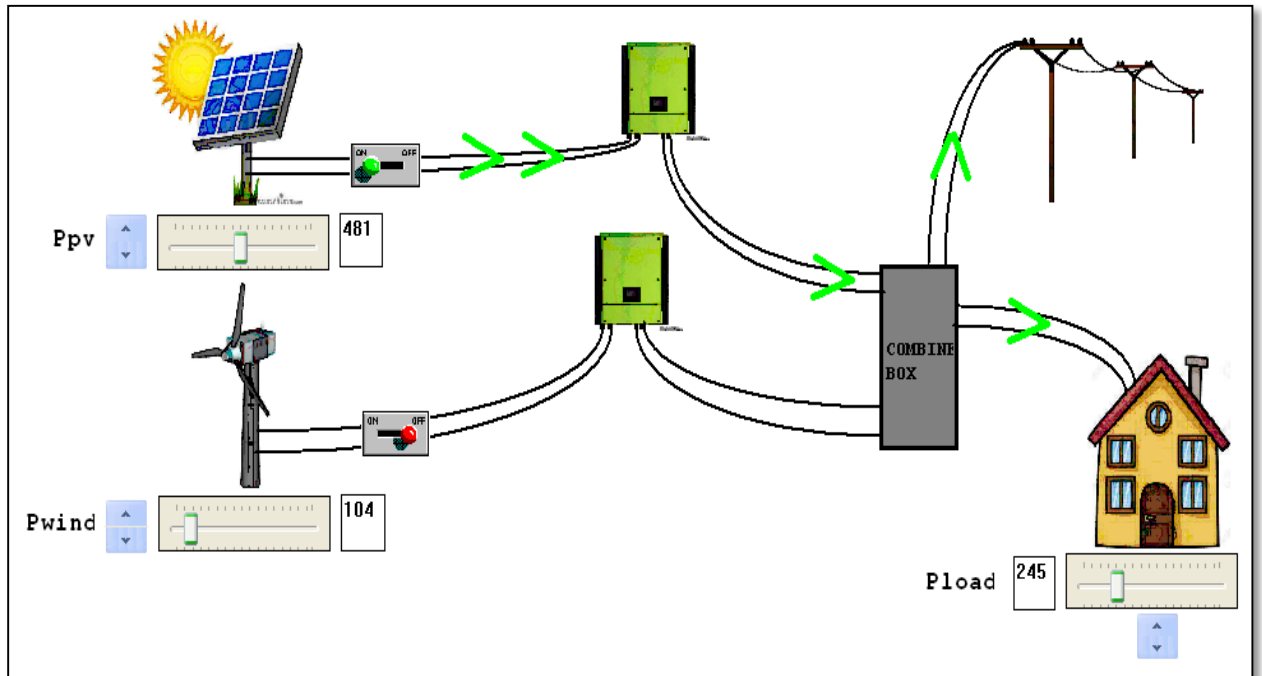


Figure (4.1): Operator Screen For The System In Unity Pro

### 4.3 Table Digital And Analog Input / Output For The Control System



Name	Q'ty	Code	Company	Specification	Digital in	Digital out	Analog in	Analog out
Power meter	3	4700B-DR	Siemens	24VDC				
DC Relay	2	G9EJ-1-E	OMRON	Coil voltage 24VDC Carry current and voltage 15A , 400V				
Total No. of in/out address						2	3	

Table (4.1) : Table Digital And Analog Input / Output For The Control System

As we see in table (4.1) the control system need two digital output (%Q0.1.0 & %Q0.1.1) and three analog input (%IW0.2.0 & %IW0.2.1 & %IW0.2.2).

### 4.4 Hardware Configuration

In hardware part in the system we need one digital output module and one analog input module and one power supply module and one CPU module , as shown in figure (4.2).

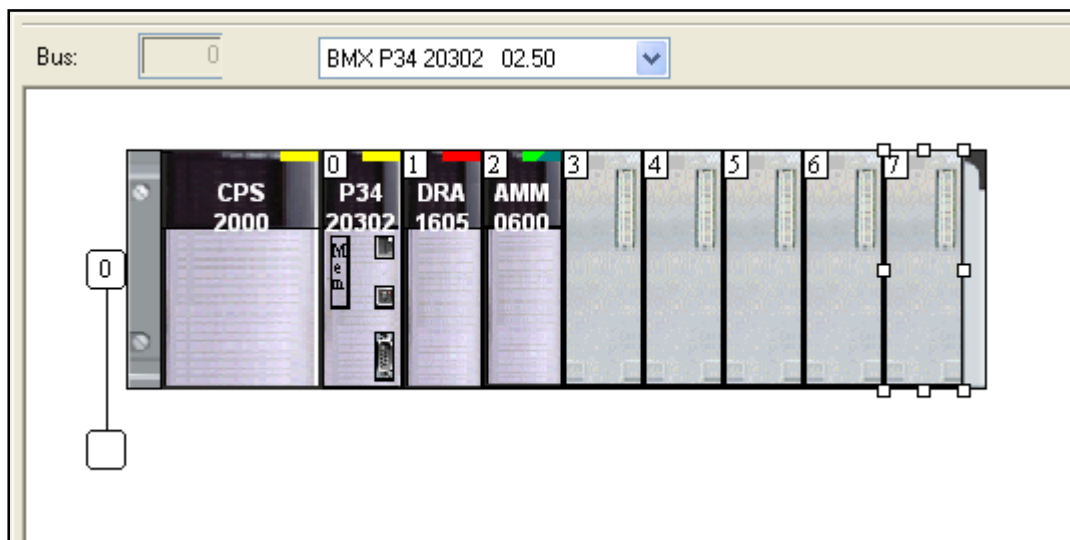


Figure (4.2) : Hardware Configuration In Unity Pro Software

## 4.5 Program Of Control System

In figure (4.3) shown the program which we are write it by Sequantal Function Chart (SFC) language with Structured Text (ST) language and ladder (LD) language used in Transitions and Steps.

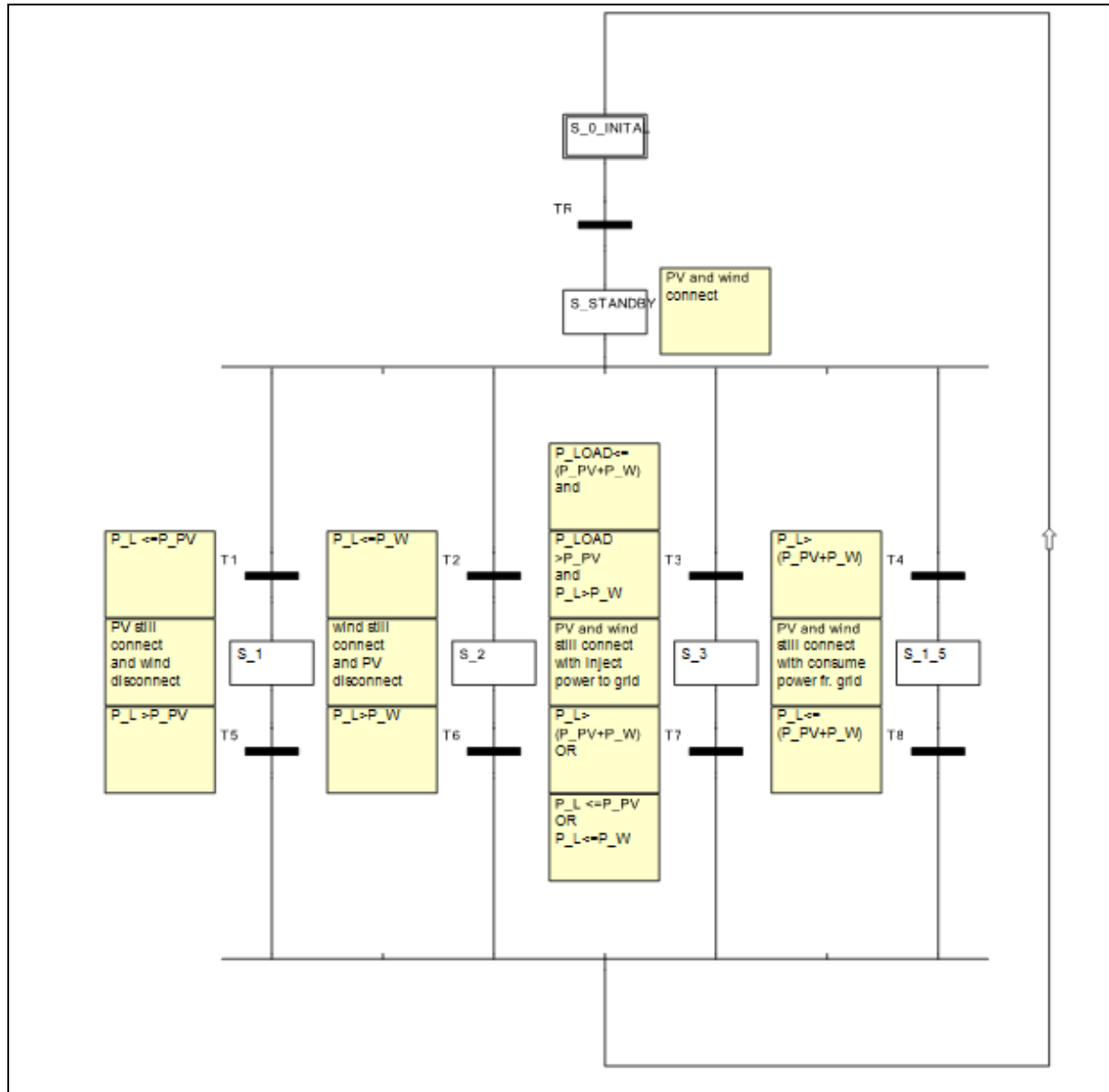


Figure (4.3) : Program Of Control System by SFC language

## **Chapter 5**

### **Results of study**

#### **5.1 Load Demand And Power Generation From PV And Wind Turbine**

##### **5.1.1 Load consumption And Power Generation In Case With Feed- InTariff**

##### **5.1.2 Load consumption And Power Generation In Case Without Feed-In Tariff**

###### **5.1.2.1 Using control system in hybrid system**

#### **5. 2 Power Generation From PV And Wind Turbine During The Day**

## Chapter 5

### Results of study

#### 5.1 Load Demand And Power Generation From PV And Wind Turbine

In this project we are study two cases ; first case when electrical company pay for customer for power injection to the grid ( with Feed-In Tariff , mean's for every kWh you generate you get paid ) , the second case when the electrical company not pay for customer for power injection to the grid ( without Feed-In Traiff ) , in this chapter we are used excel software to draw figures and analysis .

##### 5.1.1 Load consumption And Power Generation In Case With Feed-In Tariff

MONTH	LOAD(KWH)	WIND GEN.(kwh)	SOLAR GEN. (kwh)	SOLAR & WIND GEN.(kwh)
1	429	352	315	667
2	450	168	360	528
3	257	362	434	796
4	234	508	493	1001
5	281	320	520	840
6	230	292	552	844
7	289	386	546	932
8	284	368	524	892
9	304	334	503	837
10	270	722	416	1138
11	232	220	344	564
12	785	532	301	833

Table (5.1) : Energy For Load , Solar Generation And Wind Generation In Case With Feed-In Tariff

In table (5.1) shown the energy for each month through the year for load consumption, solar generation, wind turbine generation and combine solar and wind turbine generation.

