Original Research Article

Optimization of hybrid wind and solar power generator at Izazi, Tanzania

ABSTRACT

Solar can be converted directly into electrical energy by using solar photovoltaic (PV) which convert solar radiation by the photoelectric effect, wind energy can be converted into electrical energy by using alternator coupled with a wind turbine. Solar power system consists of solar panels, solar PV cells and batteries for storing DC energy. Solar energy is available only during the day time whereas wind energy is available throughout the day; it is only depending upon the atmospheric conditions. Wind and solar are complimentary to each other and therefore makes the system more reliable throughout the year. The study at Izazi village, Iringa – Tanzania shows that the available solar energy and wind energy are potential and sufficient for solar-wind hybrid technology. Using the data obtained from NASA for local wind and solar resources for Izazi village Iringa, Tanzania. The simulation using homer analysis software, shows that to reach the minimum cost, the solar PV modules should contribute more energy than wind turbine. The optimization results obtained therefore shows the solar-wind hybrid system can provide a solution for supplying electricity at Izazi. This model result from Izazi village can be applied easily to other villages with similar environmental condition with Izazi village.

Keywords: optimization, hybrid, solar power, photovoltaic

1.1. INTRODUCTION

The global penetration of renewable energy in power systems is increasing rapidly (Hosenuzzaman et al., 2015). This is due to the depletion of conventional sources of energy and the oil price increasing (Fulzele and Dutt, 2012).The electrical installation has about 22.8% renewable energy from the total energy in which 16.6% is hydropower, 3.1% is the wind, 0.9% solar and other sources such as geothermal, biomass and ocean tides(Adib et al., 2016). In Tanzania,electrical installations have a big range between rural and urban areas. A total of 32.80 % of the population access to electricity (Heine, 2019), 16.9% of rural household access to electricity (Japhet, 2017).The statistics show that household electrification, commercial premises, stimulate economic activities that bring individuals development and the nation in general (Aberilla et al., 2020). Besides this importance and the advantage of using electrical energy, the government is unable to supply entirely electrical to the rural and urban dwellers (Miller and Spoolman, 2014). Tanzania government tried to incorporate the private sectors, Tanzania rural energy agency – REA to help in investing electrical energy generation, transmission, and distribution in rural areas. The most remote areas where there is not easily reached by Nation grid are forced to utilize stand-alone renewable energy which is easily available (Doorsamy and Cronje, 2015). Utilizing renewable energy sources lead to minimize the use of fossil fuels (Naveed et al., 2016), which has led to the application of new technologies conventions such as solar energy, wind energy, biogas and other renewable energy sources (Cronshaw, 2015).

Figure 1: Location of Izazi Village, Iringa – Tanzania

Tanzania has blessed with rich renewable energy sources which are easily available in rural areas (Syed Enam Reza, 2013). Renewable energy sources are not reliable and stable (Shu and Jirutitijaroen, 2011), they usually depend on seasons time of the day and location (Mostofi and Shayeghi, 2012). The problem can be solved by utilizing the hybrid system (Islam et al., 2012). The design of a hybrid system of renewable sources face a challenge due to the uncertainty of its sources, load demand, nonlinear characteristics of the load and different time demands (Sinha and Chandel, 2015). This characteristic behavior imposes the demand for the optimized hybrid system (Ashok, 2007, Magarappanavar and

Koti, 2016). The hybrid system maximizes the availability of energy and minimizes the cost of energy production (Razak et al., 2009).

Solar energy and wind energy are available daily at Izazi village. Solar energy can be converted directly into electrical energy by using solar photovoltaic cells (solar PV). Globally solar energy has a capacity of 120,000TW which is much more energy compared to only 28,000 TW generated from fossil fuel (Lee et al., 2018). Wind energy can be converted directly to electrical energy utilizing the wind turbine coupled to a generator (Tong, 2010). Solar and wind energy have low running costs and are easy to install (Branker et al., 2011, Shezan et al., 2015). Inorder to design a solar PV system, the three basic steps are needed (i) to estimate a load profile, (ii) to estimate available solar radiation and (iii) to design and select PV system components necessary for the calculated load (Ghafoor and Munir, 2015). To design wind turbine there is also three main factors need to consider those are (i) wind speed, (ii) air density and (iii) blade radius (Tong, 2010). The turbines need an area with the regular speed of wind instead of occasionally high-speed wind (Singh and Ahmed, 2013).

This study aims to design and optimize a hybrid power system that will electrify the Izazi village using wind turbines and solar PV cells. The hybrid system ensures the reliability of power generation (Suhane et al., 2014). To optimize the system, the HOMER (Hybrid Optimization Model for Electric Renewable) software will be used, which is normally performed by undertaking three main tasks those are (i) simulation, (ii) optimization and (iii) sensitivity analysis (Farret and Simoes, 2017). Optimization of renewable energy indicates that there is a possibility of a complete switch from fossil fuels as a source of the power system to renewable energy which is worldwide available (Bhandari et al., 2016). The cost of fossil fuels and its availability shows to be higher as compared to renewable energy and therefore for sustainability renewable energy is better option (Sawle et al., 2016).

