

## Analysis of Standalone Hybrid power plant

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### Abstract

Due to increasing in the load demand in the developing countries, satisfying the demanded load is becoming a major problem. The renewable energies are playing a key role in the power industry. Mainly the remote places are facing more crisis of power. Due to fewer amounts of power generation and problems in transmitting power to the remote areas, stand alone systems are playing a key role. This paper presents the stand alone PV-Wind-Ac Generator power integrated plant to supply power to the Village DANGLA which is located in Amhara region Ethiopia. Based up on the wind flow rate and temperature conditions of the place the PV panels, Wind machines has been considered for the case study. The wind and temperatures has been taken from the National Metrological Agency of ADAMA. The simulation result has been presented clearly for the utilization of power from each source, and it has been shown clearly for every month.

Keywords: SAPS, PV, Wind power, Irradiant, simulation software.

### I. INTRODUCTION

The major stages of power production and delivering up to the load centers are classified as 3 states: Generation, transmission and distribution. The generation of power is produced from different plants it may be renewable energy and non renewable energy sources. The conventional energy sources are using fossil fuels to generate the power, these power stations are releasing harmful gases in the

environment and in order to save the fossil fuels for our future trends, the renewable energy plants came in to era, playing a key role in the power industry [1].

The generated power is boost up by using the step up transformer, transmitted via transmission lines with high voltage levels ranging from 330kV to 1000kV. The distribution network is more multifaceted network, it starts from the distribution substation to the load

centers, it may be house hold loads, schools, colleges, hotels, industries, etc,. The problems facing, in the electrical industry due to increase in the load laying of the transmission lines to the load centers are fetching a big issue, due to the capital income of the country, political influences, etc.[8]. The up gradation of the established lines is also becoming a big problem. More over there are many problems like power quality,

voltage flickering; harmonics, instability are occurring while interconnecting the renewable energy sources to the power grid [2]. Stand alone power systems (SAPS) systems are playing a key role for the remote locations, to satisfy the customer demands. In this type of systems the power generation units may be wind, PV, hydro, it has a battery storage system.

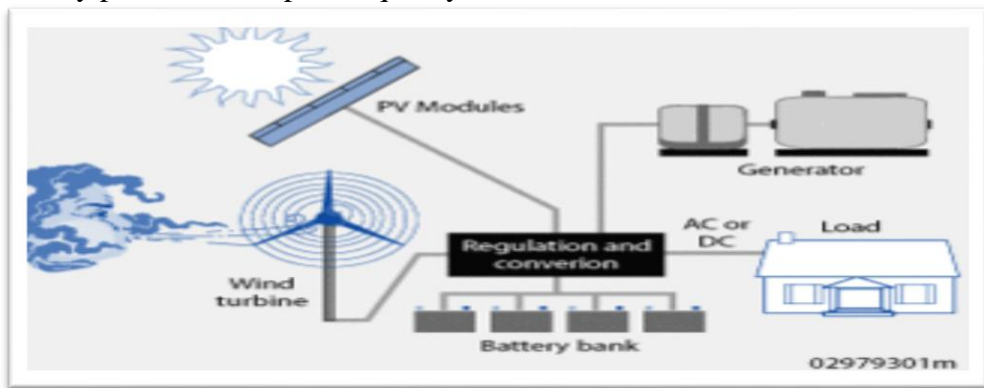


Fig.01 Overview of Standalone Hybrid power system.

## II. OVERVIEW OF DANGLA VILLAGE – ETHIOPIA.

Ethiopia is a Federal Democratic country which is located Horn of Africa. Village Dangla is located in the Amhara region, 78km from Bahirdar. The geographical location of dangla is 11.25 and 36.6. The population this village is 158,668. The village is growing rapidly in all sectors. It is having a TVET college, schools and

hotels. Due to the increasing in population the hospitals are also increasing. The Ethiopia is having a transmission system of 400kV, 212km Debremarkos – Gebreguracha – Sululuta, a new line has been establishing between Ethiopia- Kenya 315km with 500kV. The solar power plants established in the Ethiopia are

1. Debreberhan PV Power Station with capacity 10MW, located in Amhara region.
2. Metehara PV Power Station with capacity 50MW, located in Oromiya region.
3. Dera Solar Energy PV Power Station 60MW located in Oromiya region.

The Ethiopia is growing very rapidly in the wind power also Adama-II 153 MW, Ashegoda – 120MW. The biggest project going on the Hydro power plant is Grand Ethiopian Renaissance Dam with a capacity 6000 MW it is under the construction. Even through large amounts of power is generating but there is a lack of power in the remote areas. The main concern about this village is it is located near to the Tourist place Bahirdar, it is growing rapidly. In the future it will mix

with the Bahirdar, the utilization of power increases in the future. So in this paper proposing a SAPS for the villages around the Dangla.