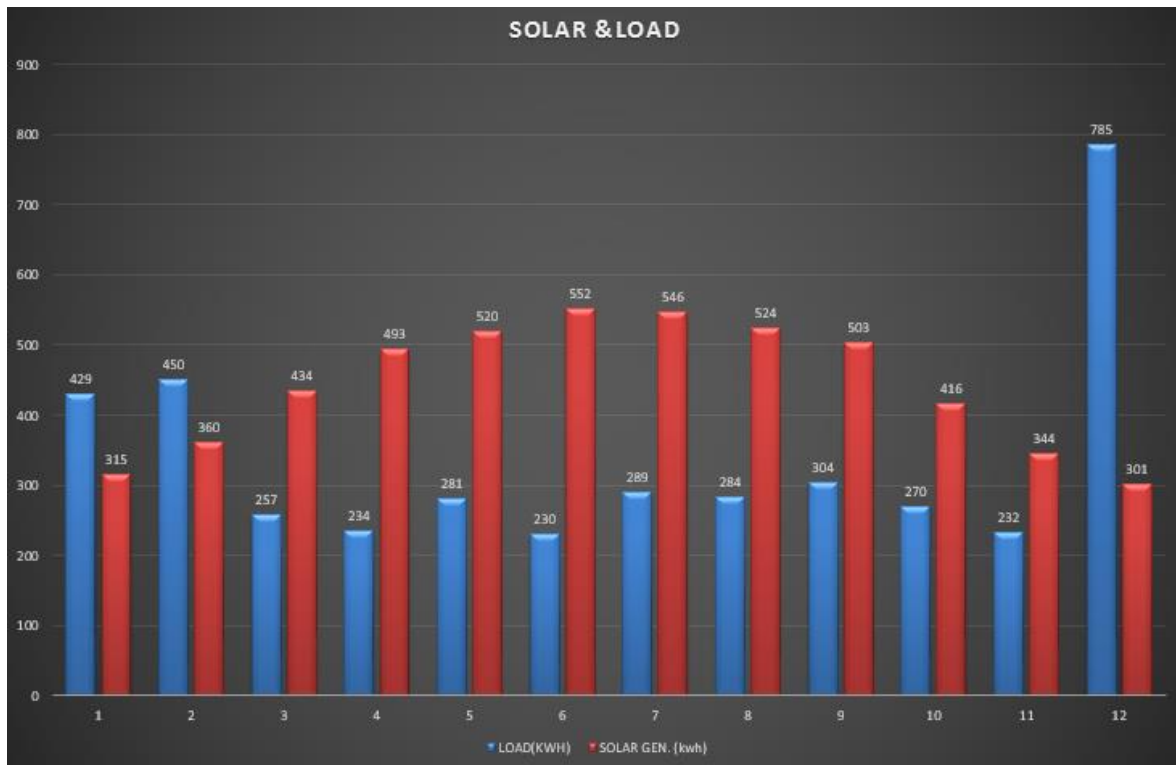


Figure (5.1) : Load Consumption And Solar Power Generation In Case With Feed-In Tariff

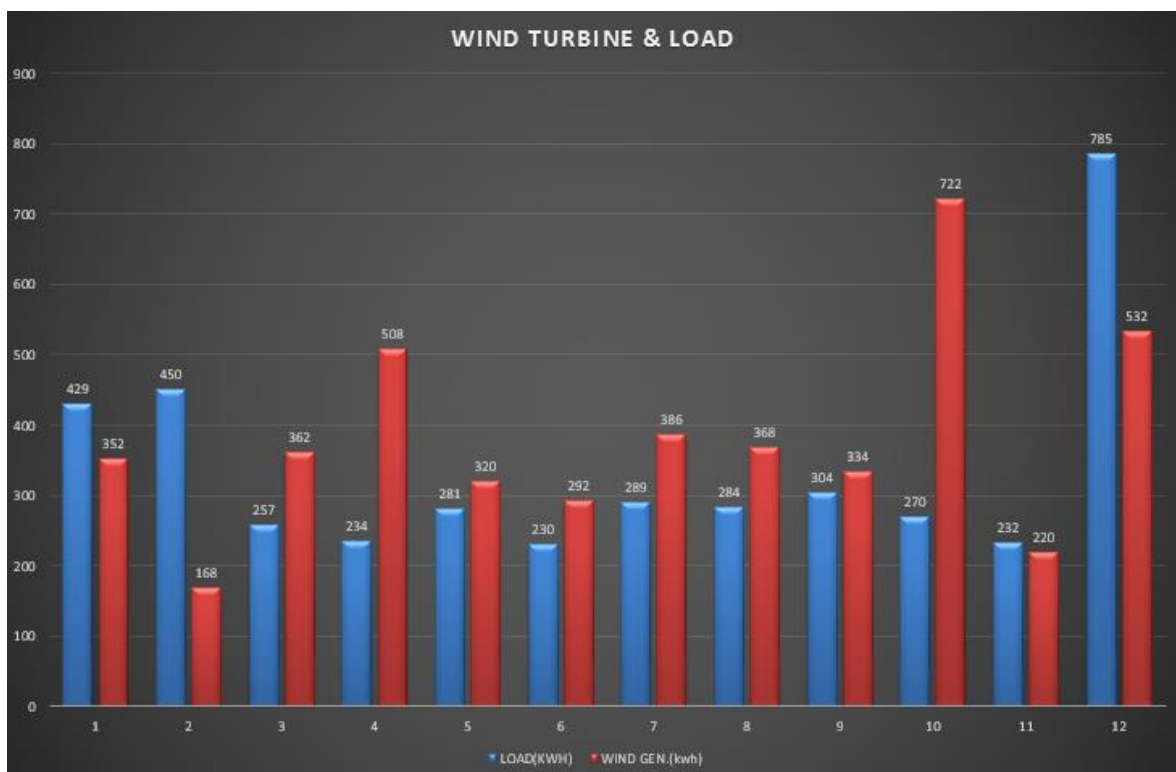


Figure (5.2) : Load Consumption And Wind Turbine Power Generation In Case With Feed-In Tariff

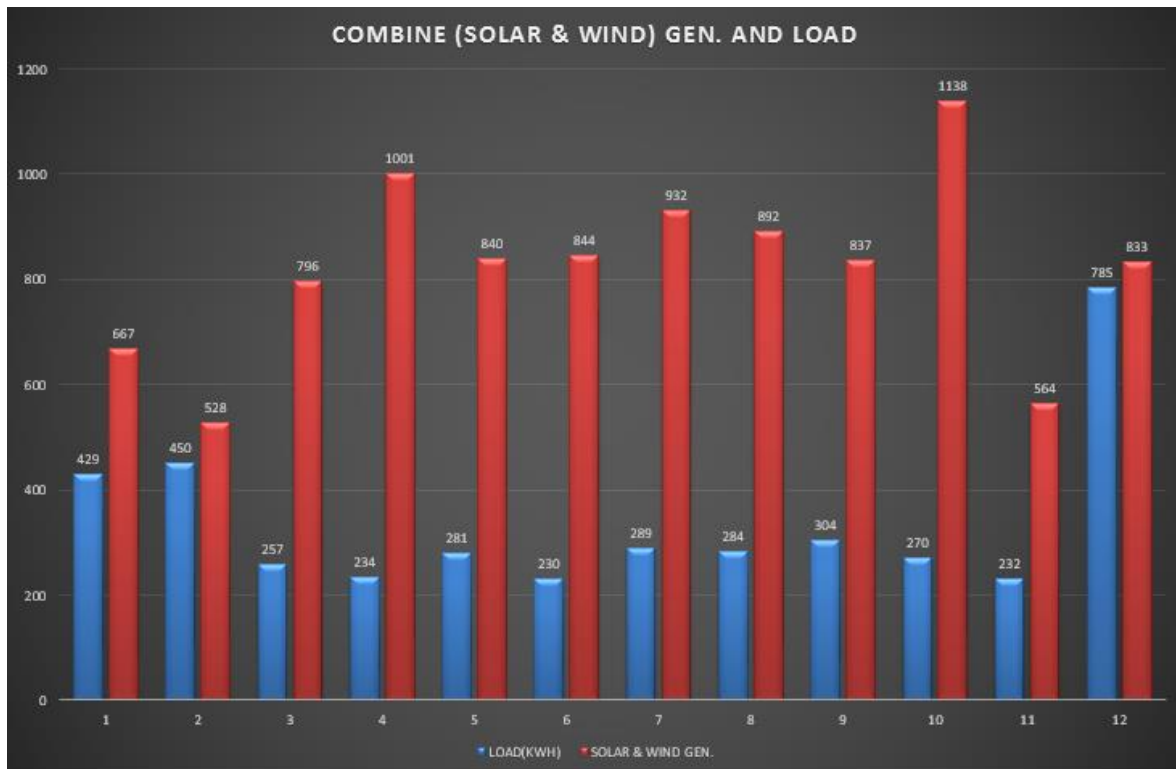


Figure (5.3) : Load Consumption And Combine Solar And Wind Turbine Power Generation In Case With Feed-In Tariff

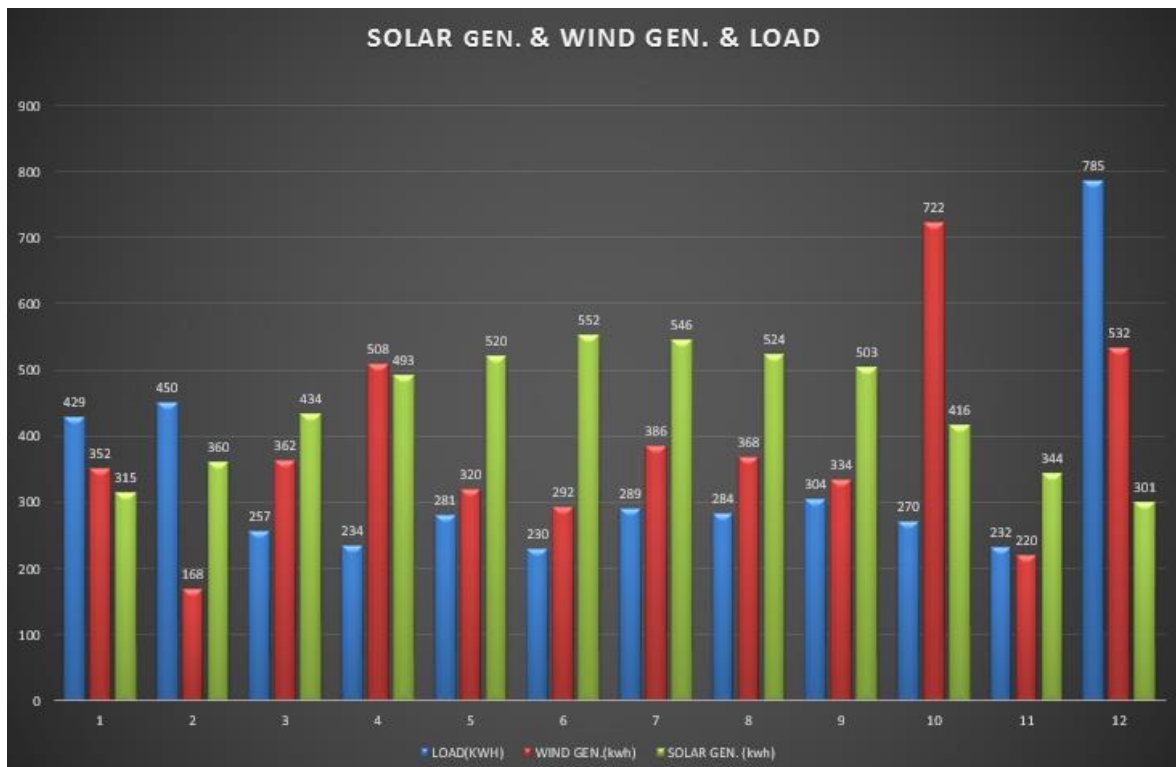


Figure (5.4) : Load Consumption And Solar , Wind Turbine Power Generation In Case With Feed-In Tariff

As we see in previous figures , when we are combine solar and wind turbine generation together we can cover all load consumption you can see it in figure (5.3), but when we are used single generation we cannot cover the load in three months (January, February, December ) you can see it in figure (5.4).

In figure (5.1) we can see the solar generation cannot cover all load in three months (January, February, December )

In figure (5.2) we can see the wind turbine generation cannot cover all load in four months (January, February, December , November ) , but in November the wind turbine cover almost of load just cannot cover 12 kwh , so we can Suppose the wind turbine cover all the load in this month.

### 5.1.2 Load consumption And Power Generation In Case Without Feed-In Tariff

MONTH	LOAD(KWH)	WIND GEN.(kwh)	SOLAR GEN. (kwh)	SOLAR & WIND GEN.
1	429	352	202	554
2	450	168	231	399
3	257	362	277	639
4	234	508	316	824
5	281	320	334	654
6	230	292	354	646
7	289	386	350	736
8	284	368	336	704
9	304	334	322	656
10	270	722	266	988
11	232	220	221	441
12	785	532	193	725

Table (5.2) : Energy For Load , Solar Generation And Wind Generation In Case Without Feed-In Tariff

In table (5.1) shown the energy for each month through the year for load consumption, solar generation, wind turbine generation and combine solar and wind turbine generation.

