Dynamic analysis of renewable energy sources in west of Algeria

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***Abstract** –: In today's world, due to the growing demands of technology and rise in population, there has been a tremendous pressure on the electricity demands. So far fossil fuels have been used to meet the demands, but since fossil fuels are finite and are getting depleted, the world needs to find alternative sources of energy. Also the use of fossil fuels like natural gas and oil has a hazardous effect on the environment because of the chemicals which pollute the air. Hence renewable sources such as solar energy, wind energy, biomass, etc. are being considered to meet the growing demands of energy. The ultimate goal of the project is find the best design in terms of cost for installing a power plant at any location considering the average hourly load profile of that location.*

Stand alone power systems are mainly benefited by small far away villages where it is difficult to supply power through the grid. This report aims at analyzing the renewable energy sources available in west Algeria to help the small villages avail electricity. Sizing of the solar panels and wind turbines is of utmost importance. The report designs an algorithm which aims at calculating the size of solar alone, wind alone and solar-wind hybrid systems.

***Keywords**: PV, wind, FFT, Solar Panels*

1. INTRODUCTION

This ultimately leads to an increase in the usage of electricity. Electricity is mainly generated from non-renewable energy sources like crude oil, natural gas, coal etc. These are termed as non-renewable since they are finite and cannot match up to the needs of the world. The oil reserves of the world will not sustain in the time to come. Currently these sources are there in abundance, but will diminish in the near future because of the increasing demand of electricity.

Even if these sources are available in quantity, the non renewable energy sources have a big negative impact on the environment. They produce immense toxic waste and pollute the environment to a great extent. It is detrimental to plant and animal life. The usage of fossil fuels is one of the reasons for global warming. Electricity generated from fossil fuels and coals result in harmful emissions of nitrogen oxides and sulphur dioxides. These chemicals lead to acidic rivers and are lethal to mankind [1].

2. SOLAR ENERGY

The scarcity of electricity in rural areas and the need for low cost power is driving the world towards the photovoltaic industry. Solar energy is one of the most prominent renewable sources of power generation in the world. It can be utilized in various methods and for different applications. In today's world PV can be used for a wide number of applications such as supplying electricity in remote villages, water pumping and navigation purposes for the coast guard [7]. Figure below shows a typical solar panel installed on a house which is remotely located [8].

Figure.1.Installed Solar Panels

Description of Photovoltaic Systems:

Photovoltaic systems consist of photovoltaic cells, which are devices that convert light energy directly into electricity. As they use sunlight as a source of energy they are known as solar cells. Photovoltaic Cells (PV) are made of at least two layers of semiconductor material mostly amorphous silicon, positive and negative. When sunlight falls on the semiconductor cells they generate electricity. Photons are produced by the sunlight. “The photons hit the cell and produce free electrons that move through the wires and cause an electric current” [9]. Figure below shows how a solar panel produces electricity [4].

3.WIND ENERGY:

Wind Energy Background:

Wind is the most prominent renewable source of energy, as it can produce electricity with natural wind, rather using non renewable sources of energy such as fossil fuels. It is also clean form of energy production, which does not emit pollution, thereby not destroying nature. Wind turbines produce significant amount of energy using only the wind. In near future, wind energy will be one of the most important sources of energy for faster development. The energy production with the wind turbines depends on the average speed of the wind in a specific area. Areas near the coast and open terrain have more flow of wind. The usage of wind turbines for energy generation is increasing day by day with a rapid growth in the past 25 years. About 25,000 MW is estimated to be in use around the world.

Description of Wind Turbines:

A modern wind turbine works on the same conventional principle as windmills work, using the natural wind to turn the blades for the production of electricity. A typical wind turbine is made up of four components, a rotor and two or three propellers, covered housing for engine, connecting cables and electric monitoring equipments. The rotor, blades and the nacelle are mounted on top of the tower and the monitoring equipments are throughout the system [8] .