### III. RECON VIEW OF WIND POWER

The wind energy is recognized as a feasible contribution towards the power industry. Beyond the environmental profit the wind penetration improves the utility's capacity with the help of converting the wind power in to electrical energy. The wind power plants can offer power to the remote areas. Even they are able to integrate with the existing power networks [3]. Schematic view of the wind turbine and its parts has been shown clearly in the fig.02 [4].

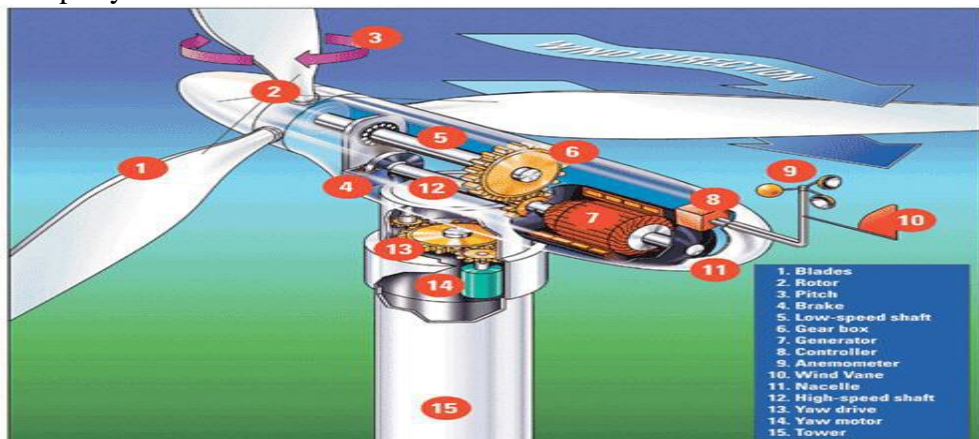


Fig.02 Representation of wind turbine with indicating the parts

A wind turbine transforms the kinetic energy in the wind to mechanical energy in a shaft and finally into electrical energy in a generator. The power can be expressed as [5]. Generally the land the wind is strongly barren by many obstacles like plants, roughness of the ground, and some geographical elements [6]. As the height is increases above the ground the undisturbed air layers of

the geostropic wind 5km above the ground the wind is no longer included by the surface. Between these two extremes, wind speed changes with height. This phenomenon is called vertical wind shear. In flat terrain and with a neutrally stratified atmosphere, the logarithmic wind profile is a good estimation for the vertical wind shear:

$$P = 1/2 \rho A V^3 \quad \dots (1)$$

$$V_2 = V_1 \frac{\ln\left(\frac{h_2}{z_0}\right)}{\ln\left(\frac{h_1}{z_0}\right)} \quad \dots (2)$$

#### IV. RECON VIEW OF SOLAR POWER

Solar energy is playing a vital role in the renewable energy sector. Unfortunately, there is no properly recorded solar radiation data and, what is available is sunshine duration data[7]. However, given knowledge of the number of sunshine hours and

local atmospheric conditions, sunshine duration data can be used to estimate monthly average solar radiation, with the help of empirical equation 3. where a and b are the regression coefficients. N is the maximum possible daily hours of bright sunshine,  $\bar{n}$  is monthly average daily number of hours of bright sunshine. And the data is given to the software.

$$\bar{H} = H_0 \left( a + b \left( \frac{\bar{n}}{N} \right) \right) \quad ..(3)$$

#### V. SYSTEM MODEL

The SAPS considered is shown in Fig.03. In the

interconnection the maximum power is extracted from the PV array as it is operates at its

maximum power point. The power delivered by the diesel generator depends on the total amount of power delivered according to its contract. In the isolated mode which is supplying a maximum power to the load. The value of the voltage for maximum power extraction and the maximum power

that can be produced is extracted by using the MPPT algorithm by using the Perturb and Observe method. Here in the modeling of the system the number of batteries connected is 10, number of wind machines is 5, number of solar panels connected in parallel is 17.