2. METHODOLOGY

2.1. Feasibility study and data collection

The data collected physically by a visitto Izazi village. Other relevant data and information for the Renewable energy system are collected from Iringa Meteorological Agency

2.2. Data analysis and design work

(i) The data collected were analyzed and the size of PV panels, battery, charge controllers, inverters and conductors' sizes were determined to estimate the costs for electrical generation using solar energy.

(ii) The size of wind turbines calculated to estimate the costs for electrical generation using wind energy.

2.2.1. Solar PV sizing

System sizingistheprocessofdeterminingthecheapestcombinationofarraysizeandstoragecapacitythat will meet load requirements with an acceptable level of security over the expected lifetime of an installation(Yang et al., 2007).

2.2.2. Solar Battery Sizing

Battery capacity is the maximum amount of energy that can be extracted from the battery without the battery voltage falls below the prescribed value; it is given in Ah at a constant discharge rate. The efficiency of the inverter normally ranges between 80% and 95%., for this case taken as 85% (Boxwell, 2016).

$$\text{Battery Capacity} = \frac{\text{Demand (Wh)} \times \text{days of autonomy(days)}}{\text{Depth of discharge(\%)} \times \text{system voltage} \times \eta_{inv}}$$

2.2.3. Charge Controller Sizing

A battery can only be expected to last several years if good battery material and charge regulator is employed (Jenkins et al., 2008). It protects the batteries from overcharging and over-discharging, both of them are harmful to the batteries (Boulmrharj et al., 2020). Nevertheless, the state of charge is difficult to determine and can only be roughly estimated. Size of the charge controller is estimated as

$$\text{Charge Controller(A)} = 1.3 \text{ x PV short circuit current}$$

Where: 1.3 is the factor of safety

2.2.4. Inverter Sizing

The solar panel generates a direct current (DC) (Boulmrharj et al., 2020, Singh, 2013)so the use of an inverter is required because the load demand has also Alternating Current (AC), the power of an inverter multiple of safety factor 1.3 and the load demand of the system

$$\text{Inverter size(W)} = 1.3 \times \text{system size (KW)}$$

Where the system size is in Watts

2.2.5. Conductor Sizing

Cables with large cross-section area allow more current to flow through them than those with small cross-section area, likewise, the length of the cable also contribute to energy loss during transmission(Wędzik et al., 2016). The size of the wire determines the amount of current that can flow(Jenkins and Coates, 2008). For domestic and household wiring, the Copper wire is normally used in preference to Aluminium(Locke, 2008).

Thecross-section area of the cable is given by:

$$A = \frac{\text{Resistivity x Maximum current x Length of cable x 2}}{\text{Voltage drop}}$$

Where the resistivity of the copper wire (ρ) = 1.724×10^{-8} m

In both the AC and DC wiring of the PVsystem, the voltage drop is taking not exceed 4% value (Jenkins and Coates, 2008).

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2.2.6. Wind Energy

There are three rules about the wind turbine is (i) the speed of blade tips is ideally proportional to the speed of the wind, (ii) the torque is proportional to the wind and (iii) the maximum power is proportional to the speed of wind cube (Paraschivoiu, 2002, Singh and Fernandez, 2018).

$$P = \frac{1}{2}\rho A C_p \eta V^3$$

Where ρ = density of air, V = the velocity of air, C_p is the power efficiency of wind turbine depend on design, A is the wind turbine rotor swept area, η is the wind turbine efficiency

2.2.7. Solar Energy

To determine the hourly power of solar PV, the following formula is used

$$P = \eta\, x N_p N_s\ x\ V\ x\ I$$

Where η = conversion efficiency of PV module, V = the operating voltage, I the operating current, $N_p N_s$ the number of parallel and series solar cells respectively(Lipian et al., 2020).

3. MODELING HYBRID ENERGY SYSTEM COMPONENTS

The proposed hybrid system contains wind energy and PV sub-system connected with battery storage. The layout of the components is shown in the Figure 2. The entire system includes solar PV system, wind turbine, Energy storage system, an inverter and a charger controller. A solar wind hybrid system designed for Izazi village to meet the load demand, taking into consideration the local resources available were using the tools are given as under.

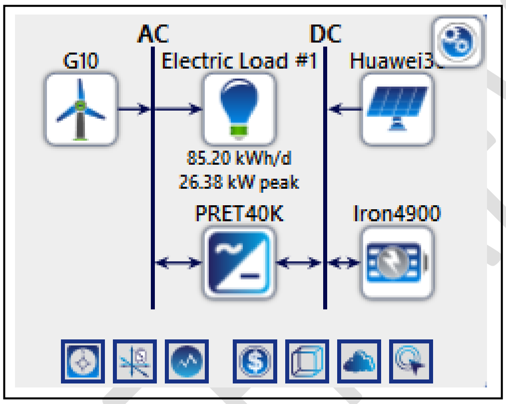

Figure 2: The schematic hybrid energy system at Izazi village.