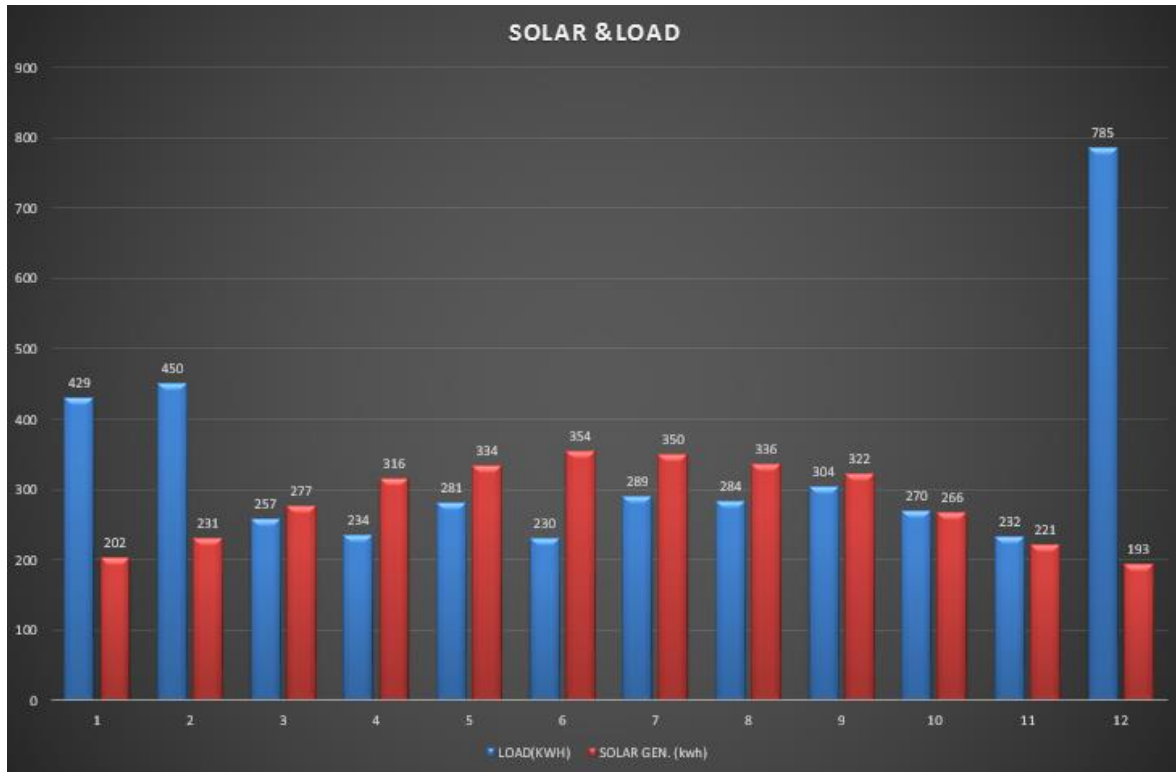


Figure (5.5) : Load Consumption And Solar Power Generation In Case Without Feed-In Tariff

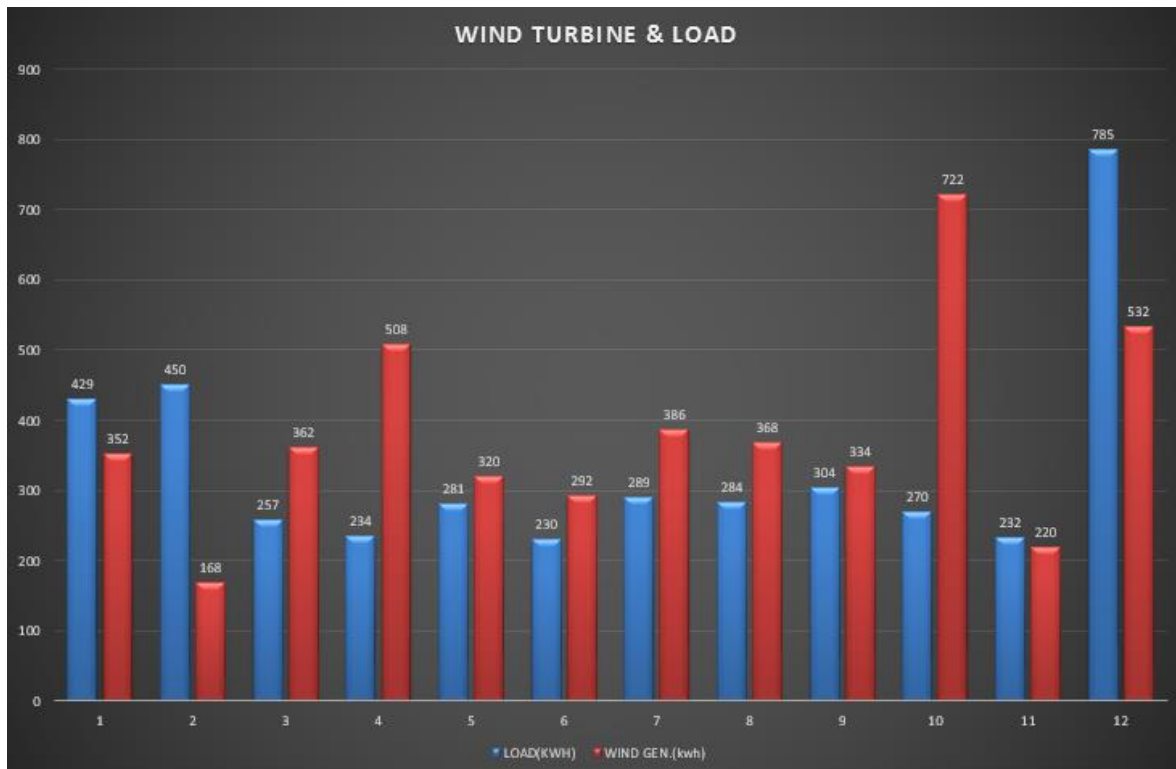


Figure (5.6) : Load Consumption And Wind Turbine Power Generation In Case Without Feed-In Tariff

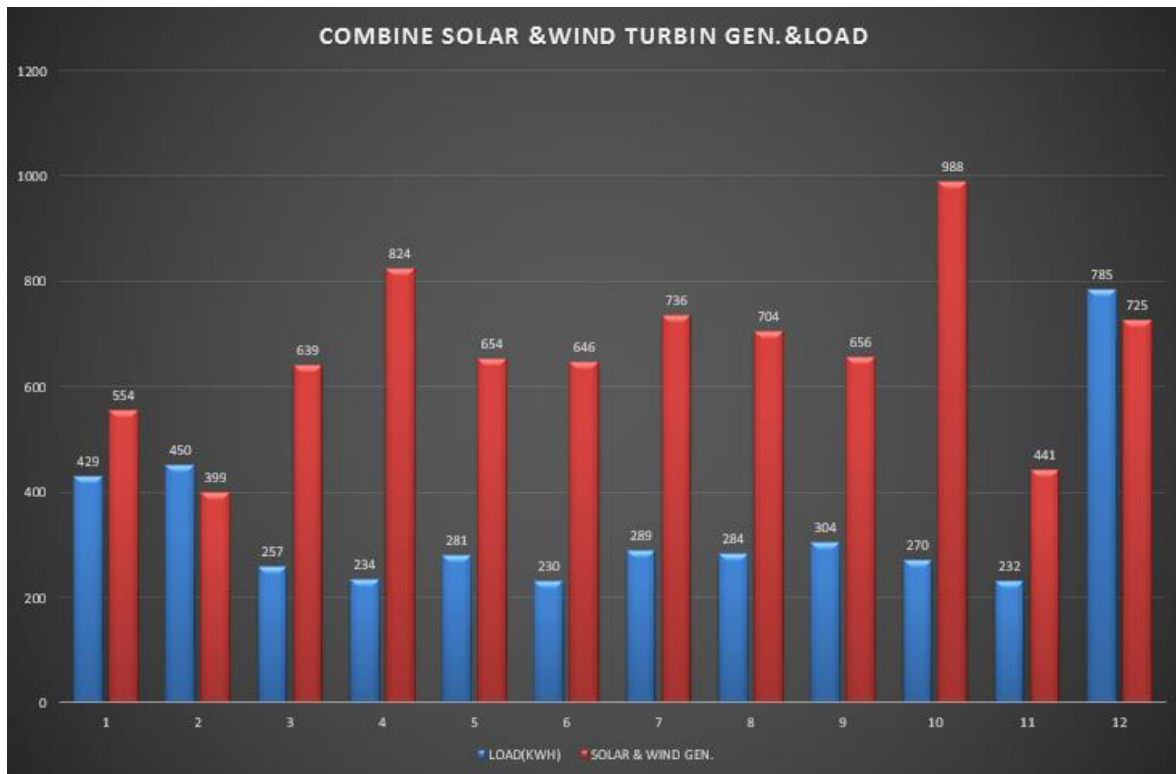


Figure (5.7) : Load Consumption And Combine Solar And Wind Turbine Power Generation In Case Without Feed-In Tariff

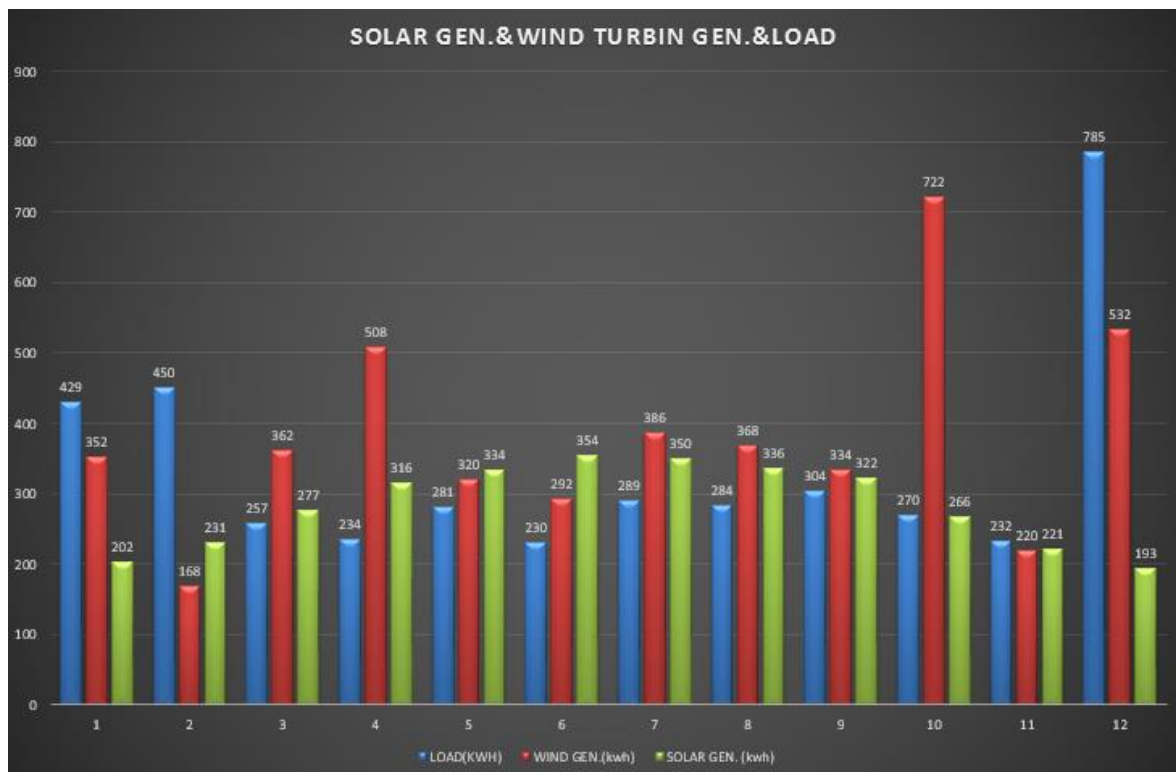


Figure (5.8) : Load Consumption And Solar , Wind Turbine Power Generation In Case Without Feed-In Tariff

As we see in previous figures , when we are combine solar and wind turbine generation together we can cover almost all load consumption you can see it in figure (5.7), but when we are used single generation we cannot cover the load in three months (January, February, December ) you can see it in figure (5.8).

In figure (5.5) we can see the solar generation cannot cover load in five months (January, February, December, November , October ) , but in November and October the solar generation cover almost of load just cannot cover a few kwh , so we can Suppose the solar cover all the load in this month . In this case for solar system we are reducing number of panels (from twelve panels to eight panels) until reach like in figure (5.5) because most months the solar system inject too much power to the grid and we are in case without feed-in tariff so we are reduce the panel to reduce the power injection to the grid.

In figure (5.6) we can see the wind turbine generation cannot cover all load in four months (January, February, December , November ) , but in November the wind turbine cover almost of load just cannot cover a few kwh , so we can Suppose the wind turbine cover all the load in this month.

### **5.1.2.1 Using Control System In Hybrid System**

In this case (Without Feed-In Tariff ) we can apply our control system for hybrid system because the aim of our control system is to cover the load consumption just and not focus to inject extra power to the grid .

This case we are apply it with control system by using simulation in unity pro software to see behavior of control system with hybrid system .