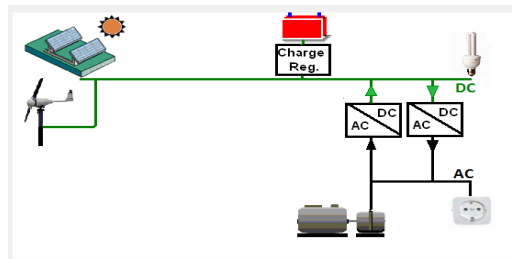


Fig.03 Schematic view of the developed stand alone isolated system

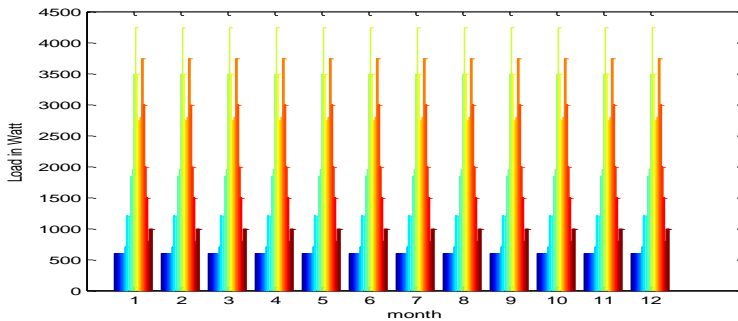
Table.01 Assumptions considered in analysis

S.No	Assumptions
1.	Converter and filter have negligible losses
2.	PV Array, Wind turbine and DG belongs to the same IPP and are coupled at the same bus

## VI. DATA COLLECTION AND ANALYSIS OF EACH COMPONENT

To run the simulation, load data has been taken average of the loads of the village. Below clearly mentioned about the load conditions, wind profiles, solar temperature, battery and AC

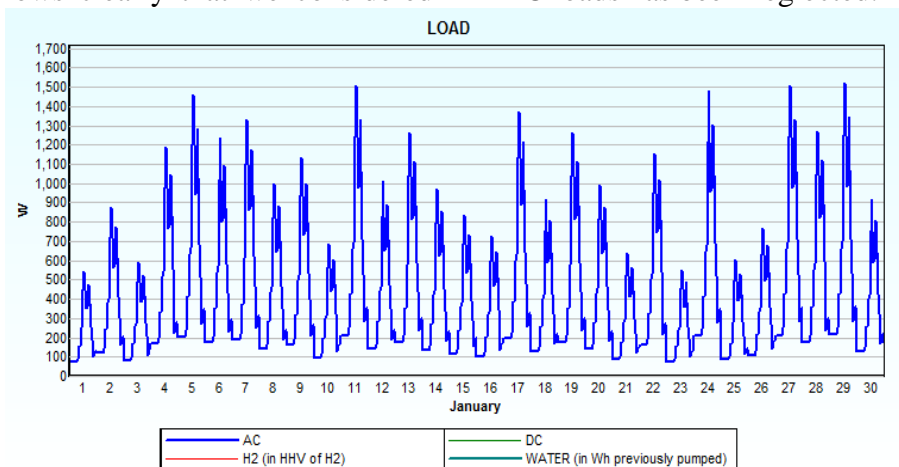
generator and its operating conditions clearly. For running the simulation studies the monthly average load has taken which includes only AC load. Graph.01 shows the load profile of the entire year.



Graph.01 Average load profile of the Dangla village for a year (this is not exact value it is assumption values).

To analyze clearly, load data for the month of January is shown below Graph.02. The below graph shows clearly that we considered

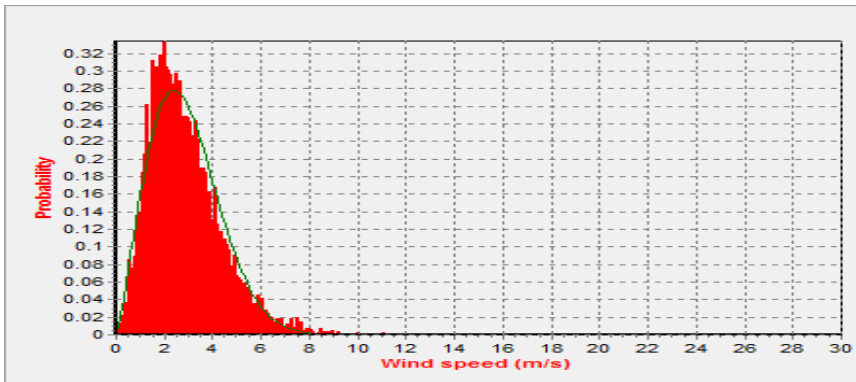
only the AC load, even there is chance of considering DC loads, for the analysis of this paper the DC loads has been neglected.



Graph.02 Load profile of month January by considering only the AC loads and neglecting DC loads.