3.1. A mathematical model of solar PV

Solar radiation available at the proper inclination angle is used to calculate by using the following equation:

$$E_{PV} = G(t)\ x\ A\ x\ P\ x\ \eta_{PV}$$

Assumed that the cells are negligibly affected by temperature.

3.2. A mathematical model of the converter

The proposed scheme shows that the converter contains both rectifier and inverter. The photovoltaic cell generator is connected to the DC bus (Singh and Fernandez, 2018). The wind energy generator is connected with the AC bus to connect AC loads.

The inverter model for PV generator is

$$E_{PV-IN}(t) = E_{PVG}(t) x\, \eta_{INV}$$

The rectifier is used to transform the AC power to DC power (Singh and Fernandez, 2018). AC generated from wind turbines. The rectifier mode is given below:

$$E_{REC-OUT}(t) = E_{REC-IN}(t) x\, \eta_{REC}$$

3.3. A mathematical model of the charger controller

The charger controller aims to prevent a battery from overcharging. When the battery is fully charged the charger control stop

The model of charger control is given by:

$$E_{CC-OUT}(t) = E_{CC-IN}(t) x\, \eta_{CC}$$

$$E_{CC-IN}(t) = E_{CC-OUT}(t) x + E_{SUR-DC}(t)$$

3.4. A mathematical model for battery

The Battery has a Battery state of charge (SOC) it is the cumulative sum of the daily battery charge or discharge. For any time, t, the state of charge of a battery is equal to the previous state of charge plus the charge produced and consumed during the time from$t-1$ to t. During the process of charging, when wind generator and solar PV are at normal conditions, the available battery bank is given by:

$$E_{BAT} = E_{BAT}(t-1) - E_{CC-OUT}(t) * \eta_{CHG}$$

When the load exceeds the available energy generated, for our case (wind turbines and solar PV). The battery bank capacity at time t can be express as

$$E_{BAT}(t) = E_{BAT}(t-1) - E_{Needed}(t)$$

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Assuming d be the ration of minimum permissible SOC voltage limit to upper level when the battery is fully charged, therefore the Depth of Charge (DOD)

$$DOD = (1 - d)x\,100$$

The DOD is a measure that shows the value of energy allowed to withdraw from the battery, it expressed as a percentage of full charge. The voltage upper level is SOC the lower level is determined by using depth of discharge (DOD) using the following formula:

$$SOC_{Min} = 1 - \frac{DOD}{100}$$

3.5. Mathematical modeling for Proposed Model

The total power generated at any time t by the hybrid system will be equals to:

$$P(t) = \sum_{W_G=1}^{W_G=N} P_{W_G} + \sum_{PV_G=1}^{PV_G=N} P_{W_G}$$

Where: N_{W_G}, N_{PV_G} are numbers of units of wind generators and number the of PV cells respectively. The generated power will feed the load. When the generated power exceeds the demand load, the excess power will be stored by battery bank to reach the maximum storage capacity using the condition $SOC_{MIN} \le SOC_{(t)} \le SOC_{MAX}$. the dump load is the load that drains the excess load from the system when the battery is fully charged and the power generated exceeds the demand.

The main purpose of engineering design is to minimize the cost of production and management. The capital cost for the proposed Solar – wind hybrid system is given by:

$$C_C = \sum_{W_G=1}^{W_G=N} C_{WG} + \sum_{PV_G=1}^{PV_G=N} C_{PV} + \sum_{B=1}^{B=N} C_{BAT} + C_F$$

The annual operating cost computed based on the operating cost of each equipment installed for hours in days for the whole year. Assuming at Izazi the sunrise and sunset are constant throughout the year.

$$C_O = \sum_{t=1}^{365} \left\{ \sum_{t=1}^{24} \left(C_{OW_G}(t) + C_{O_{PV}}(t) + C_{O_{BAT}}(t) + C_{OF}(t) \right) \right\}$$

Total Annual cost of the system comprises of Capital cost and operating cost,

$$C_{Annual} = (C_C CRF + C_O)$$

The unit cost of electrical generation by solar – wind hybrid will be given by:

$$COE = \frac{C_{Annual}}{C_T}$$

3.6. Feasibility study and data collection

3.6.1. Izazi village is located at latitude 07 14 South and Longitude 035 43 East. The number of houses in the village is 63 houses. The raw data were obtained from these houses and tabulated in Table 1 and Table 2

