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IMPLEMENTATION AND FEASIBILITY STUDY OF RENEWABLE ENERGY RESOURCES FOR ELECTRIFICATION

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Abstract — *Ethiopian countries have one of the regions with the lowest electricity access rates, particularly in rural areas. The main reason for the low rate of services is the distance between these communities, geological location, economy of country, the electricity grid and lack of capacity of installed generation of power plant in the country. In many cases extension of the grid to rural communities is difficult due to high costs. Off-grid power systems are self-sufficient electrical networks, consisting of small-scale power generation and distribution, which can supply electricity to a community that is not yet connected to the grid. The energy problem of rural differs from those in urban because rural need to manage their own energy supplies. The rural are decent test divans for the utilization of renewable energy production and storage technologies. Wind and photovoltaic (PV) based power generation are two of the most promising renewable energy technologies. Fuel cell (FC) systems also show great potential in applications of the future due to their fast technological development and the merits they have, such as high efficiency, zero or low emissions (of pollutant gases) and flexible modular structure. The main power for the hybrid system comes from the solar and wind energy while the fuel cell and rechargeable batteries are used as a secondary and primary energy back up units respectively. In this work, implementation and feasibility study of renewable energy (using HOMER) of emission free hybrid power system of solar, wind and fuel cell power source unit for a given rural village, Abomsa that can meet the electricity demand in a sustainable manner has been studied.*

Keywords- *Wind, Solar, Hybrid, HOMER*

I. INTRODUCTION

Ethiopia found in Sub-Saharan Africa (SSA) and electricity consumption is very low. This is primarily because people don't have access to this resource. The Ethiopia access to electricity rate is 45% in urban area and less than 2% in rural area [1]. Rural area are forced to do their day to day domestic activities such as cooking, using fuel wood which leads to a rapid growth of deforestation; they travel long distances to fetch water; they also use kerosene for light. Additionally, due to lack of access to electricity, the communities in the rural villages are not able to benefit from social services such as clinics and schools sufficiently. Therefore, village electrification is a vital step for improving the socio-economic conditions of rural areas and crucial for the counters overall development.

Off-grid electricity solutions are often combined with renewable energy systems. This is mostly because of the small amount of power capacity required, which will be uneconomic using conventional power sources [3]. Up until recently, renewable energy was criticized for its high capital costs and intermittency. With the development of the technologies and market developments in economies of scale, renewable energy has become both more reliable and cheaper [2].
Hence, availability of electricity reduces poverty and helps economic development by enhancing the health, education, water supply (for drinking and irrigation) needs of the rural population and it creates employment opportunities for the villages, youth and promotes a better standard of life .In this paper, off-grid solutions for Abomsa remote rural areas in Ethiopia were investigate for implementation and economic feasibility using HOMER. The selected areas were Abomsa, Oromia, Ethiopia and have the distinct feature of being coastal. The Hybrid Renewable Energy System (HRES) proposed for these regions aims to provide reliable and cost effective solutions to the off-grid systems

II. STUDY OF RESOURCES

A. *Solar resource analysis:*

Solar energy is that energy which is gets by the radiation of the sun. Solar radiation is in the form of radio magnetic wave emanates and propagates spherically in space. Some part of the radiation reaches the earth surface after atmospheric effect, such radiation is called diffused radiation. There is also some part of radiation that reaches the earth surface without such atmospheric effect which is called direct radiation [3, 9].

On a clear day, approximately 4.4 x 1017 photons strike a square centimeter of the earth surface every second. Those photons with energy in surplus of the band gap energy of the semiconductor material being used can be converted into electricity by the solar cell. Solar panels are the medium to convert solar energy into the electrical energy. Solar panels can convert the energy directly and heat the water with the induced energy.

To meet higher loads the H_2 PV cells must be connected in series and/or in parallel depending on the magnitude of the voltage and current required. Modules are the basic building blocks of systems. For more voltage or current, modules are connected in series or in parallel respectively to form a panel and then panels can be assembled into a group to form a complete PV array. Solar energy is freely available and it is pollution free [4]. Only problem with solar system it cannot produce energy in bad weather condition. It has long life span and has lower emission. So the study area, Abomsa has high potential of solar radiation that collected data from NMSA of Ethiopia, this data is collected in the form of solar sun shine, it converts to solar radiation by using empirical formula.