The wind, solar radiation, earth temperature, air temperatures data has been taken from the National Meteorological Laboratory of Adama. The average wind speed is

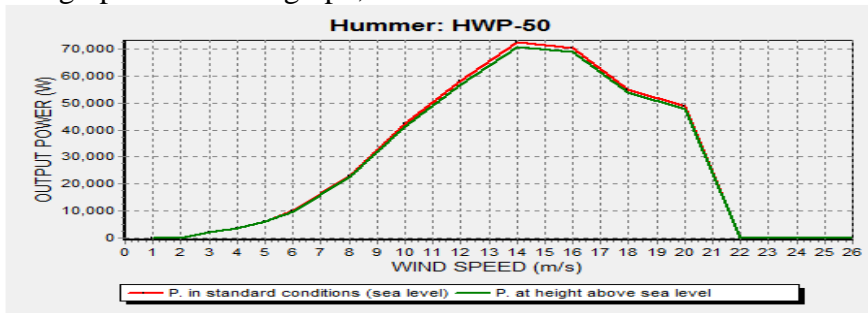
calculated as 2.92m/s. Here for the analysis the wind speed and the probability is shown in the below graph.



Graph.03 wind profile of the Dangla village.

Here for the analysis of this paper we had considered the family of 5 wind turbines and the characteristic curves of the turbine is shown below graph.04. In the graph, the

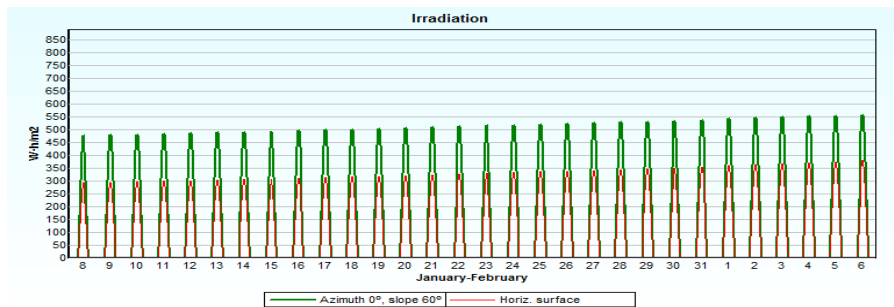
output power of the Hummer HWP-50 has been shown in two different cases: at the standard condition (sea level), at the height above the sea level.



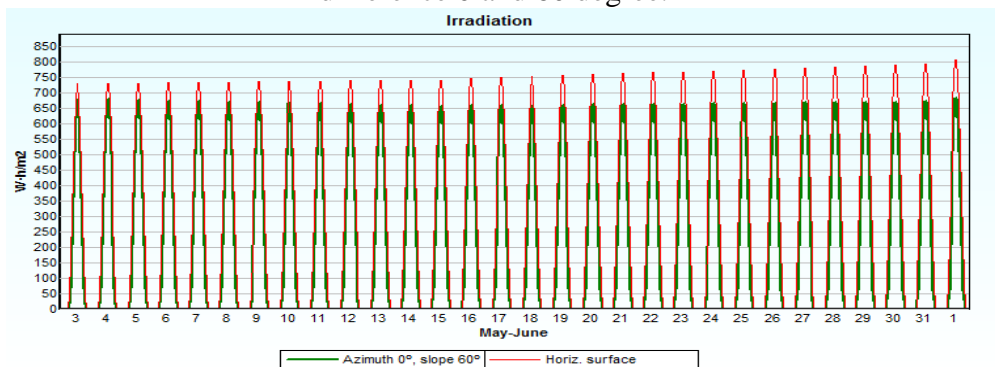
Graph.04. Power output of the Hummer HWP-50 wind machine

Daily solar radiation has been taken from the NML and the irradiation has been calculated by using the empirical formula. Here the data is considered in the horizontal plane. But for the optimal slope also has

been considered as 60 degrees. The below graph shows the graphical results of the PV panel with respective to the irradiation for the month of January –February.



Graph.05. Irradiation for the month of January- February with a slope difference 0 and 60 degree.