Table 1: Load estimation at Izazi village

S/N	Appliance	Quantity	Power (W)	Total power (W)	Time of use (hrs./day)	Energy per day (kWh/day)	Duration
1	Lightings	63×5	18	5670	4	22.68	18:00-22:00
2	FM radio	42	30	1260	4	5.04	18:00-22:00
3	Fan	25	60	1500	14	21	18:00-08:00
4	Fridge	10	120	1200	15	18	07:00-11:00, 16:00-03:00
5	Iron	27	300	8100	0.5	4.05	06:30-07:00
6	TV	38	80	3040	4	12.16	18:00-22:00
7	DVD player	38	40	1520	2	3.04	06:00-08:00
8	Cooker / Oven	2	2500	5000	1	5	07:00-07:30
9	Hair drier	4	600	2400	1.5	3.6	18:30-19:00
10	Phone charger	63	5	315	1	0.315	16:00-17:30
	Total			**30005**		**94.885**	

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Table 2: Energy needed for a Hospital Service in Izazi

S/N	Appliance	Quantity	Power (W)	Total power (W)	Operation time in hrs.	Total Energy Kwh/day	Duration
1	Fridge	1	120	120	13	1.56	08:00-21:00
2	Theatre light	4	18	72	8	0.576	05:00-07:00 18:00-23:00
3	Ward lighting	10	18	180	8	0.144	05:00-07:00 18:00-23:00
4	TV	2	80	160	9	1.44	11:00-20:00
	Total			**532**		**3.72**	

3.6.2. Meteorological Data

The meteorological data collected from Iringa meteorological agency tabulated in table 3

Table 3: The average wind speed and solar radiation energy in Izazi village

MONTHS	SPEED (M/S)	SOLAR RADIATION ($KWH/M^2/Day$)
JANUARY	4.24	5.17
FEBRUARY	3.77	5.41
MARCH	3.50	5.46
APRIL	4.37	5.05
MAY	5.16	4.79
JUNE	5.56	4.94
JULY	5.85	5.06
AUGUST	5.87	5.51
SEPTEMBER	5.76	6.24
OCTOBER	5.57	6.49
NOVEMBER	4.65	6.18
DECEMBER	3.93	5.49

Source: Tanzania meteorological Agency – Iringa.

3.7. Solar PV system

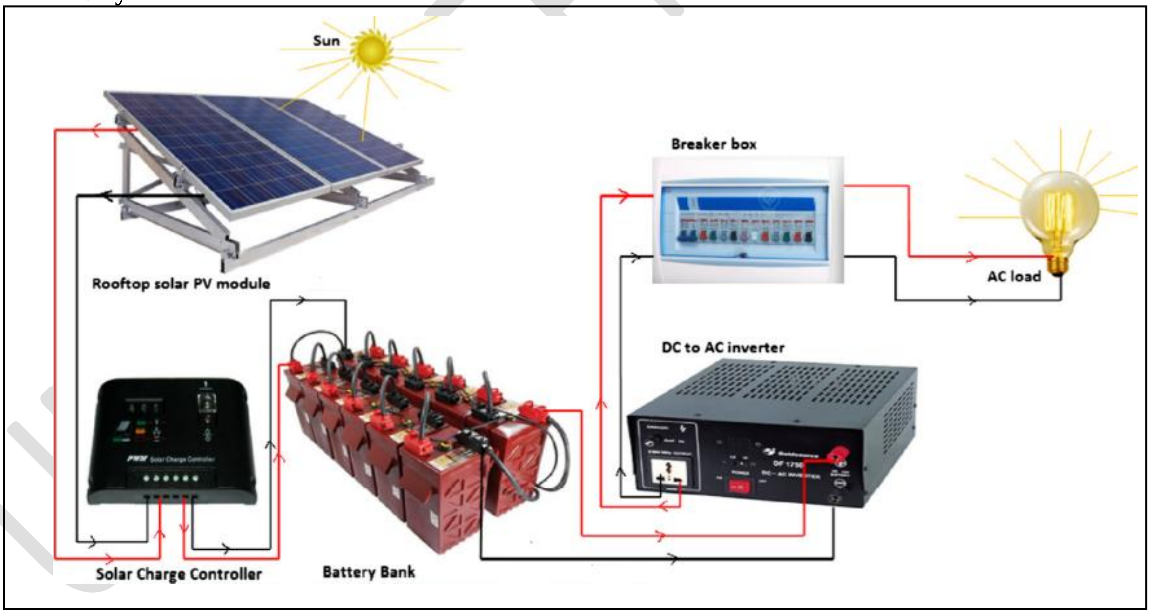

Figure 3: Solar PV system

3.7.1. Solar Panel Sizing

In order to get the good size we first consider the losses. The losses of solar panel that are considered are as follows 5% for losses due to sunlight reflection, 10% for losses due to sunlight absorption, 5% for losses due to dirt, 10% allowance for solar module aging, 15% for losses due to temperature