A rotor is pivoted with three propellers or blades known as airfoils. The wind moves the blades eventually spinning the rotor. The faster the wind blows, the better the spinning of the rotor. Electricity is produced when the rotor spins in the housing and the rotor is connected to a gearbox with low speed axle, increasing the speed of rotation. The gearbox on the other side is connected with high speed axle spinning the generator to produce electricity. An electromagnet attached to the axle rotates within a wired mesh, creating magnetic field which produce strong electric current [8] .

Cables carry the electric current to the base of the tower and the transformer steps up-down the voltage according to the usage on site. Control systems and other electronics monitor, manage, and optimize turbine operations. They also optimize the energy production according to the wind conditions [8] .

3. STAND ALONE HYBRID SYSTEMS

Stand alone hybrid systems consist of electricity produced by solar and wind energy.

Since wind and solar insolation occur naturally, they cannot be totally replaced by fossil fuels altogether. There are many locations where there is more wind and less sunshine in the winter season and locations where there is plenty of sunshine in the summer but rarely any wind. So there needs to be a provision during worst case situations as explained. Having a wind turbine and solar panels produce electricity together eliminates the drawbacks of a standalone solar/wind system. This ensures load is met. When the electricity supply demands are not met, a backup diesel generator is also used to meet the demands [5] .