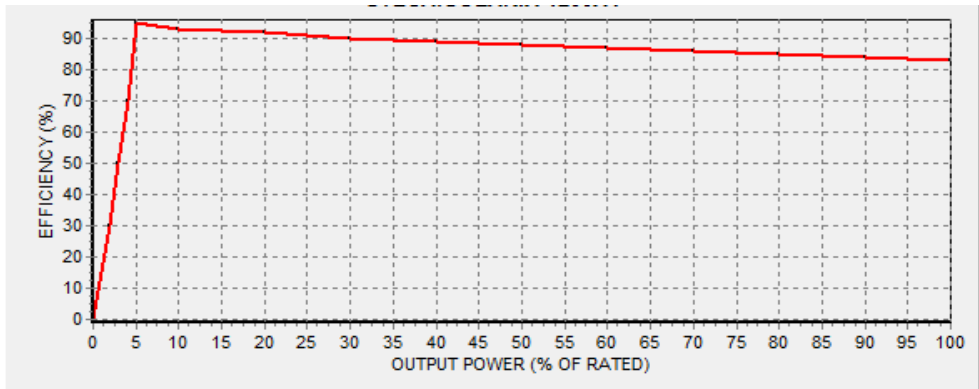


Graph.06. Irradiation for the month of May - June with a slope difference 0 and 60 degree.

From the Graphs.04 and 06. We can see the variation of the temperature conditions. From Graph.04 the power produced by the panel in horizontal surface is less as compared with the slope 60 degrees. Whereas in the graph.05 the power produced in the horizontal condition is more as compared with the slope of 60 degrees. The inverter has been considered for conversion of dc to

ac, the MPPT is using in designing the inverter by considering the Pertur band Observer methods. The maximum power demanded by the load is 1564.9VA. The inverter selected is the one of 1800VA. The average power is 23.1% of the rated power of the selected inverter. Inverter average efficiency considered will be 91.3%.





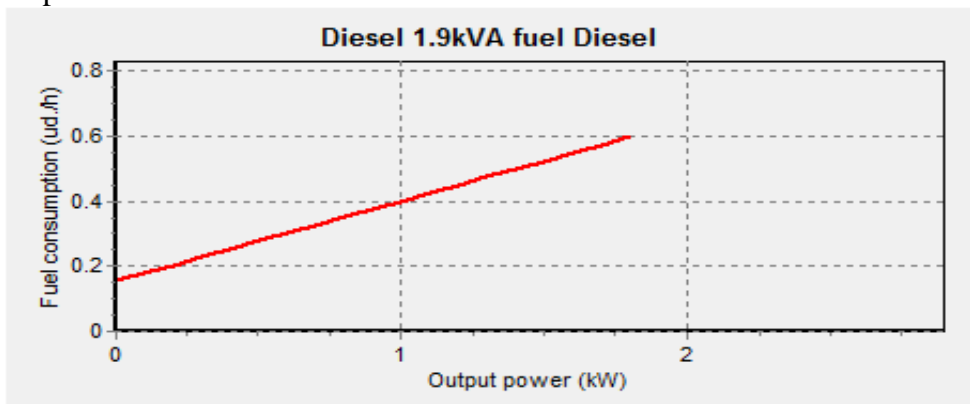
Graph.07. Efficiency of the inverter.

The AC generator is considered as one of the sources of generation of the power. This AC generator is connected to the system and it will be in online for 24 hours, whenever

the power demanded exceeds the limits it will supply the power to the load. The power delivered is given as

$$\text{Consumption(liter/hour)}= P_n(\text{kW})-B + P(\text{kW})- A \quad ..(4)$$

The graphical results of the AC generator considered is shown below in Graph.08



Graph.08. Fuel consumption of the AC generator with respect to output power (kW)

## VII. SIMULATION RESULTS AND ANALYSIS

For running the simulation the constraints taken are

1. Maximum Unmet Load allowed is 1% of the annual load

2. Maximum number of days it can provide the power by the (batteries+ Ac generators) is 3 days
3. Minimum renewable fraction is 1
4. Maximum levelized cost of energy is 130 \$/kWh
5. Nominal interest rate (price of money) is 4%
6. Annual inflation rate is 2%
7. System life time is 25 years

8. Annual real discount rate is 1.96%
9. Amount of loan is 80 %
10. Loan interest is 7 %
11. Duration of loan is 10 years

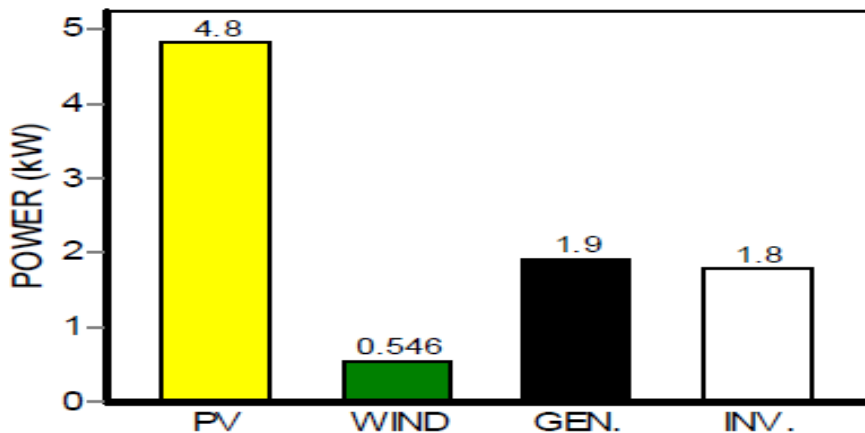
The simulation results has been presented based on the design parameters of the wind plant, solar plant and Ac generator and the load conditions of the Dangla village.