Therefore, Panel Generation Factor (PGF) = (0.95×0.9×0.9×0.95×0.85) × Average Isolation (lowest) as from table 3, the average radiation at Izazi, Iringa - Tanzania

$$PGF = (0.95\times0.9\times0.9\times0.95\times0.85) \times 4.79$$

$$PGF = 2.98$$

In solar panel sizing the following steps are also considered the daily load estimation at Izazi village

Total load is 98.61kwh/day as from table 1 and table 2

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- To determine total Watt peak rating needed for the PV module

$$\text{Total Watt peak} = \frac{\text{total Wh /day}}{\text{panel generation factor}}$$

$$\text{Total Watt peak} = \frac{98.61\text{Kwh/day}}{2.98}$$

$$\therefore \text{Total Watt peak} = 33.1\text{kW}$$

- Selection of PV module type

The PV module selected is Elfeland Solar Panels due to availability in the Market with the following specifications:

The PV module selected

Brand: Elfeland
Model: SP-34
Name: Elfeland Solar Panels
Colour: Black
Size: 1570 x 920 x 2 mm
Voltage: 42
I_{sc} = 7.8A
Junction Box IP67
Operating Temperature -40℃ +85℃
Price: U$450.91

- To determine the number of PV module in System

$$\text{No of module} = \frac{\text{Total watt} - \text{peak needed from the PV module}}{\text{rated output watt peak of PV module}}$$

$$\text{No of module} = \frac{33.1\text{kW}}{300\text{W}}$$

$$\text{No of module} = 110.3 \text{ module}$$

Hence finally it is obtained that the number of solar panel modules required to supply the load of 98.61KWH is 111 PV modules of Elfeland Solar panels.

$$\text{No of the module in series} = \frac{\text{system voltage}}{\text{module voltage}}$$

$$\text{No of the module in series} = \frac{48}{24}$$

$$\text{No of the module in series} = 2 \text{ modules}$$

$$\text{No of the module in parallel} = \frac{\text{number of modules}}{\text{module in series}}$$

$$\text{No of the module in parallel} = \frac{111}{2} = 55.5$$

$$\text{No of the module in parallel} = 56 \text{ modules}$$

Hence the number of strings is 56 in the system

3.7.2. Solar Battery quantity Sizing

$$\text{Battery Capacity} = \frac{98610 \text{ Wh} \times 3(\text{days})}{48 \times 0.8 \times 0.85}$$

$$\text{Battery Capacity} = 9063.42\text{Ah}$$

Hence after determining the battery capacity then the number of batteries required can be obtained, let's use 48V 500Ah Deep Cycle Lithium-Ion Battery because can be recharged thousands of times providing 100% DOD;

The number of batteries in parallel

$$\text{Number Battery} = \frac{\text{Battery capacity}}{\text{The capacity of the selected battery}}$$

$$\text{Number Battery} = \frac{9063.42\text{Ah}}{500\text{Ah}}$$

$$\text{Number Battery} = 19$$

$$\text{Number Battery in series} = \frac{\text{Nominal system voltage}}{\text{Nominal battery voltage}}$$

$$\text{Number Battery in series} = \frac{48 \text{ volts}}{48\text{volts /battery}}$$

$$\text{Number Battery in series} = 1$$

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$$\text{Number Battery in parallel} = \frac{\text{Number of battery required}}{\text{Number of batteries in series}}$$

$$\text{Number Battery in parallel} = \frac{19}{1}$$

A total number of batteries required is 19.

1. Let use 48V 500Ah, deep cycle lithium Ion Battery, DOD 100% with specification:
   48V 500Ah Lithium-Ion Battery
   Product: 48V 500Ah lithium Ion Battery
   Price 25,999.80U$
   Nominal Voltage 51.2V (48V)
   Charge voltage 58.4V
   Peak discharge (5 sec) 500A
   Continuous discharge / discharge rate 100A
   Capacity (Ah) 500Ah
   Capacity watts 6400Wh
   To get 48V and 9000Ah we need 19 pcs parallel
   Total cost = 19 x 25999.80U$= 493996.2U$

2. 12V 1000Ah price 180U$
   Size = 351 x 475 x 174 mm
   Weight 62kg
   To get 48V and 9000Ah we need 24pcs parallel and 9 pcs series
   = 24 x 9 = 216
   Total cost = 216 x 180U$ = 38,880U$

3.7.3. Charge Controller Sizing

$\text{Charge Controller(A)} = 1.3 \text{ x } 8.3\text{A x } 111$
$\text{Charge Controller(A)} = 1197.69\text{A}$

$$\text{Number of Charge Controller(A)} = \frac{\text{solar charge controller rating}}{\text{selected controller current}}$$

$$\text{Number of Charge Controller(A)} = \frac{1197.69\text{A}}{440\text{A}}$$

$\text{Number of Charge Controller(A)} = 2.72 \cong 3$ ∴The number of charge controllers will be 3.