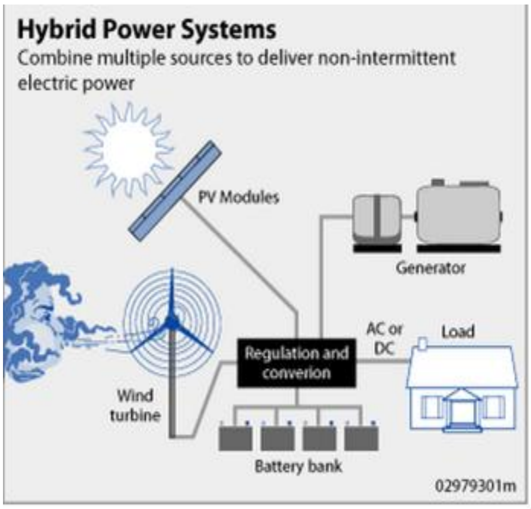

Figure 2. Hybrid Power System

3. METHODOLOGY:

4.1 Flowchart

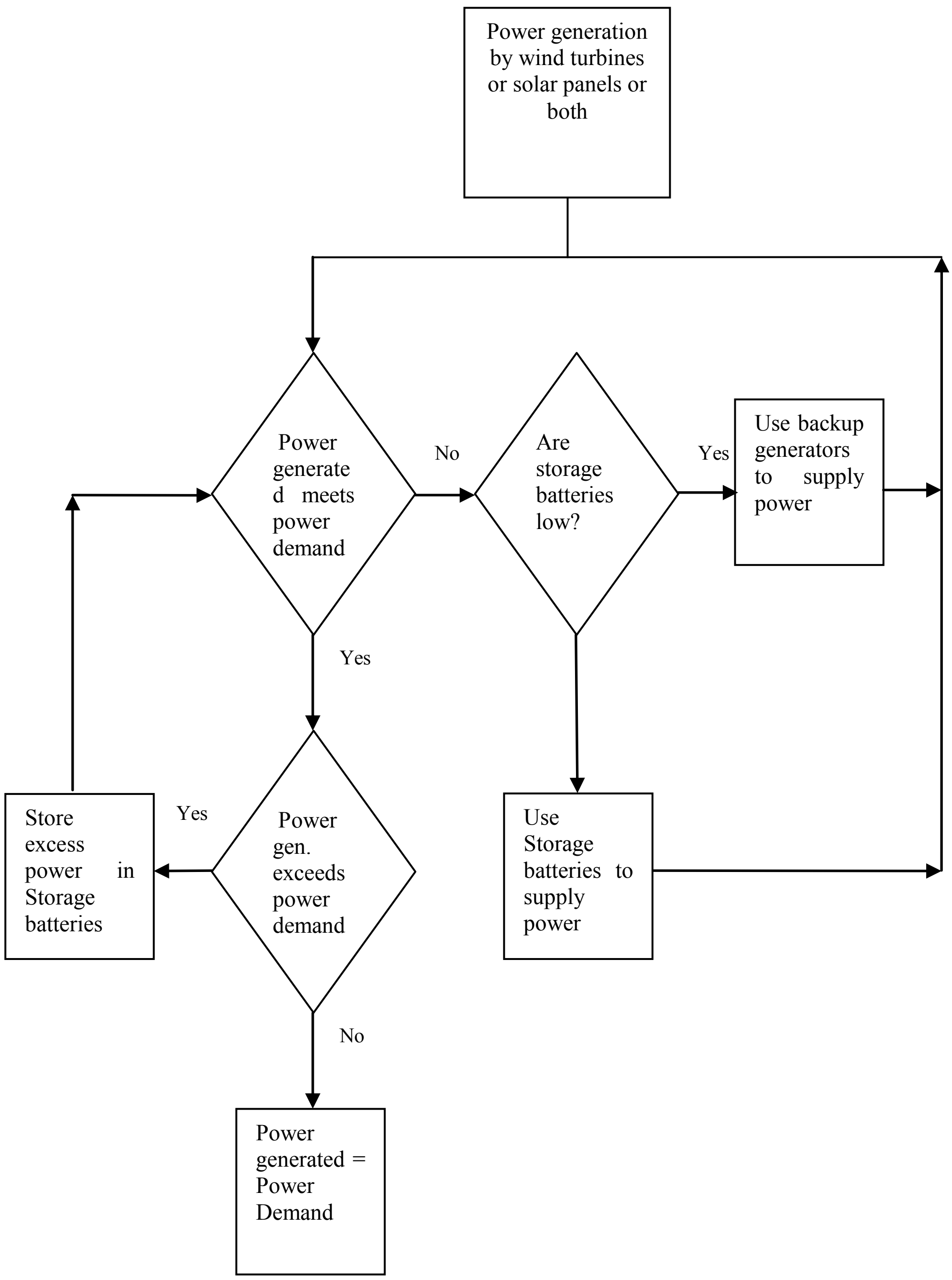

Figure 3.Flowchart

4.2 Algorithm:

The steps involved for choosing the number of wind turbines and solar panels are as follows:

- Find the average power demand of the location.
- Find the average hourly wind, solar insolation of location under study. Depending upon the available data, the number of wind and solar turbines should be selected such that the power generated by these devices should match the actual power demand of that area.
- The number of wind turbines should be kept as minimum as possible because the ratings

of the wind turbines are much greater than that of solar panels.

- Select the appropriate combination of wind turbines and solar panels by selecting 'n' number of wind turbines and increasing the number of solar panels such that over a given period of time, the power deficit/surplus (the average hourly mean value of the difference between the power generated and power demand) for wind turbines or solar panels or combination of both should be zero.
- For selecting various combinations of devices, following three cases are consider:

o Case I: Wind Alone power generating system (zero solar panels):

Select 'n' number of wind turbines such that the graph of power deficit (wind turbines) for 'n' number of wind turbines should be equal to or greater than zero.

o Case II: Solar Alone power generating system (zero wind turbines):

Select a number of solar panels such that the graph of power deficit (solar panels) for solar panels should be equal to or greater than zero.

1. Select a single wind turbine and increase the number of solar panels such that the graph of power deficit (solar panels and wind turbines) for single wind turbine and solar panels should be equal to or greater than zero.
2. Now, select two wind turbines and increase the number of solar panels such that the graph of power deficit/surplus (solar panels and wind turbines) for two wind turbines and solar panels should be equal to or greater than zero.
3. Repeat the above step till 'n-1' number of wind turbines.

- Calculate the average power deficit/surplus for each hour of the day.
- Calculate the average daily energy for each combination from the power deficit/surplus data obtained in each case above.
- Calculate the annual cost of every combination above and select the combination which has the lowest price.