Calculation for the output powers,

Table.02. shows the calculated powers of the each component

S.no	Calculated parameters
1.	DC Voltage: 48 V. AC Voltage: 230 V
2.	PV panels aSi12-Schott: ASI100 (100 Wp): 4 serial x 12 par. P total = 4.8 kWp, 60° slope
3.	Batteries OPZS-Hawker:TLS-3 (Cn=180 A·h): 24 s. x 5 p. E total = 43.2 kWh (2.9 d.aut.)
4.	1-Wind Turbines DC AIR X (546.8 W at 14m/s). P. total 0.546 kW
5.	AC Generator Diesel 1.9kVA of rated power 1.9 kVA
6.	Inverter STECA:SOLARIX 1200X2, rated power 1800 VA
7.	PV Battery charge controller Generic of 106 A
8.	Battery charger (AC/DC converter) of 1900 W
9.	AC Generator Minimum Power : 1634 W

The total powers generated by the all power generation equipment's



Graph.09 The output powers of each power generation units  
 The cost Analysis of the installed systems in terms of the dollars, below table.03 show the values

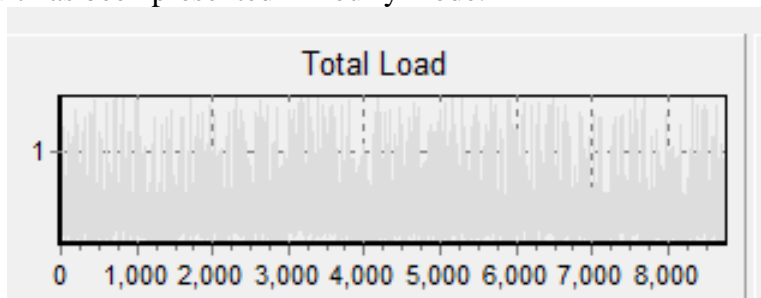
S.No	Financial Analysis in dollars
1.	Initial Investment: 25181 \$.
2.	Loan: 80 %
3.	Annual quota: 2868.2 \$.
4.	Cost AC gen. fuel during 1st. year: 1773.63 \$
5.	PV Generator Costs (NPC): 7336 \$
6.	Battery bank Costs (NPC): 22625 \$
7.	Wind turbines Costs (NPC): 2463 \$
8.	AC Generator Costs (NPC): 38230 \$
9.	Auxiliary Components Costs (NPC): 1821 \$
10.	Inverter Costs (NPC): 2632 \$
11.	AC Generator Fuel Costs (NPC): 50334 \$

Table.03 show the financial cost of the proposed SAPS for an year  
 Calculated energy during one year:

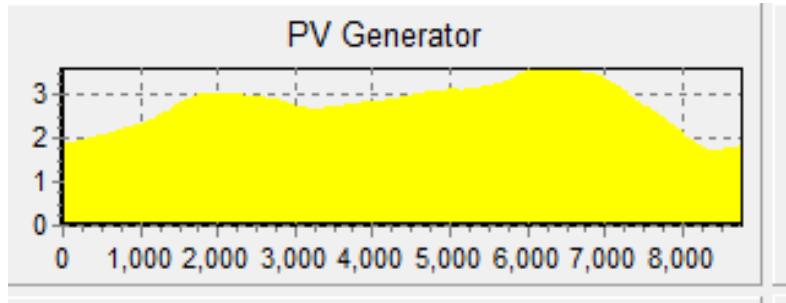
S.No	Over all Energy produced in one year
1.	Overall Load Energy: 3650 kWh/yr. From Renewable: 99%
2.	Excess Energy: 2681 kWh/yr
3.	Energy delivered by PV generator: 6844 kWh/yr
4.	Energy delivered by Wind Turbines: 104 kWh/yr
5.	Energy delivered by Hydro Turbine: 0 kWh/yr
6.	Energy delivered by AC Generator: 35 kWh/yr