When we use control system (PLC) with hybrid system , the control system let solar generation and wind turbine generation connect together in the same time on the grid to cover almost all load in three months in year (January, February, December) , but from March to October the control system let one generation system (solar system or wind turbine generation) connect on the grid to cover almost all load ; as we see form these behavior the main aim for control system (PLC) cover the load without care inject extra power to the grid because the electrical company will not pay anything to the costumer .

In Figure (5.9) , Figure (5.10) and Figure (5.11) , simulation in unity pro software which show for us behavior of control system with hybrid system in each month during the year .

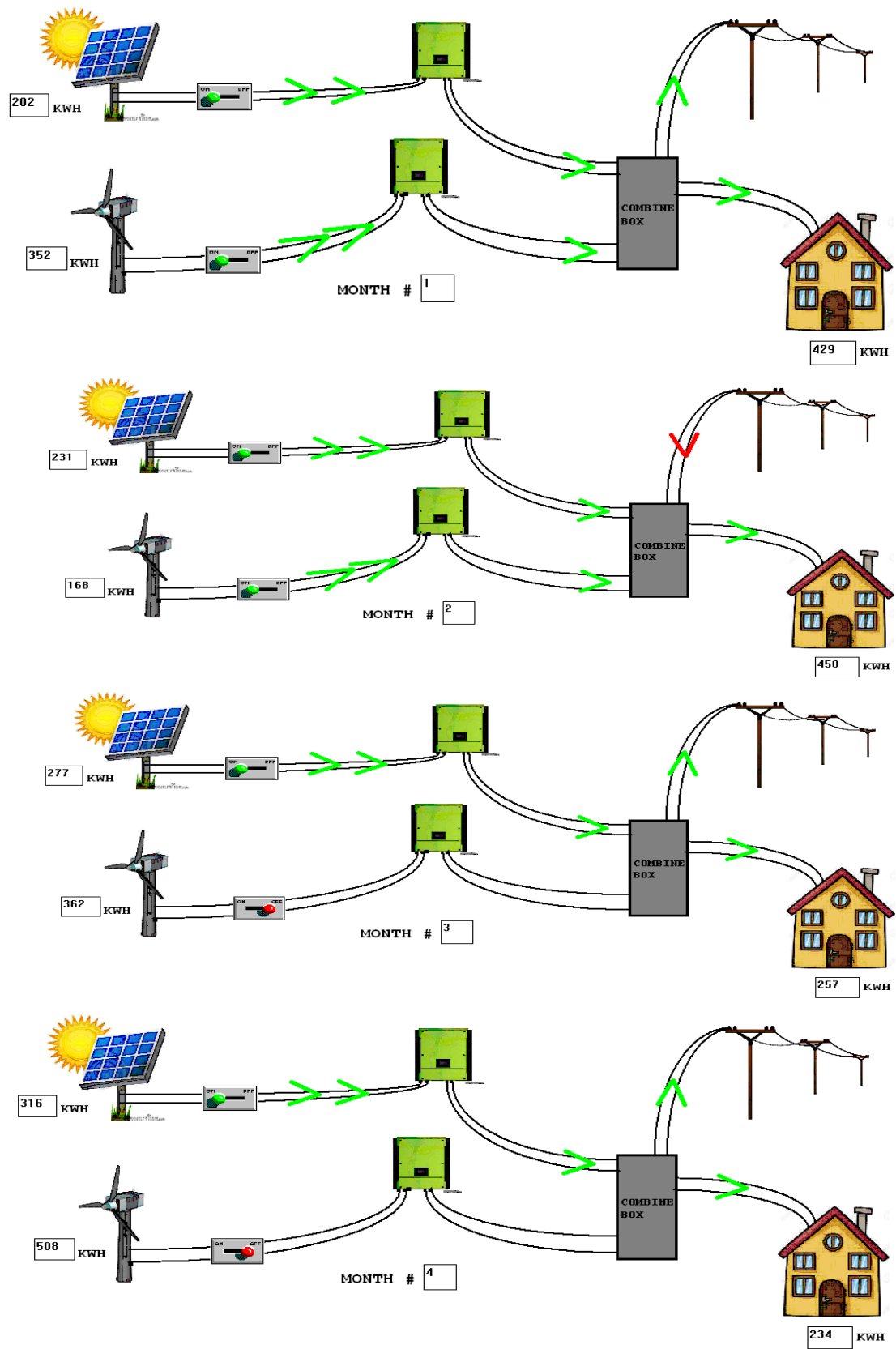


Figure (5.9) : Operator Screen In Unity Pro Software Part 1

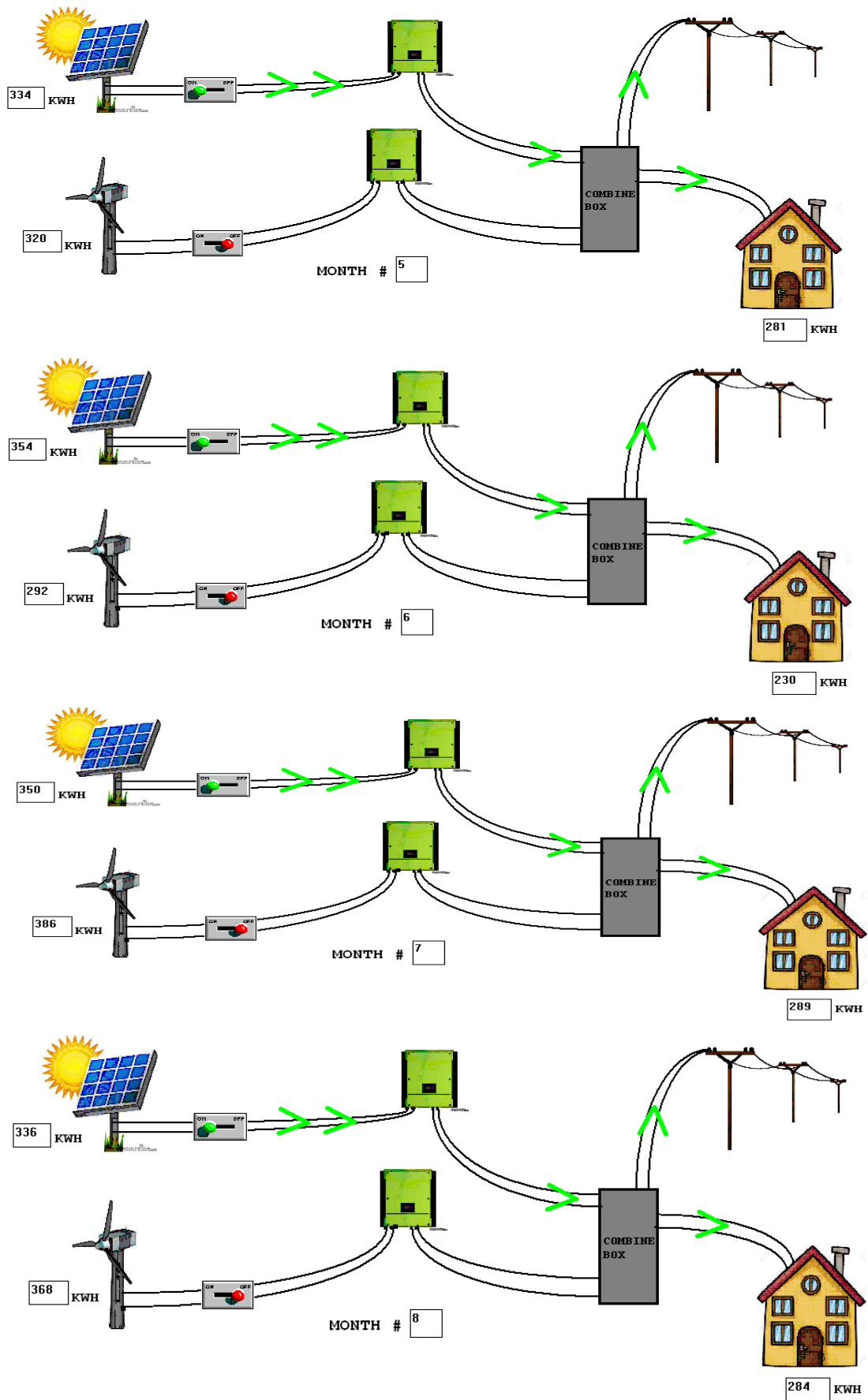


Figure (5.10) : Operator Screen In Unity Pro Software Part 2

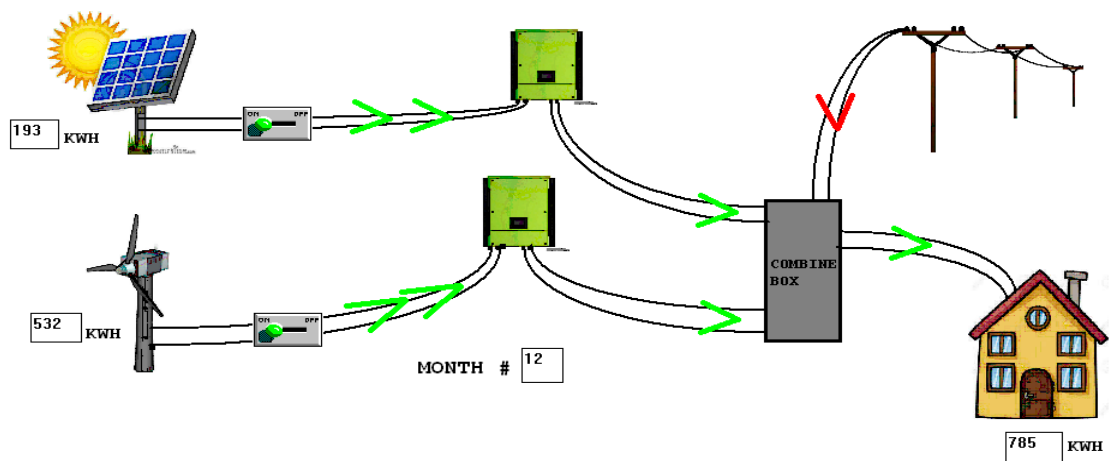
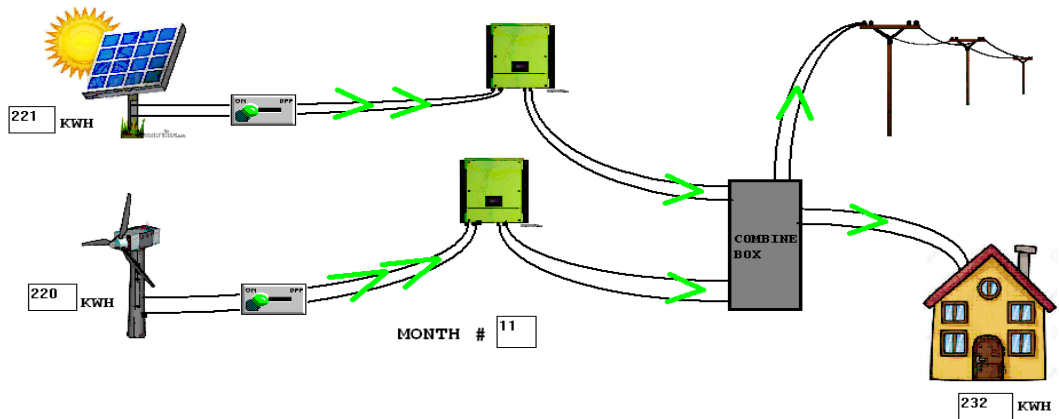
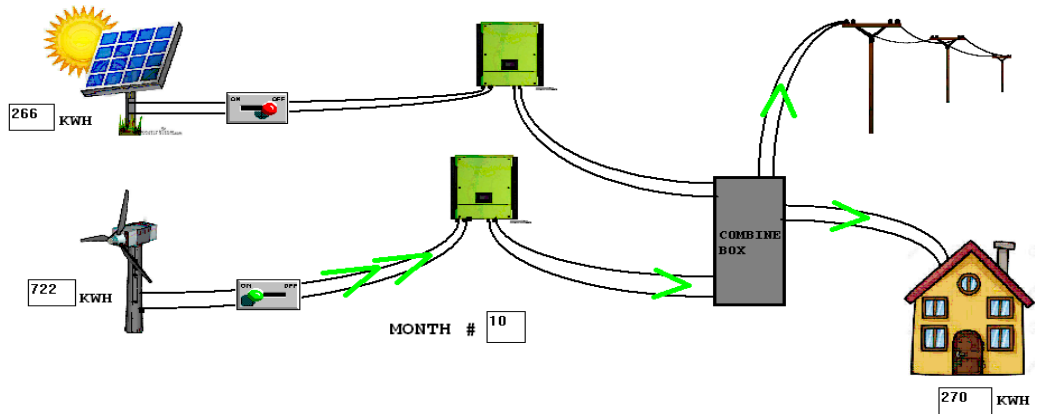
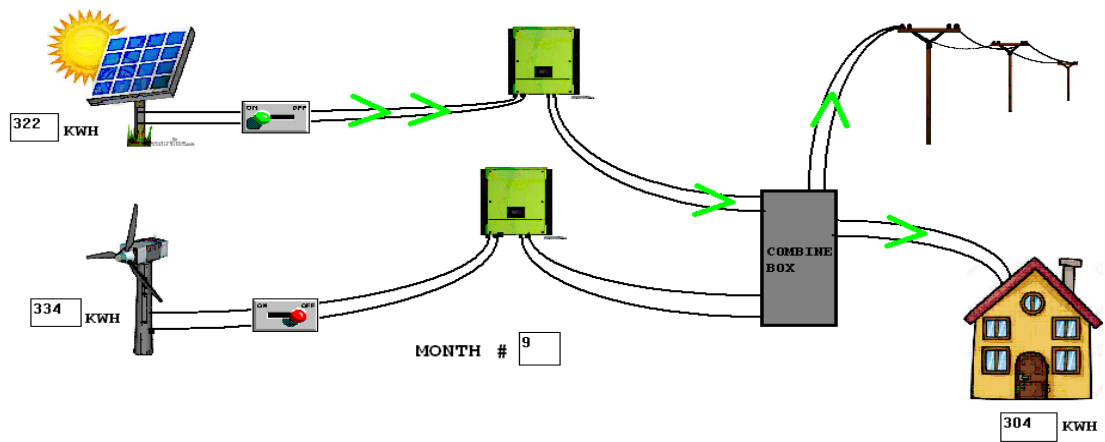