3.7.4. Inverter Sizing

$\text{Inverter size} = 1.3 \text{ x } 30.54\text{KW}$
$\text{Inverter size} = 39.7\text{KW}$

The size of inverter required is 39.7 KW but the inverters available in the market are of 5KW hence the number of inverters needed will be

$$\text{Number of Inveter} = \frac{39.7\text{KW}}{5\text{KW}} = 8$$

For a load of 39.7 KW, the number of 5KW inverters will be 8.

1. 400/600W 12V LED Hybrid solar wires

3.7.5. Conductor Sizing

Determination of the cable size for PV modules and through the battery voltage controllers
Maximum voltage drop $VD = 0.04 \text{ x } 48 = 1.92V$
Length of the cable 5m

$$\text{A} = \frac{2\rho\text{IL}}{\text{Vd}} = \frac{1.724 \text{ x } 10^{-8}\text{x } 5 \text{ x } 100}{1.92} = 9mm^2 = 10mm^2$$

(Selected from the nearest IEEE standards)

Therefore, any copper cable of a cross-section area of 10mm^2, 100A, and ρ of $1.724\text{x}10^{-8}\Omega$m will be used for this wiring from the PV module and the charge controller.

3.8. Wind turbine selection

3.8.1. Wind turbine blade selection

Due to the average speed of the wind at Izazi village which is 5m/s and the load required which is 30.54KW the turbine can be calculated as
The total power to be generated by the wind turbine is 30.54kW
The power in the wind is given by the rate of change of energy;

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Hence by differentiation of energy a mass flow rate,
Power can be defined as; $P = \frac{1}{2}\rho A V^3 C_p N_g N_b$
Where:

C_p = Power coefficient = 0.45
N_g = Generator efficiency = 0.95
N_b = Gear box efficiency = 0.65
$P = 0.5 \; x \; 1.225 \; x \; A \; x(5)^3 \; x \; 0.45 \; x \; 0.65 \; x \; 0.95$
$A = \pi r^2$, D = 10, r = 5 $\therefore A = 3.14 \; x \; 5^2 = 78.54 m^2$
$P = 0.5 \; x \; 1.225 \; x \; 78.54 \; x(5)^3 \; x \; 0.45 \; x \; 0.65 \; x \; 0.95$
$P = 573.13W$

The total number of turbines required $= \frac{30.54KW}{573.13W} = 53.28$
The number of turbines required will be 54.