B. *Wind resource analysis*

Wind is the movement of air caused by the irregular heating of the Earth's surface. It happens at all scales, from local breezes created by heating of land surfaces that lasts some minutes, to global winds caused from solar heating of the Earth. Wind power is the transformation of wind energy into more useable forms, typically electricity using wind turbines [6].
Wind energy is one of the oldest sources of energy used by humankind, comparable only to the use of animal force and biomass [7]. However, for much of the twentieth century there was small interest in using wind energy other than for battery charging for distant dwellings. These low-power systems were quickly replaced once the electricity grid became available. The wind turns the blades, which spin a shaft, which connects to a generator and makes electricity. The distribution of wind is expressed by Weibull distribution over a certain period of time at a particular site. The Weibull probability density function is given by equation [8].

$$f(u) = \frac{k}{c}(\frac{u}{c})^{k-1}\, ept\left[-\frac{u^k}{c}\right] \quad (1)$$

Where,
u = the wind speed,
k = a constant known as shape factor, as the value of k increases the curve will have a sharper peak
c = a scale parameter in m/s; the larger the scale parameter, the more spread out the distribution.
The area under the curve is always unity. The power density can in this case be expressed by equation (2).

$$\frac{P}{A} = \frac{1}{2}\sum_{j=1}^{n} pV_j^{\,3}\ f_j \quad (2)$$

Where
V_1 = The median velocity in class j and f_1 is the frequency of occurrence in the same class. For k = 2 the Weibull is commonly known as the Rayleigh density function in which

$$f(u) = \frac{2u}{c^2} exp\left[-\left(\frac{u}{c}\right)^2\right] \quad (3)$$

C. *fuel Cell Analysis*

Fuel cells are electrochemical devices that convert the chemical energy of a fuel (Hydrogen) directly to usable energy - electricity and heat - without combustion. Fuel cells have emerged as one of the most promising technologies to meet the nation's energy needs, it produce electricity at efficiencies of 40 to 60% with negligible harmful emissions. Fuel cells are particularly well suited to the distributed power generation market because of these characteristics as well as their high efficiency and modularity [5].
Fuel is electrochemically oxidized on the anode surface, and oxidant is electrochemically reduced on the cathode surface. Ions created by the electrochemical reactions flow between the anode and cathode through the electrolyte. Electrons produced at the anode flow through an external load to the cathode, completing an electric circuit [5, 10].

A typical fuel cell requires both gaseous fuel and oxidants. Hydrogen is the preferred fuel because of its high reactivity, which minimizes the need for expensive catalysts. Oxygen is the preferred oxidant because of its availability in the atmosphere. The anodic half reaction; cathode half reaction and the overall reaction takes place in the typical fuel cell can be generalized by the set of reactions indicated in following equation [5, 10].

Anode half reaction $H_2 \Rightarrow 2\,H^+ + 2e^-$ .... (4)
Cathode half reaction $\frac{1}{2}O_2 + 2H^+ + 2e^- \Rightarrow H_2\,O$ .... (5)
The overall reaction $H_2 + \frac{1}{2}O_2 \Rightarrow H_2O$ .... (6)

D. *Electrolyzer*

Electrolyzer are used widely in industry to synthesize various types of products, in a sense electrolyzer are reverse of fuel cells. When electric current is forced through an electrolyzer from an outside source, chemical reactions generate new products occurring at the electrodes [3]. An electrolyzer converts electrical energy into chemical energy which produces hydrogen through the process of electrolysis which is very well known electrochemical process for hydrogen production.

III . Simulation using HOMER Software and Hybrid System

HOMER simulates all the possible system configurations based on the combinations of the components specified to it as input data and discards the infeasible system configurations that do not adequately meet the suggested load with the available resource and/or specified constraints [5]. Hence, only feasible combinations are displayed according to the total net present cost (NPC) in an increasing order. The optimization results are given out in an overall form and in a categorized form. For a particular set of sensitivity variables (solar radiation, average wind speed, fuel cell, etc.), the overall table displays all feasible system configurations according to cost effectiveness. The categorized table displays only the most cost effective configuration from each possible hybrid system types.

It is to be noted that the results can further be refined with the refinement of the component sizes, but at a cost of much longer running time of the software. In this work a step by step repeated simulation is carried out by varying different type of storage system. Since the price for diesel and for PV panels are more dynamic than other types of components, a range of diesel price and a PV capital and replacement cost multipliers are used as sensitivity parameters.