Figure (5.11) : Operator Screen In Unity Pro Software Part 3

## 5.2 Power Generation From PV And Wind Turbine During The Day

To draw curves for power PV and power Wind Turbine during the day we are went to Meteorology in Hebron and take from them some of data for radiation and wind speed for two month (January and July) to see behavior of power generation from PV and wind turbine system throw day in summer (July) and day in winter (January) . we are used excel software to analysis the data and draw the curves .

TIME IN DAY	WINDTURBINE IN JANUARY (kwh)	PV IN JANUARY (kwh)		WIND TURBINE IN JULY(kwh)	PV IN JULY (kwh)
1	0.9	0		0.6	0
2	0.6	0		0.6	0
3	0.6	0		0.6	0
4	0.6	0		0.6	0
5	0.6	0.02618228		0.6	0.03235088
6	0.6	0.32529084		0.6	0.42234348
7	1.01	0.67950556		0.6	0.74146572
8	0.9	1.21425464		0.6	1.43125228
9	1.01	1.62535756		0.416	1.69238968
10	1.01	1.61397992		0.416	1.73529572
11	1.01	1.58012116		0.416	1.63317112
12	0.9	1.12323352		0.416	1.28416544
13	0.9	0.96476904		0.6	0.95736672
14	0.9	0.46360456		0.416	0.42193224
15	0.9	0.08183676		0.416	0.06593548
16	0.9	0		0.416	0
17	0.9	0		0.416	0
18	1.01	0		0.6	0
19	1.01	0		0.6	0
20	1.01	0		0.6	0
21	1.01	0		0.6	0
22	1.01	0		0.6	0
23	0.9	0		0.6	0
24	0.9	0		0.416	0

Table (5.3) : Power Generation For PV System And Wind Turbine System During The Time In Day For January And July

After we are used excel software to analysis the data which we take it from Meteorology in Hebron we reach for the previous table (5.3) this table show for us power generation for PV System and Wind Turbine System during the time in day for January and July.

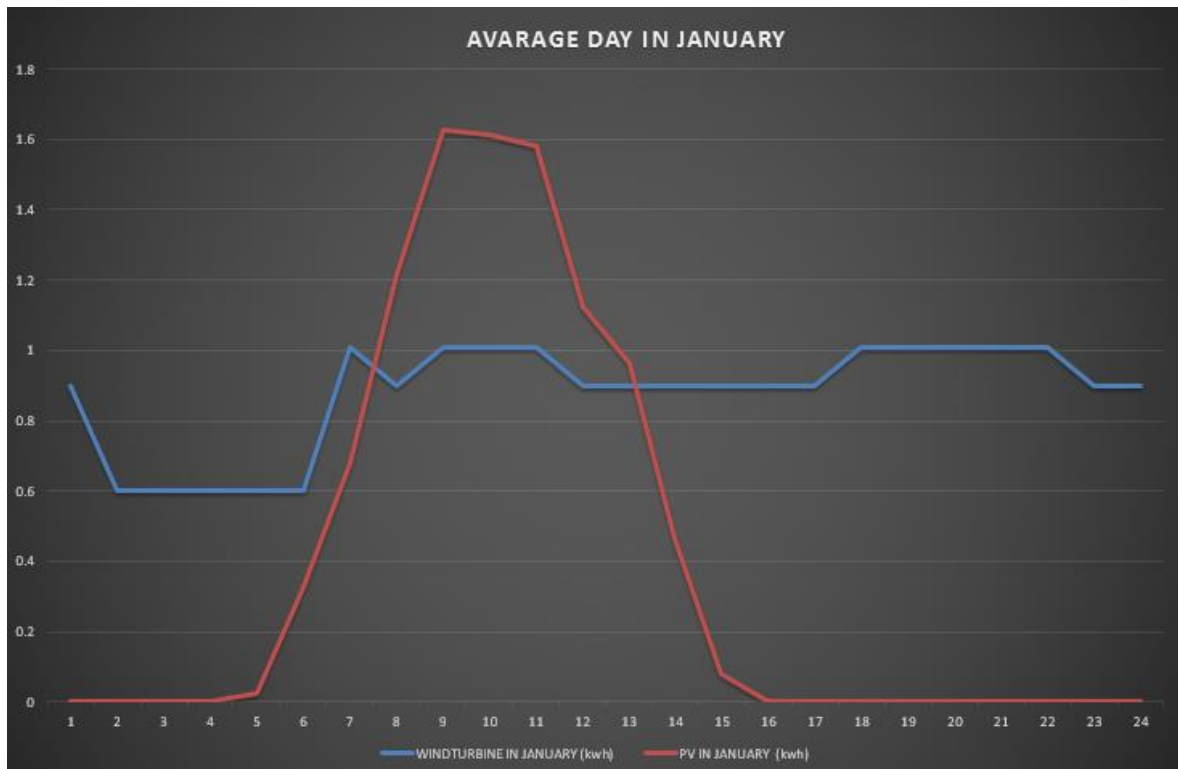


Figure (5.12) : Power Generation For PV System And Wind Turbine System During The Time In Day For January

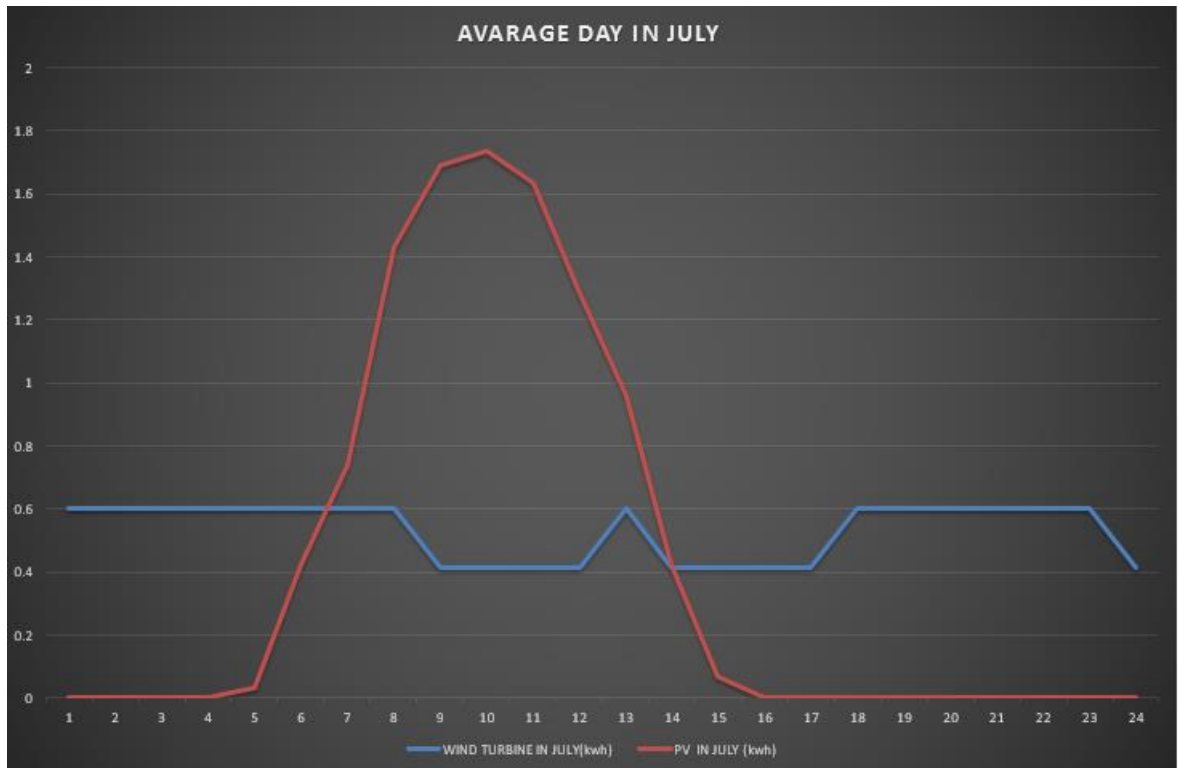


Figure (5.13) : Power Generation For PV System And Wind Turbine System During The Time In Day For July

In the previous figures (5.12 & 5.13) we can see the level power wind turbine in January(winter weather) is higher than the level power wind turbine in July (summer weather) , also we can see the peak sun power in July (summer weather) is higher than peak sun power in January (winter weather) , in addition we can see the wind turbine system generation power perfectly in night and solar system generation power perfectly In the daytime , so the hybrid system is better than single system because the hybrid system can cover the load in daytime and night .

## **Chapter 6**

### **Economic Feasibility**

#### **6.1 Economic Feasibility Study In Case With Feed-In Tariff**

6.1.1 Economic Feasibility Study solar system In Case With Feed-In Tariff

6.1.2 Economic Feasibility Study Wind Turbin system In Case With Feed-In Tariff

6.1.3 Economic Feasibility Study Hybrid system In Case With Feed-In Tariff

#### **6.2 Economic Feasibility Study In Case Without Feed-In Tariff**

6.2.1 Economic Feasibility Study solar system In Case Without Feed-In Tariff

6.2.2 Economic Feasibility Study Wind Turbin system In Case Without Feed-In Tariff

6.2.3 Economic Feasibility Study Hybrid system with control PLC In Case Without Feed-In Tariff

## Chapter 6

### Economic feasibility

Economic feasibility study is important to compare between systems and decide which one is better than others , so in this chapter we will Economic feasibility study for three systems (PV System ,Wind Turbine System and Hybrid System) in two cases , the first case with Feed-In Tariff and second case without Feed-In Tariff . We are assume the life cycle for the system is 25 years . In this chapter we are used excel software to analysis the data .

#### 6.1 Economic Feasibility Study In Case With Feed-In Tariff

In this case the electrical company will paid for the customer for every KWH inject to the grid. With Feed-In Tariff mean's for every kWh you generate you get paid. So in this case we are focus to cover the load and inject to the grid , so our control system cannot apply in this case because the aim our control system focus to cover the load just .

##### 6.1.1 Economic Feasibility Study solar system In Case With Feed-In Tariff

Equipment	Number	Cost/1piece(NIC)	Total cost(NIC)
PV panels	12	500	6000
Inverter	1	1500	1500
Protection Equipment			500
installation			1600
Total			9600

Table (6.1) : Equipment Cost For The Solar System In Case With Feed-In Tariff

In table (6.1) shows the final prices for solar system , these prices include panels cost , inverter cost, protection equipment cost and insulation cost.