3.8.2. Solar Radiation Data from NASA

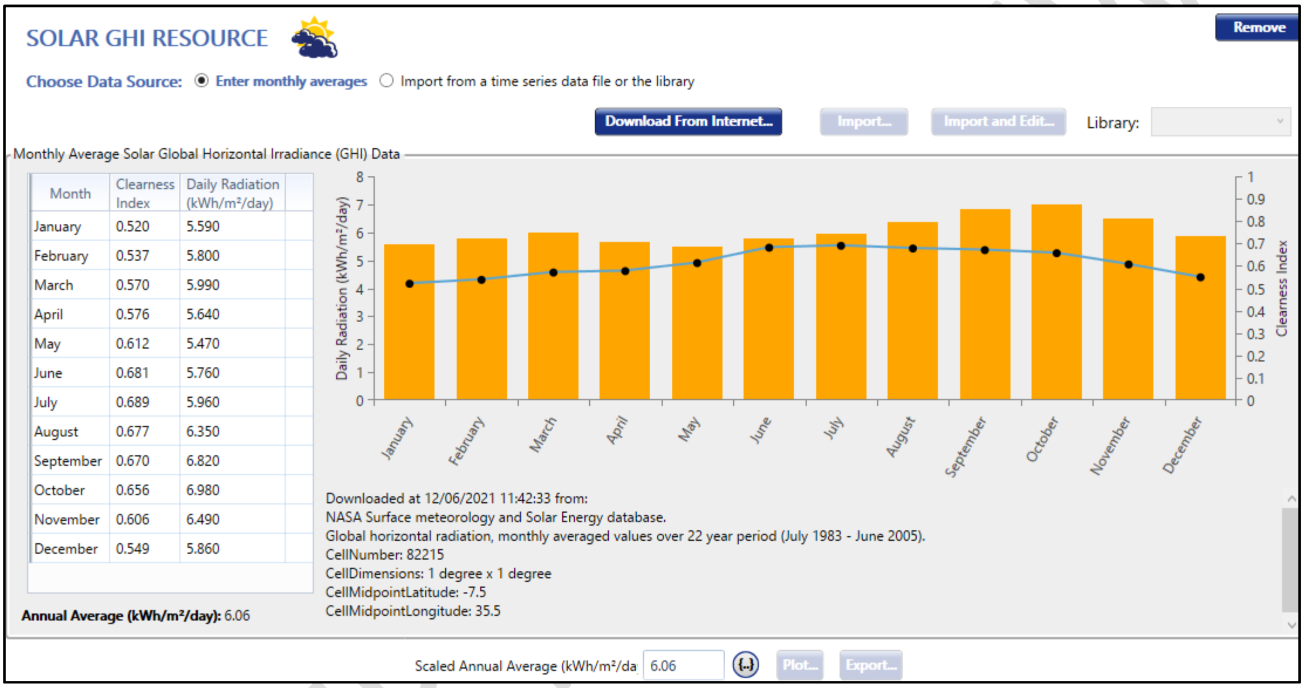

Figure 4: Monthly average solar irradiation at Izazi, Tanzania

The additional information of meteorological data from Iringa the other value data was collected from National Renewable energy Lab (NREL) database and NASA meteorology and solar energy database, both showed similarity with raw data collected from Iringa as shown in Figure 4.

3.8.3. Wind speed data from NASA

Figure 5: Monthly average Wind Speed data at Izazi, Tanzania

The additional information of meteorological data was collected from NASA surface meteorology and solar energy database, wind speed above 50m shows similarity with raw data collected from Iringa. As shown in Figure 5.

3.8.4. Electric load

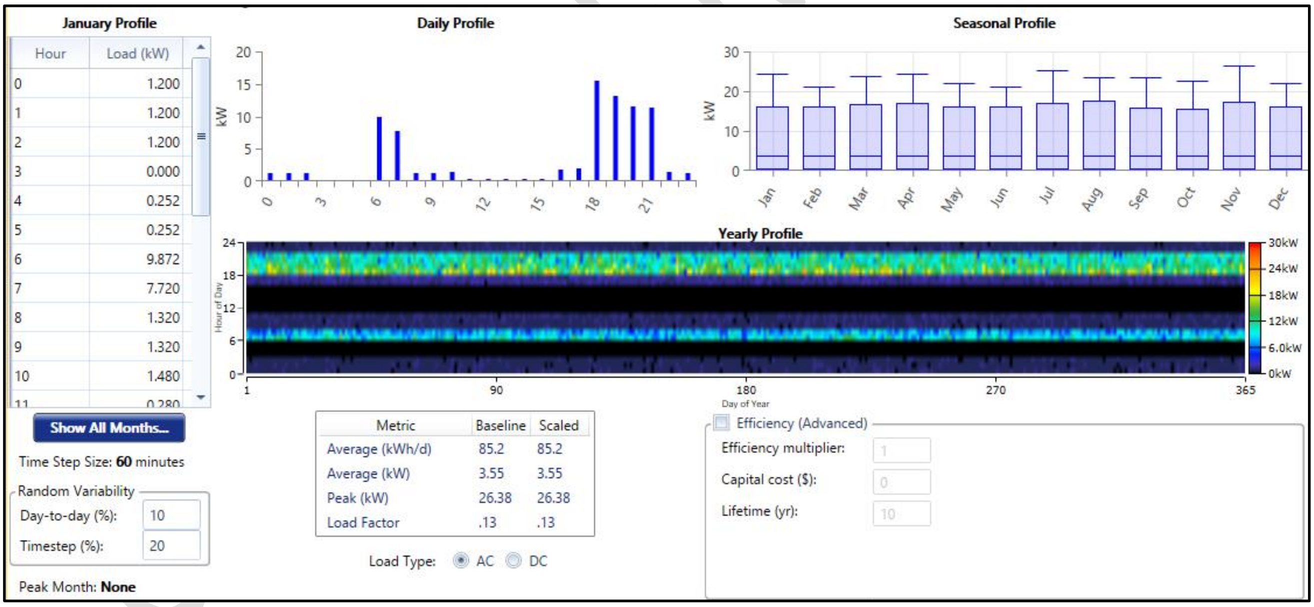

Figure 6: AC Primary load monthly average

Daily load profile for the consumption is shown in Figure 6. The seasonal profile is slightly varying as shown in Figure 6. The highest demand being July and August while the least being the months of September and October.

4. MODELING RESULTS AND DISCUSSION

HOMER helps the end-user to determine how different sources of the hybrid system can interact to give optimal value with minimum cost. The potential sources of energy in this study are Wind and Solar. The detailed parameters such as solar and wind resource potential at Izazi village, load profile, description of system components has been done.