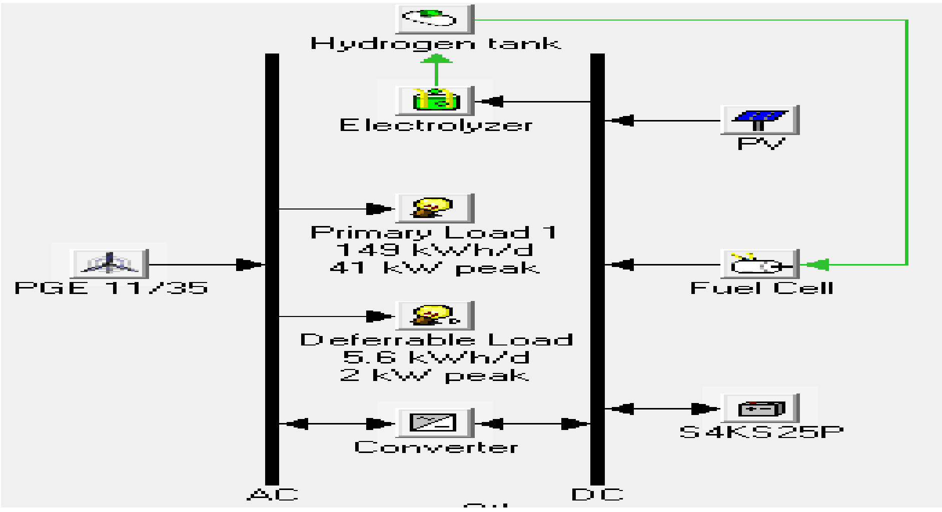

Figure 1. Hybrid System set up

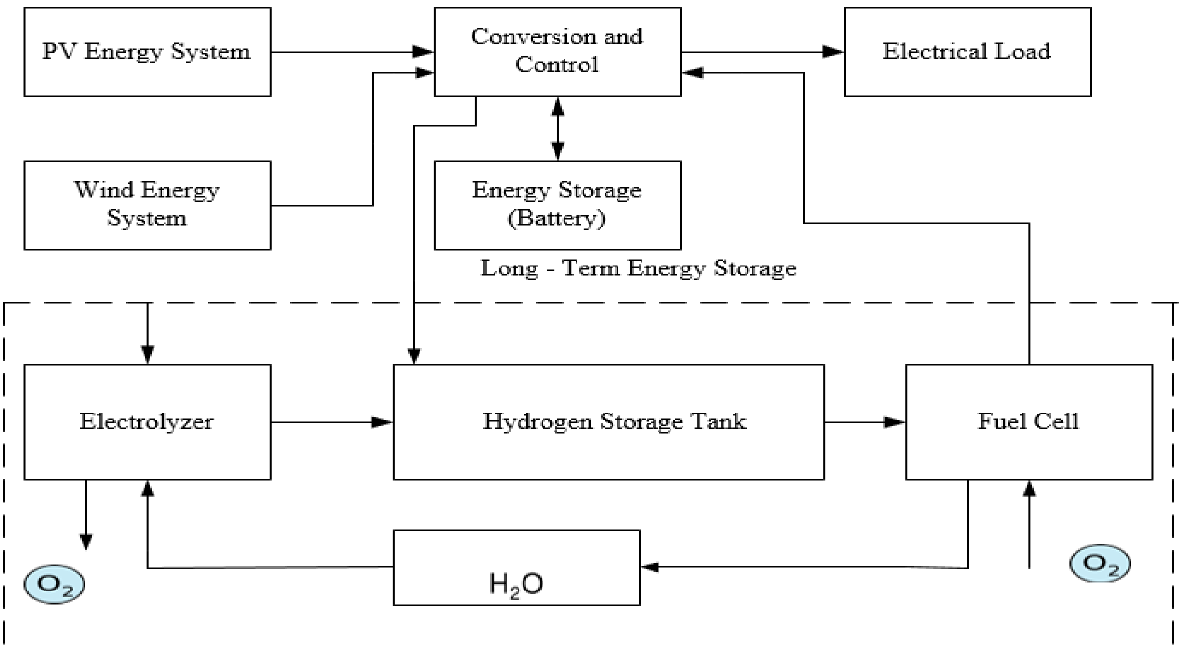

Figure 2. Block Diagram of Hybrid System

Table I. Solar Radiation Data and Wind Speed at 10m collected from NMSA and NASA Respectively.