5. CALCULATIONS AND SIMULATIONS

5.1 Load Demand

Load energy profile is daily recorded for a period of 1 month and then the average hourly load profile is calculated. Figure below shows the typical average load demand of a small village on hourly basis.

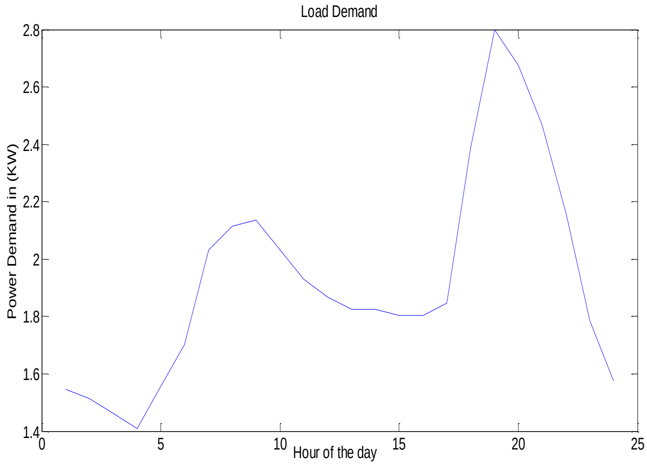

Figure 4. Average Hourly Load Demand

5.2 Formulas and Specifications

5.2.1. General formula and specifications for output power generated by a single PV Panel are as follows:

Maximum Power	120 W
Efficiency	12 %
Area	1.07 m^2

Table.1. PV Panel Parameters

Output power generated by a single PV panel is calculated using the following equation. The equation below ignores the temperature effect on PV cells [6] .

Ppv(t)= Ins(t) * A * Effpv

Where,

Ins(t) = Insolation data at time t in KW/m^2

A= Area of a single panel in m^2

Effpv= Efficiency of the PV panels.

The graph below shows the average hourly solar insolation data for a day in the west of Algeria [9] .

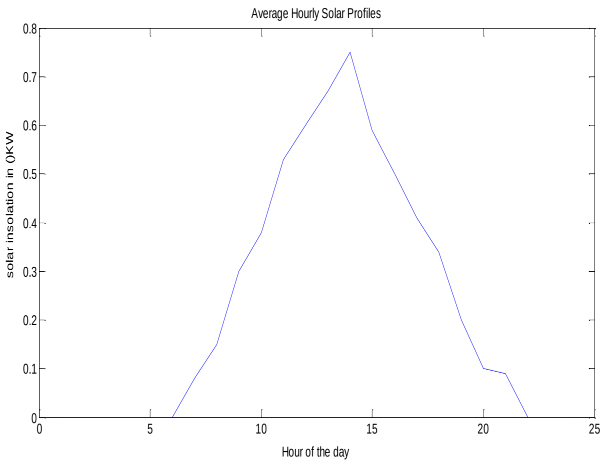

Figure 5. Average Hourly Solar Profiles

Substituting the insolation values from the above figure and the PV panel parameters in the above equation we can plot the output power generated by a single PV panel at each hour. These values have been generated from the code given in topic 8.

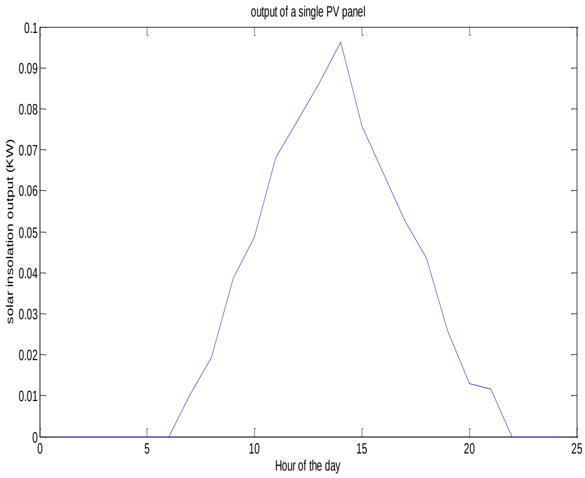

Figure 6 Graph of output of a single PV panel at each hour of the day

5.2.2. General formula and specifications for output power generated by a single wind turbine are as follows:

Rated Power	10 KW
Rotor Diameter	7 m
Wind Turbine Efficiency (Cp)	30% Assumed
Air density	1.225 kg/m3
Effad	95% Assumed