- 7. Hours of AC Generator operation: 8760 h/yr
- 8. PV Battery charge controller Generic of 106 A
- 9. Energy delivered by Fuel Cell: 0 kWh/yr
- 10. Energy charged by Batteries: 1316 kWh/yr
- 11. Batteries Lifetime: 18 years
- 12. Energy discharged by Batteries: 1336 kWh/yr

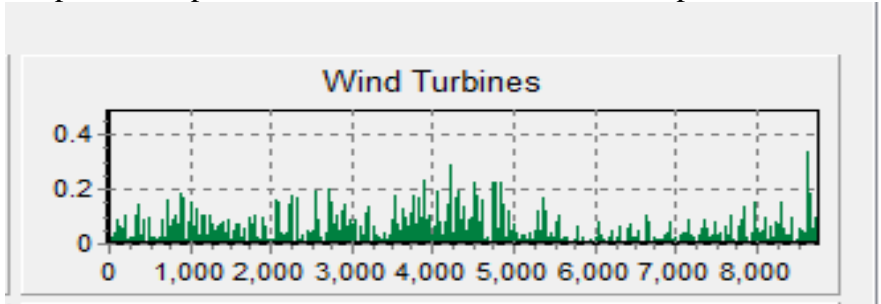
Tabel.04 Show the total power produced by all components for an year  
The vast set of results has been presented in the graphical approach clearly.  
The result has been presented in hourly mode.



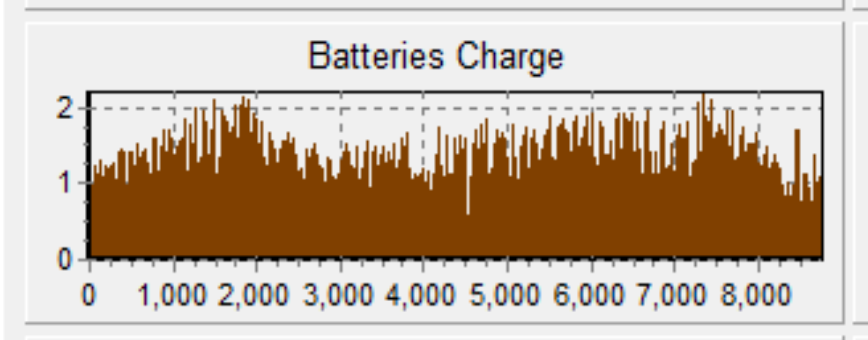
Graph.10. Graphical results shows the total load on the system in each hour



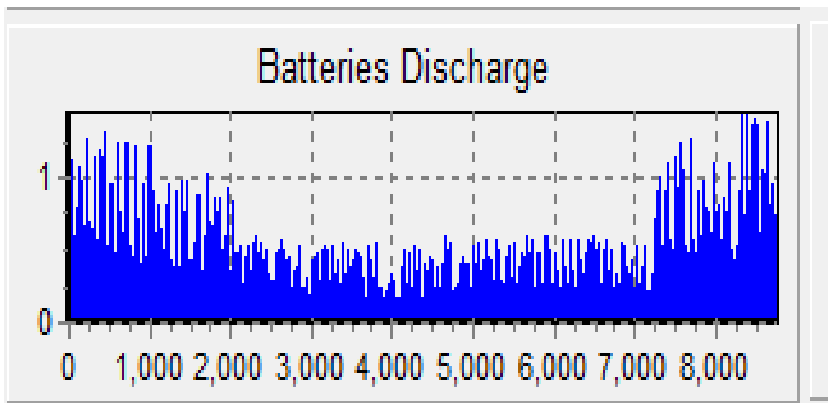
Graph.11. Graphical results of the PV Generator output in each hour



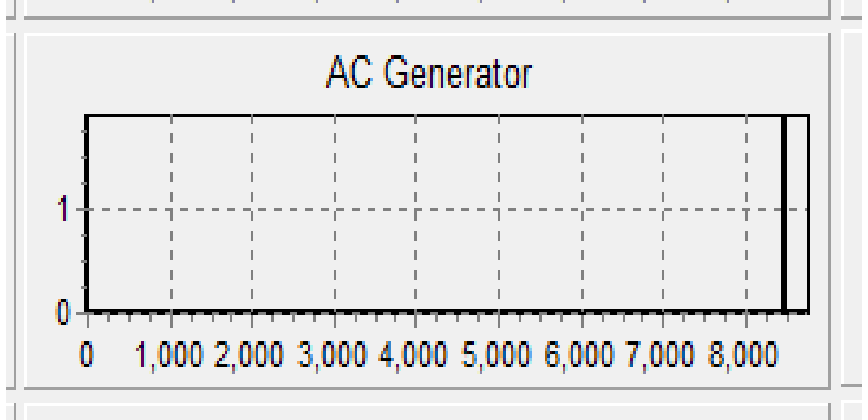
Graph.12. Graphical results of the Wind Turbine output in each hour.