4.1. Simulation results

4.1.1. Average Monthly electrical production

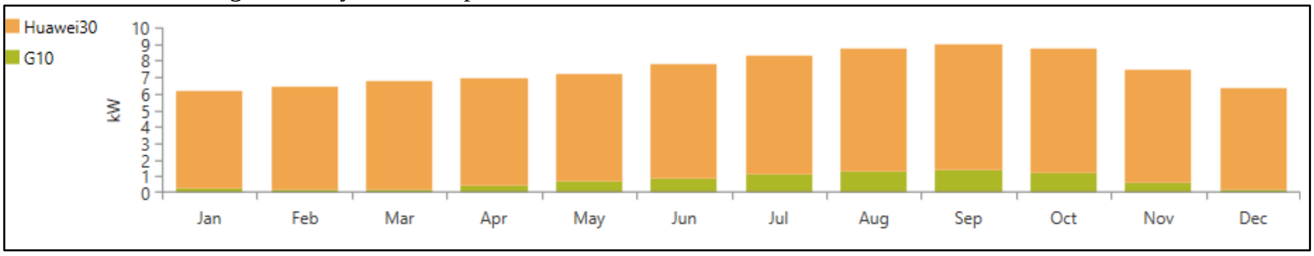

Figure 7: Monthly Average Electric Production

The figure above shows the annual average hybrid generation with a minimum generation of 5.8kWh for December month and a maximum of 8.5kWh in September.

4.1.2. Electrical Comparison

Production	kWh/yr	%
Huawei SUN2000 30kW with Generic PV	59,338	9(
Generic 10 kW	6,164	9.
Total	65,503	1(

Consumption	kWh/yr	%
AC Primary Load	31,097	100
DC Primary Load	0	0
Total	31,097	100

Quantity	kWh/yr	%
Excess Electricity	32,561	49.7
Unmet Electric Load	0	0
Capacity Shortage	0	0

Quantity	Value
Renewable Fraction	100
Max. Renew. Penetration	38,062

Figure 8: Electrical comparisons

The electrical optimization results with three combinations at variable net profit cost. The load being 31097 kWh/year. From the optimization table, we observe different combinations. A combination of solar PV with storage give the total power of 59338 kWh/year, a combination of wind with storage gives 252740 kwh/year, a combination of solar PV, wind turbine and storage, gives the total power 65503 kWh/year. Although all three combinations meet the Izazi village load demand, but due to reliability component, the combination of solar, wind turbine and storage is the one selected. The selected combination gives 65503 kWh annually while the load is 31097 kWh per year. The selected combination ensures reliability with an excess electricity of 32561 kWh annually.

4.1.3. Economic comparisons

The optimized table shows all the feasible combination of components of energy sources which can satisfy the proposed load demand of Izazi village. The optimization figure is categorized based on the overall power generation with respect to overall net profit cost. From the optimization result, the combination solar PV and storage system has lower cost but due to reliability component, this combination is rejected. The best selected combination of the optimization table is the one comprising solar PV, wind turbine and storage due to reliability component.

You may choose a different base case using the Compare Economics button on the Results Summary Table.

	Architecture										Cost	
						Huawei30 (kW)	Huawei30-MPPT (kW)	G10	Iron4900	PRET40K (kW)	NPC (TSh)	Initial capital (TSh)
Base system						30.0	30.0		1	40.0	TSh200,601	TSh200,925
Current system						30.0	30.0	1	1	40.0	TSh220,116	TSh217,592

Metric	Value
Present worth (TSh)	-TSh19,515
Annual worth (TSh/yr)	-TSh1,510
Return on investment (%)	-4.4
Internal rate of return (%)	n/a
Simple payback (yr)	n/a
Discounted payback (yr)	n/a

Figure 9: Economic comparisons

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

A hybrid power generation system which comprises of PV arrays and wind turbines with battery banks has been discussed in this project to achieve a cost-effective system configuration which is supposed to supply electricity to Izazi village of 63 households and village dispensary to improve the life of people in the rural areas where electricity from the main grid has not reached yet.

A Solar PV-Wind hybrid system aimed in protecting the environment from degradation since the use of fossil fuel contribute much into global warming which leads to climate change, the improvement of life of people living in a rural area, development of clean energy, the future situation regarding fossil fuel sources, and its contribution to the reduction of pollutant emissions into the environment should be taken into account. Taking these issues into account the free solar and wind energy of the country should be utilized to improve the quality of life of the communities living in rural areas.

The utilization of hybrid system is suitable use in remote areas where the accessibility of grid ids difficult. The utilization of hybrid can be easily converted and storage. The utilization of hybrid and storage together make the system reliable and suitable for stand alone.

Where we consider environmental degradation, the use of the hybrid renewable is a better option. There is also insufficient water at Izazi village, and therefore the hybrid system can also be combined with water pumping system.

5.2. Recommendation

Tanzania has a huge potential for renewable energy resources which can be used for rural electrification through the off-grid system. Many challenges like, the absence of awareness of how to use the resources, and what is the economic importance of renewable energy, etc. Thus, it recommended to the government, non-governmental organizations and the private sectors should make combined efforts to overcome these challenges by using more flexible approaches to improve the current poor status of rural electrification in Tanzania.

As far as the environmental aspects are concerned, this kind of hybrid systems have to be widespread to cover the energy demands of rural communities, and in that way to help reduce the greenhouse gases and the pollution of the environment.

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