Tableau.2 Wind Turbine Parameters

Output power generated by a single wind turbine is calculated using the following equation [6] .

$$P_{Wind}(t) = \frac{1}{2}\rho A v(t)^3 C_p \, Eff_{ad},$$

Where,
ρ = air density in kg/m3
A= swept area of the motor in m2
v= wind speed in m/s
Cp= efficiency of the wind turbine
Effad= efficiency of the converter

The graph below shows the average hourly wind data measured at the given site which in this case is in the west of Algeria [9] .

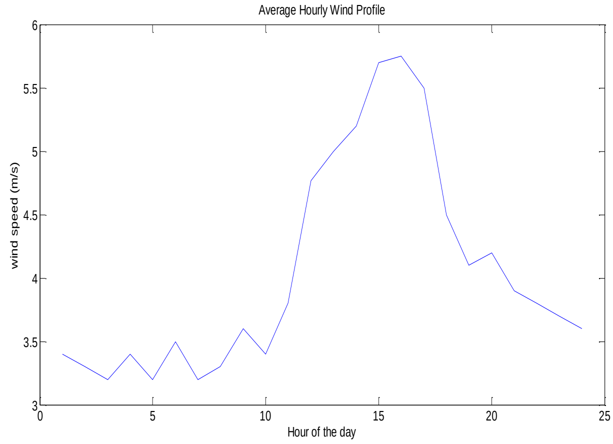

Figure.7 Average Hourly Wind Profile

Substituting the hourly average wind speed from above figure and the wind turbine parameters in the wind equation we can plot the power output generated at each hour by a single wind turbine. . These values have been generated from the code given in topic 8.

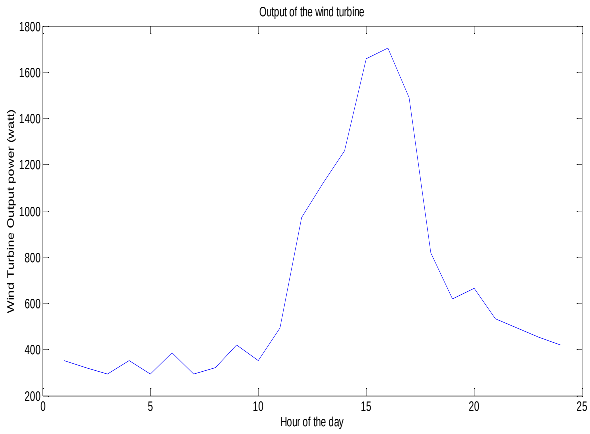

Figure .8 Graph of output of a single wind turbine at each hour of the day

5.3. General formula for Power deficit/surplus is as follows:

Power deficit/surplus is obtained by taking difference between power generated and power demand which is given as follows:

Power deficit/surplus = Power Generated – Power Demand.

5. 4. Battery Specifications

Type	Deep Cycle
Voltage	12 V
Capacity	100 Ah
Rating	1200 W = 1.2KW

Table.3 Battery Specifications

5.5. General formula for calculating number of batteries is as follows:

Number of batteries>=Required Storage Capacity (0.8) (rated capacity of each battery)

where, 0.8 means batteries should not be cycled more than 80% of their rated capacity.

5.6 Simulations

The codes used for simulation and to obtain the following graphs are given in topic 4.5.