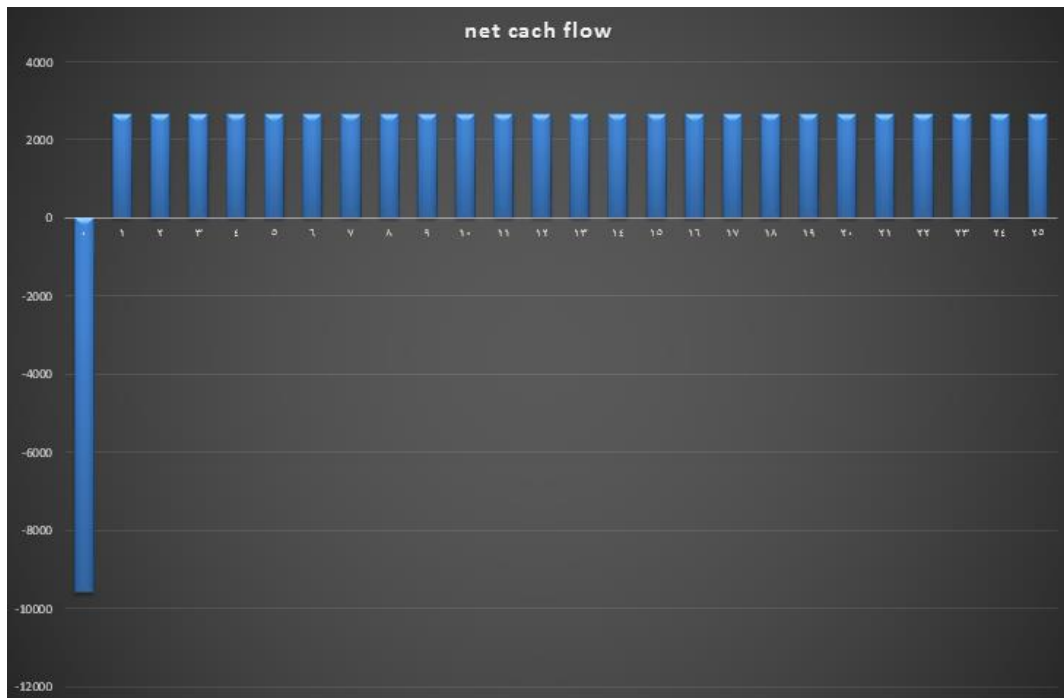


Figure (6.1) :Net Cash Flow For Solar System In Case With Feed-In Tariff

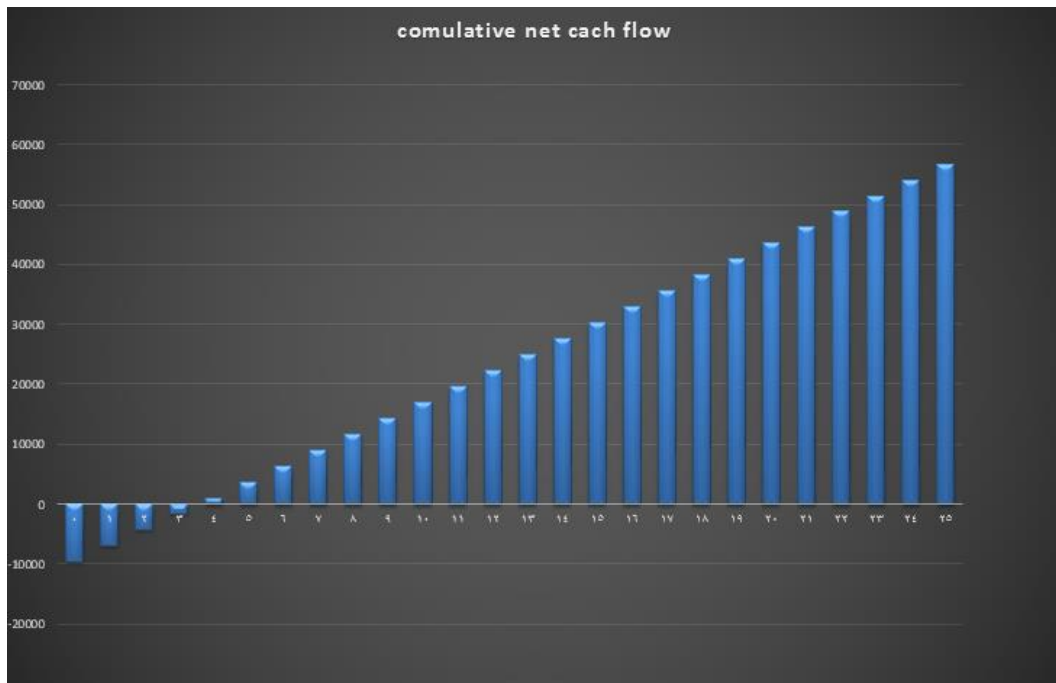


Figure (6.2) :Cumulative Net Cash Flow For Solar System In Case With Feed-In Tariff

In figure (6.1) : we can see net cash flow for the solar system which show for us the income and outcome in a given period , the value of outcome (capital cost ) is -9600 NIC at year zero(present year) and the value of income (price of load power which covered by system and price of power injection to the grid ) is 2655.3834 NIC each year .

In figure (6.2) : we can see net cash flow for the solar system which show for us the payback period for the system which equal 4 years .

### 6.1.2 Economic Feasibility Study Wind Turbin system In Case With Feed-In Tariff

Equipment	Number	Cost/1piece(NIC)	Total cost(NIC)
Wind turbine	2	2500	5000
Inverter	1	800	800
Protection Equipment			500
installation			1600
Total			7900

Table (6.2) : Equipment Cost For The Wind Turbine System In Case With Feed-In Tariff

In table (6.2) shows the final prices for Wind Turbine system , these prices include Wind Turbine cost , inverter cost, protection equipment cost and insulation cost.

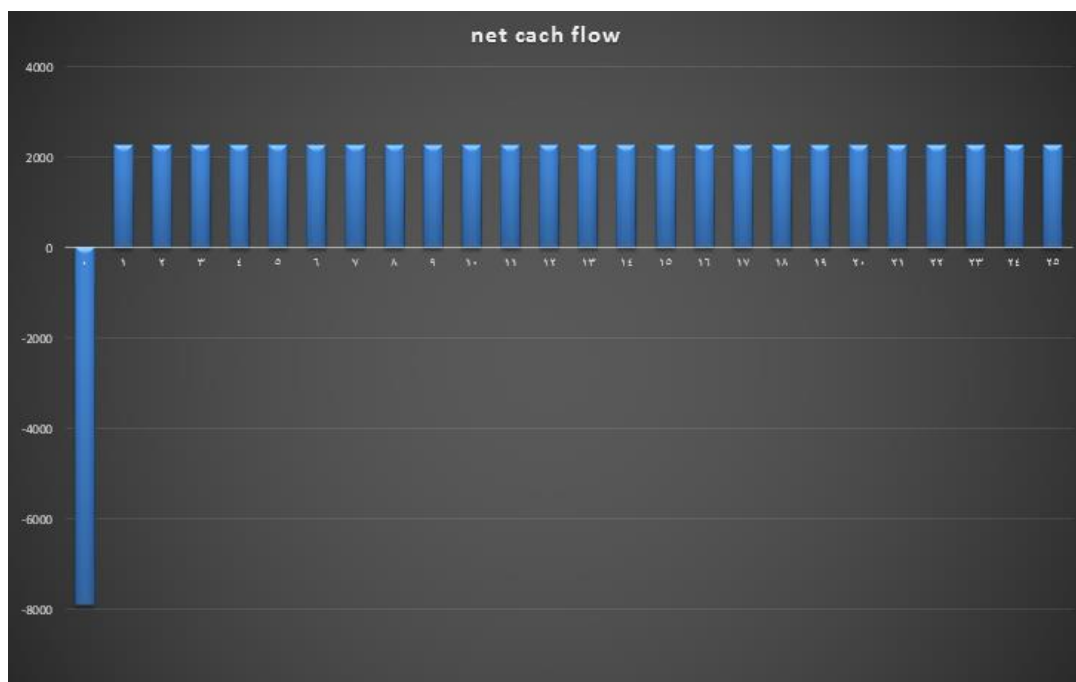


Figure (6.3) : Net Cash Flow For Wind Turbine System In Case With Feed-In Tariff

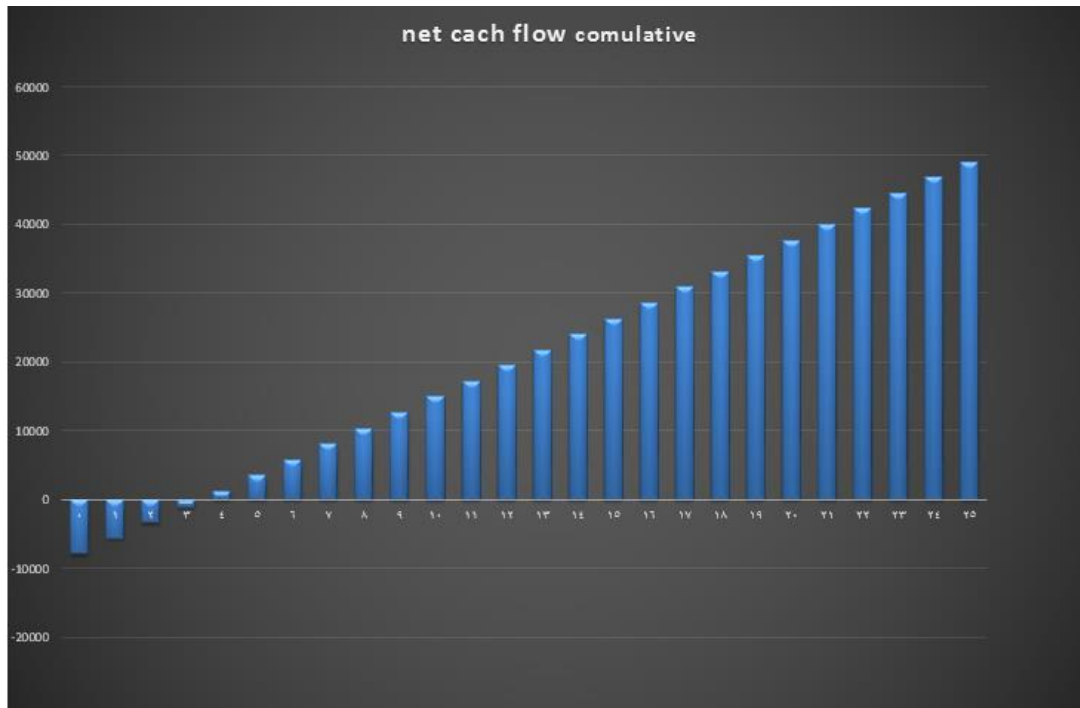


Figure (6.4) :Cumulative Net Cash Flow For Wind Turbine System In Case With Feed-In Tariff

In figure (6.3) : we can see net cash flow for the wind turbine system which show for us the income and outcome in a given period , the value of outcome (capital cost ) is -7900 NIC at year zero(present year) and the value of income (price of load power which covered by system and price of power injection to the grid ) is 2280.468 NIC each year .

In figure (6.4) : we can see net cash flow for the wind turbine system which show for us the payback period for the system which equal 4 years .

### 6.1.3 Economic Feasibility Study Hybrid system In Case With Feed-In Tariff

Equipment	Number	Cost/1piece(NIC)	Total cost(NIC)
PV panels	12	500	6000
Wind turbine	2	2500	5000
Inverter for pv	1	1500	1500
Inverter for wind turbine	1	800	800
Protection Equipment			700
installation			1400
Total			15400

Table (6.3) : Equipment Cost For The Hybrid System In Case With Feed-In Tariff

In table (6.3) shows the final prices for Hybrid system , these prices include solar panel cost, Wind Turbine cost , inverter cost, protection equipment cost and insulation cost.