Month	Wind Speed in m/s	Solar Radiation in KWh/m^2/day
Jan	3.9	5.8
Feb	4.1	5.5
Mar	3.9	6.4
Apr	3.6	6.9
May	2.8	6.6
Jun	3.75	6.4
Jul	3.6	5.5
Aug	3.3	6.4
Sep	2.3	6.1
Oct	2.9	5.8
Nov	3.91	5.5
Dec	4.1	5.8

IV. RESULT AND DISCUSSION OF POTENTIAL OF STUDY AREA

The optimization results are given out in an overall form and in a categorized form which represents feasible system configurations capable of meeting the system load and constraints. Systems with batteries are observed to have very high COE, low renewable fraction and needs large simulation time corresponding to the large size of components required. Therefore, the simulation and optimization analysis is made to include fuel cell systems.
In this case renewable energy resources are Wind and Solar panel combined with fuel cell and Battery storage system. The levelized COE is observed to be in the range of $0.167/kWh to $0.204/kWh. It can be seen that the set up PV-wind-fuel cell –battery-converter system types is selected in terms of NPC, COE and continuity of power throughout the year.

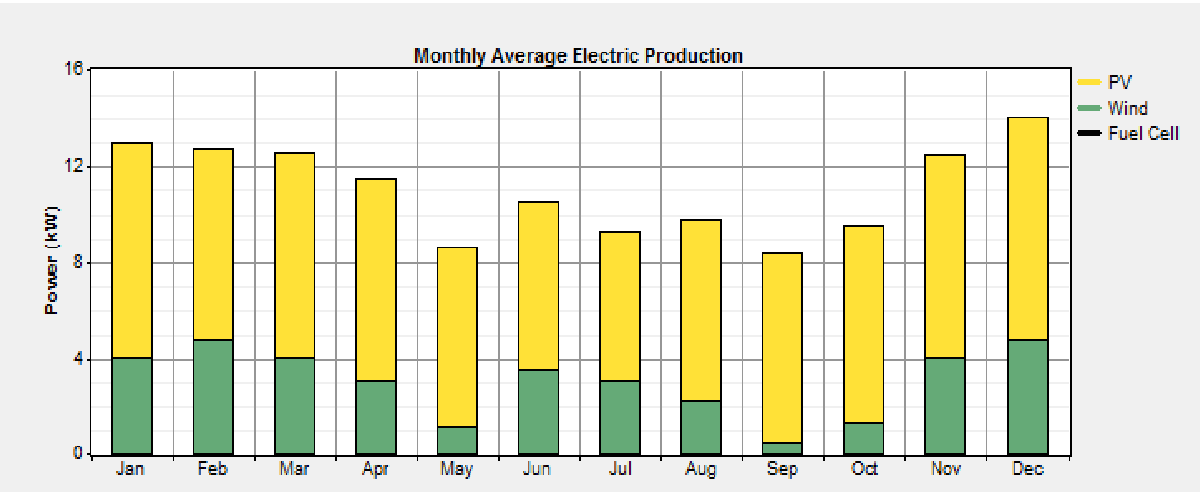

Figure.3 Contribution of the power units for the most cost effective system

V. CONCLUSION

In implementation and feasibility study of renewable energy recourses for electrification of model 200 house hold is carried out. HOMER is used for optimization and sensitivity analysis of different possible hybrid system. Monthly average wind speed data from NASA and solar radiation data from NMSA is calculated from daily sunshine hour data using empirical formulas is used to synthesize the overall feasible system. Hourly Primary and Deferrable electric load of the community consisting of lighting, TV set, Refrigerator, radio receiver, Electric mitad, health post, clinic, flour mills water pumps for daily used, water pump is determined.
The model community of 200 house hold is estimated to have a primary peak demand of 149 kW, a deferrable peak demand of 5.6 kW. Different optimum and feasible system configurations with different level of renewable fraction and total NPC are obtained. The levelized COE is $0.204/kWh and NPC is 142,652. This cost is slightly higher than the current energy tariff in the country. However system with Photovoltaic-wind turbine-fuel cell-battery combination is

feasible in case of energy need of community, decreasing of deforestation, clean energy and independent of national grid is the best alternative ways of energy for rural community that far from national grid.

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