The three cases for different combination of wind turbines and PV panels are as follows:

Case I: Wind Alone power generating system (zero solar panels):

The number of wind turbines required for the balanced system (power deficit/surplus = 0) can be obtained from the following graph:

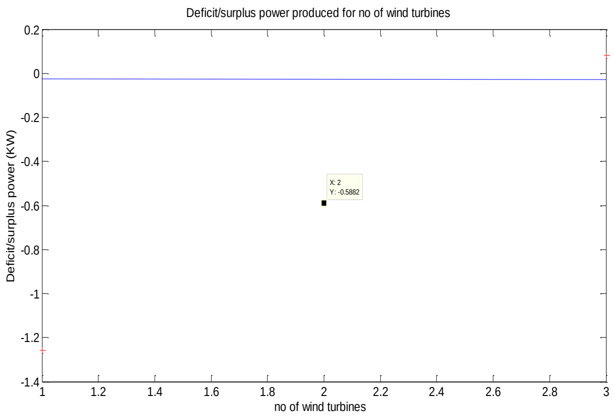

Figure.9 Graph of Deficit/Surplus Power produced by 'n' no. of wind turbines

From the graph, it is clear that 3 wind turbines are required for the system to meet the load i.e. power deficit/surplus to be equal to or greater than zero. So, the value of 'n' for wind turbines is 3 i.e. 'n' = 3.

Also, the graph of average daily power deficit/surplus obtained by using the power deficit/surplus equation is as follows:

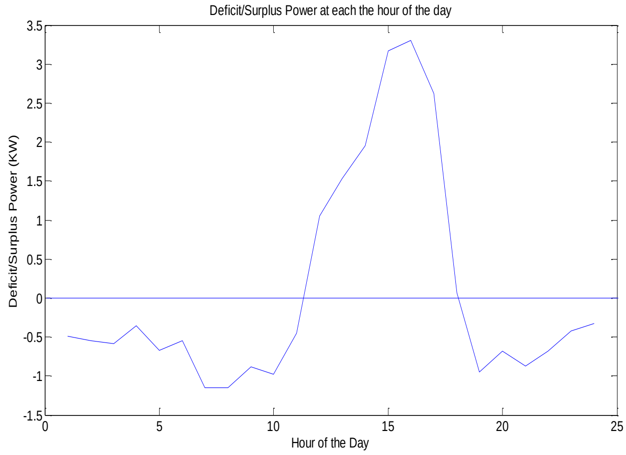

Figure.10 Graph of average Deficit/Surplus Power at each hour of the day

The above graph of average daily power deficit/surplus can be used to obtain average daily energy curve by taking hourly summation of power deficit/surplus for the entire day.

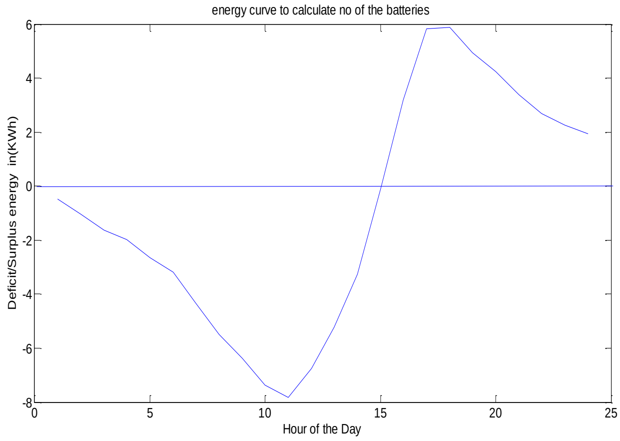

Figure.11 Average Daily Energy Curve for Wind Alone Design

From the above graph, it is clear that the difference in the peak to peak values of energy curve is 14.39KWh.

So, the number of batteries can be calculated from the batteries equation as

Number of batteries >=Required Storage Capacity

(0.8) (rated capacity of each battery)

= 14.39/ (0.8*1.2)

= 14.98

=15

Case II: Solar Alone power generating system (zero wind turbines):

The number of solar panels required for the balanced system (power deficit/surplus = 0) can be obtained from the following graph:

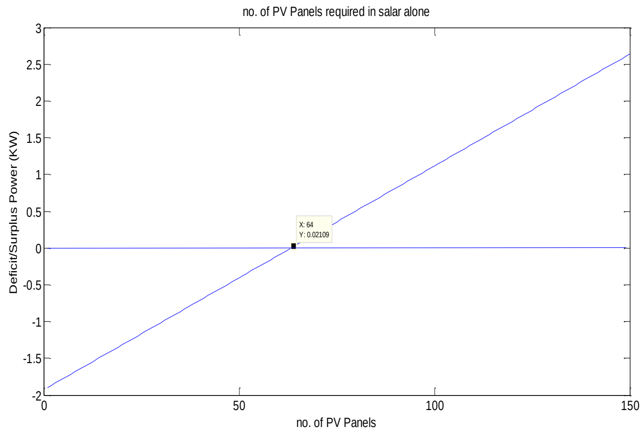

Figure.12.Graph of Deficit/Surplus Power produced by 'n' no. of PV Panels

From the graph, it is clear that 64 solar panels are required for the system to meet the load i.e. power deficit/surplus to be equal to or greater than zero.

Also, the graph of average daily power deficit/surplus obtained by using the power deficit/surplus equation is as follows:

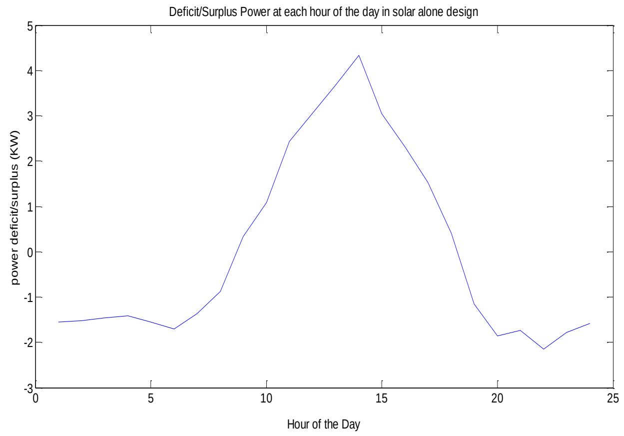

Figure.12.Graph of Average Deficit/Surplus Power at each hour of the day

The above graph of average daily power deficit/surplus can be used to obtain average daily energy curve by taking hourly summation of power deficit/surplus for the entire day.

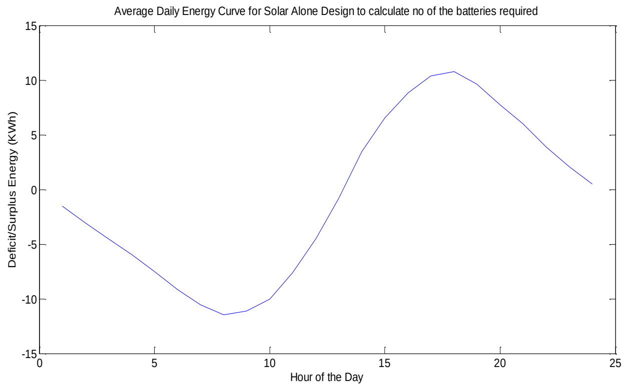

Figure.13. Average Daily Energy Curve for Solar Alone Design

From the above graph, it is clear that the difference in the peak to peak values of energy curve is 22.34KWh.

So, the number of batteries can be calculated from the batteries equation as
Number of batteries >=Required Storage Capacity
(0.8) (rated capacity of each battery)
= 22.34/ (0.8*1.2)
= 23.27
= 24

5.7. Results

The following are the sizing requirements for various designs in order to meet the load.

Design Type	No of Wind Turbines	No of PV Panels	No of Batteries
Wind Alone	3	0	15
Solar Alone	0	64	24

Table.3. Result of Sizing Algorithm

6. CONCLUSION

From the above results we conclude that for this case study, a solar alone design I would make sense rather than installing the wind alone design. The algorithm was designed to find the optimum size of the solar panels and wind turbines. It also calculated the amount of storage required to meet the required load demand. This analysis can be used at any location to decide the optimal sizing of a power plant for standalone installations. An economical analysis was also done in order to find the most economic design.

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