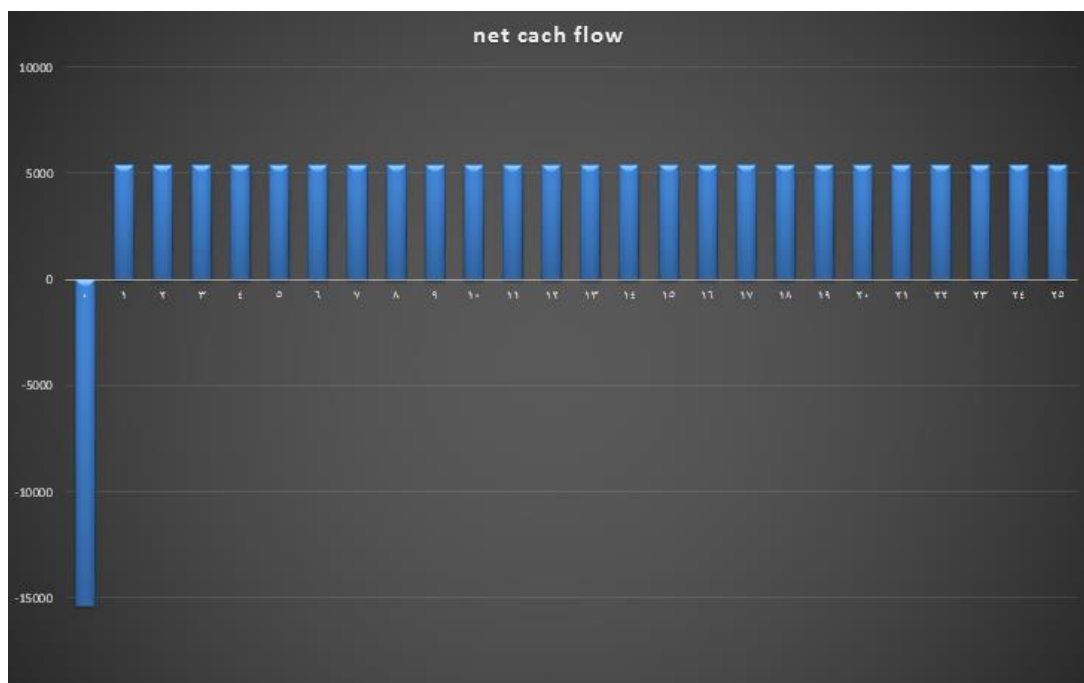


Figure (6.5) : Net Cash Flow For Hybrid System In Case With Feed-In Tariff

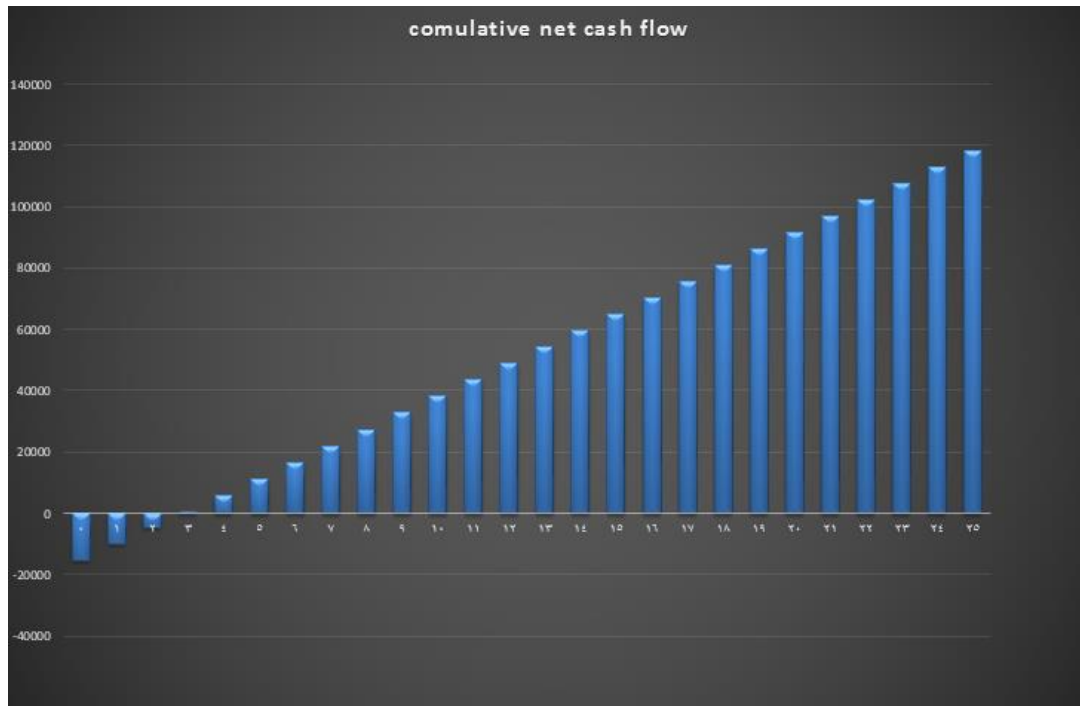


Figure (6.6) :Cumulative Net Cash Flow For Hybrid System In Case With Feed-In Tariff

In figure (6.5) : we can see net cash flow for the hybrid system which show for us the income and outcome in a given period , the value of outcome (capital cost ) is -15400 NIC at year zero(present year) and the value of income (price of load power which covered by system and price of power injection to the grid ) is 5345.8314 NIC each year .

In figure (6.6) : we can see net cash flow for the hybrid system which show for us the payback period for the system which equal 3 years .

## 6.2 Economic Feasibility Study In Case Without Feed-In Tariff

In this case the electrical company will not paid for the customer for every KWH inject to the grid. With Feed-In Tariff mean's for every kWh you generate you get paid. So in this case we are focus to cover the load just by the system , so our control system can apply in this case because the aim our control system focus to cover the load just .

### 6.2.1 Economic Feasibility Study solar system In Case Without Feed-In Tariff

Equipment	Number	Cost/1piece(NIC)	Total cost(NIC)
PV panels	8	500	4000
Inverter	1	1500	1500
Protection Equipment			500
installation			1600
Total			7600

Table (6.4) : Equipment Cost For The Solar System In Case Without Feed-In Tariff

In table (6.4) shows the final prices for solar system , these prices include panels cost , inverter cost, protection equipment cost and insulation cost.

Also you should to know we are reduce the number of panels (from twelve panels to eight panels ) to reduce the power which injection to the gird because this case Without Feed-In Tariff .

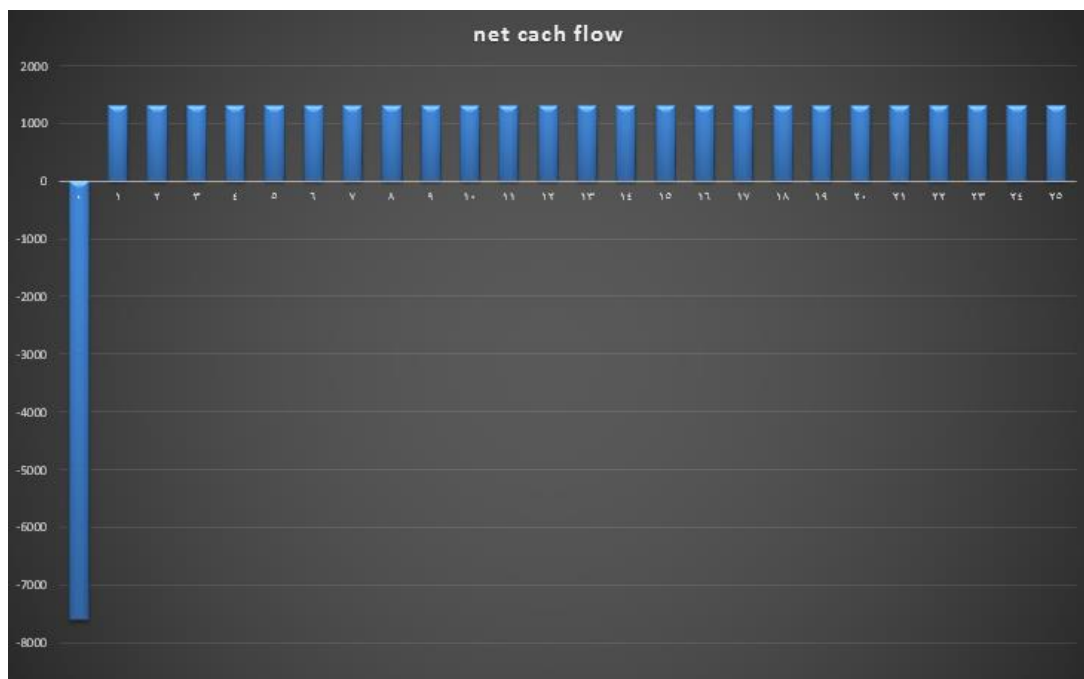


Figure (6.7) :Net Cash Flow For Solar System In Case Without Feed-In Tariff

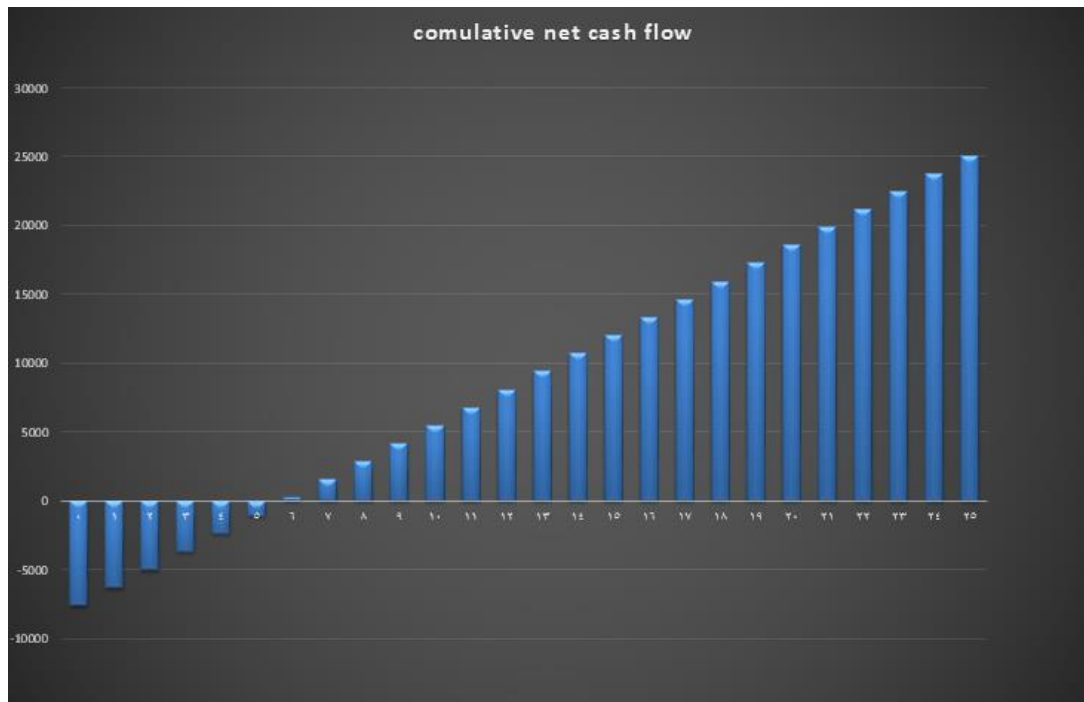


Figure (6.8) :Cumulative Net Cash Flow For Solar System In Case Without Feed-In Tariff

In figure (6.7) : we can see net cash flow for the solar system which show for us the income and outcome in a given period , the value of outcome (capital cost ) is -7600 NIC at year zero(present year) and the value of income (price of load power which covered by system ) is 1307.777 NIC each year .

In figure (6.8) : we can see net cash flow for the solar system which show for us the payback period for the system which equal 6 years .

### 6.2.2 Economic Feasibility Study Wind Turbin system In Case Without Feed-In Tariff

Equipment	Number	Cost/1piece(NIC)	Total cost(NIC)
Wind turbine	2	2500	5000
Inverter	1	800	800
Protection Equipment			500
installation			1600
Total			7900

Table (6.5) : Equipment Cost For The Wind Turbine System In Case Without Feed-In Tariff

In table (6.5) shows the final prices for Wind Turbine system , these prices include Wind Turbine cost , inverter cost, protection equipment cost and insulation cost.