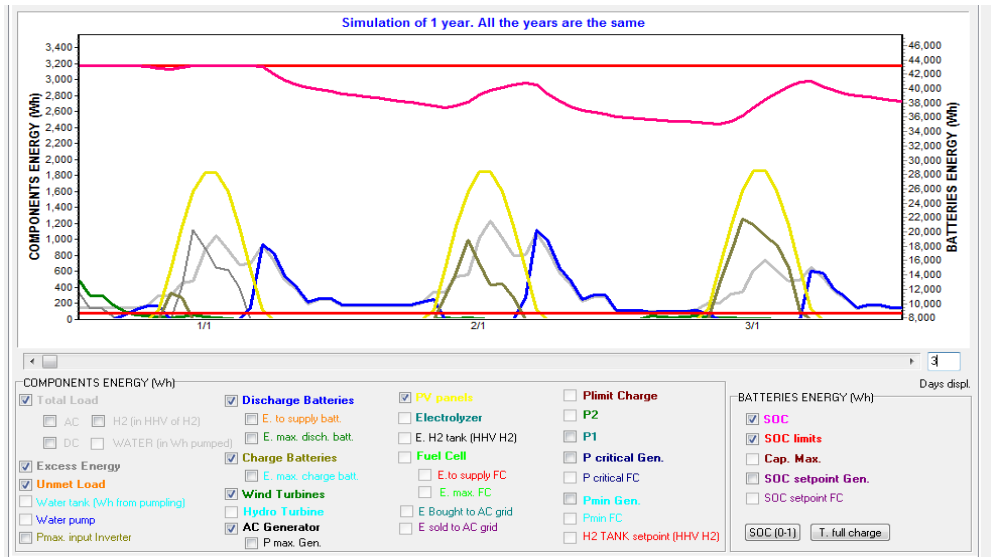
Graph.13. Graphical results of Battery charge in each hour



Graph.14. Graphical results of Battery Discharge charge in each hour



Graph.15. Graphical results of AC Generator in each hour



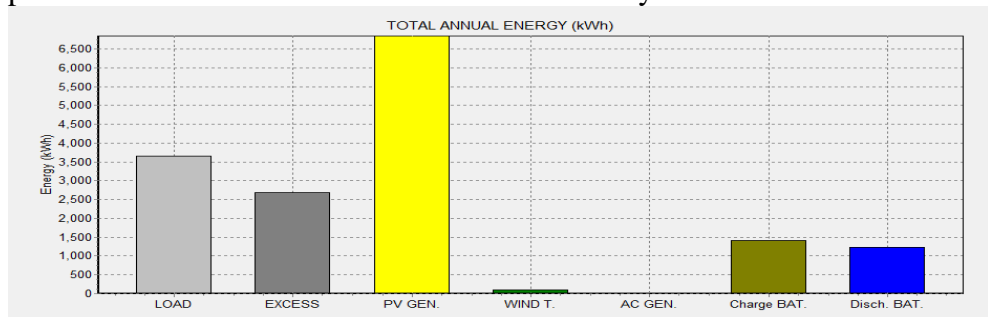
Graph.16. Graphical results power generated by each machine for three days.



Graph.17. Graphical results power generated by each machine for 10 days.

The results in the graphs.15 and 16 shows clearly the power production of each machine here for the case study we have considered PV, wind, battery charge, battery discharge, AC generator output powers clearly. In the graph

15 the output powers has been shown for 3 days, in graph 16 shows the output powers of each machine for the duration of 10 days.



Graph.18. Graphical results Total Annual energy.

## VIII. CONCLUSION

A SAPS system which consists of PV arrays, wind turbines and diesel generator with battery bank and power conditioning units has been discussed clearly in the paper. The design of standalone electric power supply system for the model community has been conducted based on the investigation of the wind energy and solar energy potentials of the Dangla village. There are many simulation software's are there in the present electrical field, but the software

used is Hybrid optimization By Genetic algorithms, the simulation tool is used for the optimal design and control strategies of the hybrid renewable systems using Genetic Algorithms. Even by using this software we can analyze the optimal location of the devices. So concluding, based on the NML data if we installed the SAPS in the Dangla it will support the near to villages, in the Gojam. Even the installed plants are produced more power as compared with the load demanded.

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