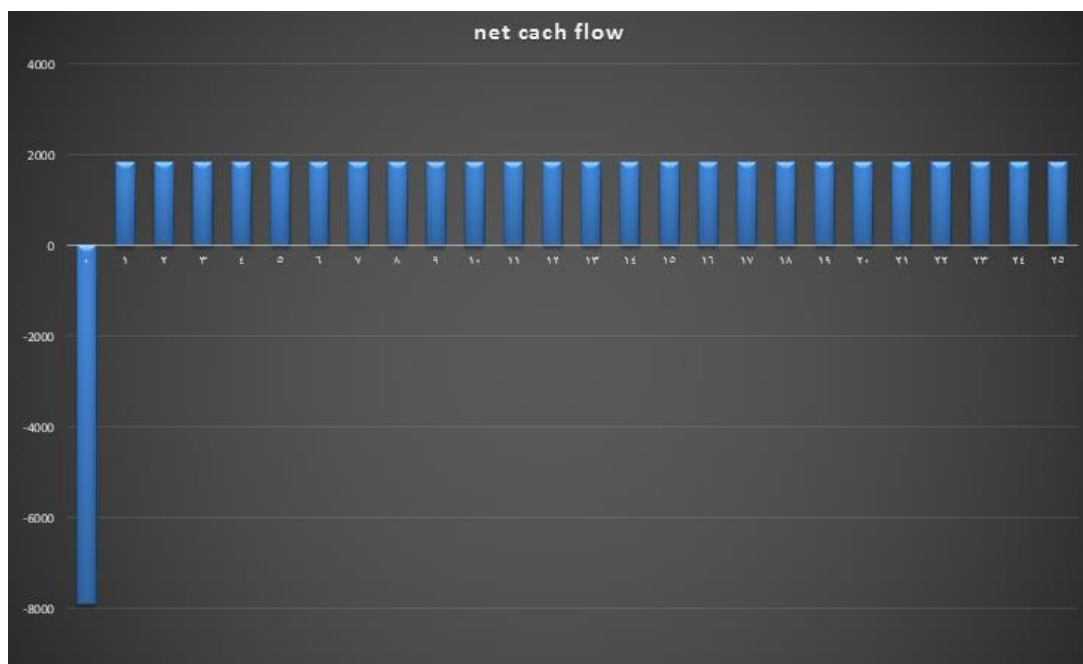


Figure (6.9) : Net Cash Flow For Wind Turbine System In Case Without Feed-In Tariff

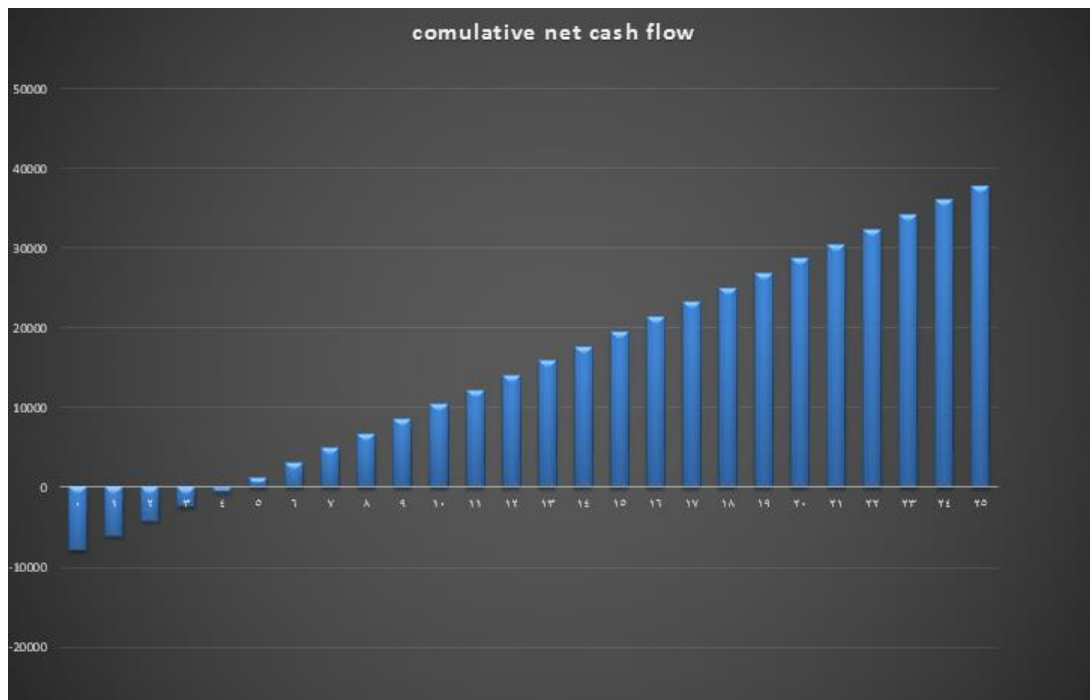


Figure (6.10) :Cumulative Net Cash Flow For Wind Turbine System In Case Without Feed-In Tariff

In figure (6.9) : we can see net cash flow for the wind turbine system which show for us the income and outcome in a given period , the value of outcome (capital cost ) is -7900 NIC at year zero(present year) and the value of income (price of load power which covered by system ) is 1828.068 NIC each year .

In figure (6.10) : we can see net cash flow for the wind turbine system which show for us the payback period for the system which equal 5 years .

### 6.2.3 Economic Feasibility Study Hybrid system with control PLC In Case Without Feed-In Tariff

Equipment	Number	Cost/1piece(NIC)	Total cost(NIC)
PV	8	500	4000
Wind turbine	2	2500	5000
Inverter for pv	1	1500	1500
Inverter for wind turbine	1	800	800
PLC	1	1000	1000
Protection Equipment			700
installation			1400
Total			14400

Table (6.6) : Equipment Cost For The Hybrid System with control PLC In Case Without Feed-In Tariff

In table (6.6) shows the final prices for Hybrid system with control PLC , these prices include solar panel cost, Wind Turbine cost , inverter cost, protection equipment cost and insulation cost and PLC cost.

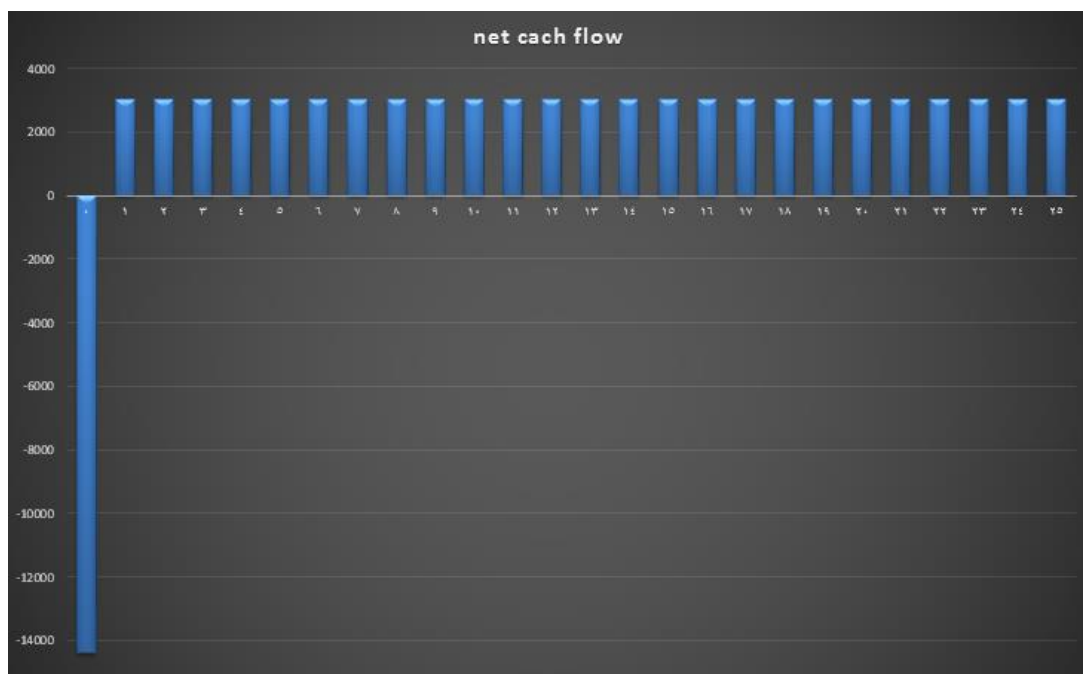


Figure (6.11) : Net Cash Flow For Hybrid System with control PLC In Case Without Feed-In Tariff

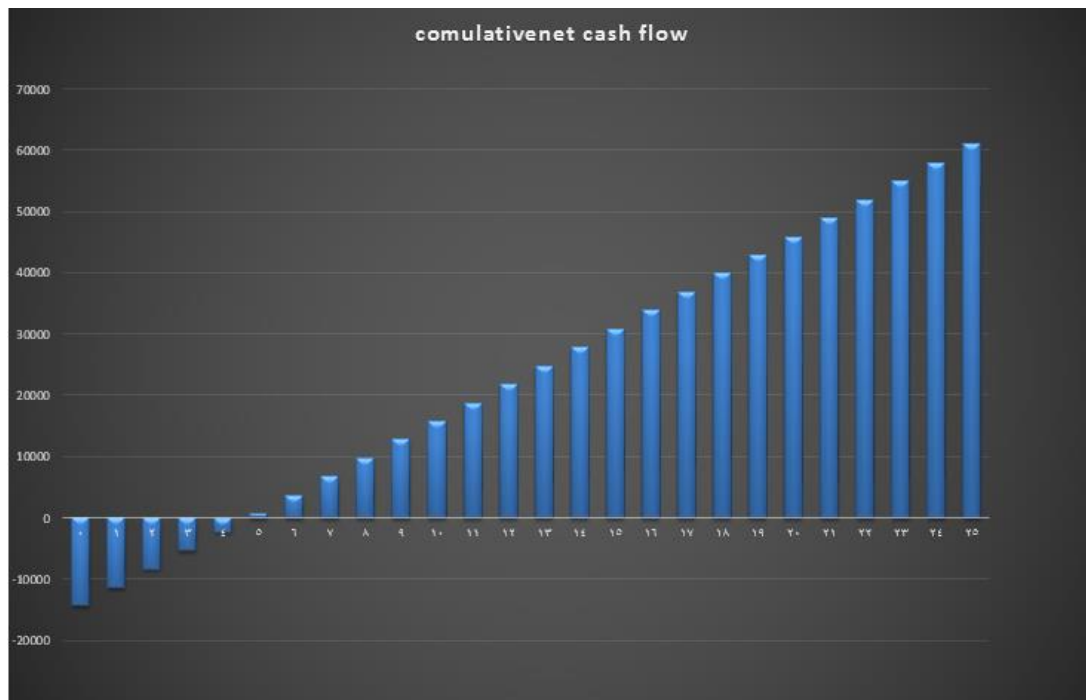


Figure (6.12) :Cumulative Net Cash Flow For Hybrid System with control PLC In Case Without Feed-In Tariff

In figure (6.11) : we can see net cash flow for the hybrid system with control PLC which show for us the income and outcome in a given period , the value of outcome (capital cost ) is -14400 NIC at year zero(present year) and the value of income (price of load power which covered by system and cost of power injection to the grid ) is 3015.0314 NIC each year .

In figure (6.12) : we can see net cash flow for the hybrid system with control PLC which show for us the payback period for the system which equal 5 years .

System	Capital Cost (NIC)	Income / Year (NIC)	Payback Period (YEAR)
<b>In Case With Feed-In Tariff</b>			
Solar	9600	2655.3834	4
Wind Turbine	7900	2280.468	4
Hybrid	15400	5345.8314	3
<b>In Case Without Feed-In Tariff</b>			
Solar	7600	1307.777	6
Wind Turbine	7900	1828.068	5
Hybrid With Control PLC	14400	3015.0314	5

Table (6.7) : Abstract Of Economic Feasibility Study

In table (6.7) we can see abstract of Economic Feasibility Study for all system (solar , wind turbine , hybrid) in two case ( With or without Feed-In Tariff ) . as we see in case with Feed-In Tariff the lowest payback period for hybrid system (3 years) , and in case without Feed-In Tariff the payback period for hybrid system with control plc is equal with wind turbine system (5 years) but the wind turbine is not reliable because the wind speed is under rated speed for wind turbine so not good let load house covered by wind turbine generation alone.

## **Chapter 7**

### **Conclusion And Recommendation**

#### **7.1 Conclusion**

#### **7.2 Recommendation**

## **Chapter 7**

### **Conclusion And Recommendation**

#### **7.1 Conclusion**

The hybrid system generation (PV and wind turbine system) is better than the individual system generation (PV or wind turbine system) in many of aspects as we saw in chapter Results and chapter Economic Feasibility. In chapter Results we saw the hybrid system can cover almost of home load during the year but individual system cannot cover all the home load like hybrid system , also we are saw the power generation for solar system and wind turbine system during the day , the solar system generate power perfectly in daytime and wind turbine system generate power perfectly in night so when we combine two system together with control system that let the system more reliable . In chapter Economic Feasibility we saw in case without Feed-In Tariff the payback period for hybrid system with control plc is equal with wind turbine system (5 years) but the wind turbine is not reliable because the wind speed is under rated speed for wind turbine so not good let load house covered by wind turbine generation alone.

The electrical company in Hebron don't pay for the energy which inject to the grid , most electrical company not allow to inject energy equal double energy load along the year , the importance of the control system (PLC) shown here which let the one of systems (solar or wind turbine system) or twice connect with grid to cover home load just and not focus to inject exceed energy to the grid.

Finally the hybrid system with control system (PLC) is better than individual system and it is more reliable and more economically.

## **7.2 Recommendation**

- Recommend students to study and do projects for another type of hybrid system such as wind turbine with geothermal.
- Recommend electrical company to put laws and regulations help and encourage people to install alternative energy systems .
- Recommend government to reduce taxes for devices and equipment for the alternative energy systems to reduce capital cost for the design alternative energy systems .

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# Appendix