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Design of Hybrid Power System of Renewable Energy for Domestic Used in Khartoum

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Abstract: Application of renewable energy in Sudan is a major issue in strategic planning for alternatives fossil fuels to provide part of local energy demand. Sudan is an important case study in the context of renewable energy because Sudan possesses relatively high profusion of solar radiation, moderate wind speeds. This study discussed the efficient system of sustainable renewable energy for domestic used and its total cost. The method of this study was collection of the basic data of solar radiation, wind speed and others required input data and then hybrid optimization simulation model was developed using the electric renewable energy software HOMER. The simulation model has been used to find out the best technically viable renewable based energy efficient system for different numbers of house hold. It finds as the result some topologies of hybrid power. The simulation results have been presented the most efficient achievement and economic way for different numbers of house hold. The overall cost of energy would be low if the turbine cost decreases in Khartoum. The project life time has been considered for 25 years and the annual real interest rate has been taken as 4%.

Key words: Homer, khartoum, renewable energy, hybrid power system, domestic

INTRODUCTION

A hybrid energy system generally consists of a primary energy sources working in parallel with standby secondary energy storage units. HOMER has been used to optimize the best energy efficient system for Khartoum considering different load and wind-PV combination. Figure 1 reflects the propose scheme as implemented in HOMER simulation tool. HOMER software developed by National Renewable Energy Laboratory (NREL), USA for micro-power optimization model, has been used to find out the best energy efficient renewable based hybrid system options for Khartoum. It contains a number of energy component models and evaluates suitable technology options based on cost and availability of resources (HOMER, 2005).

HOMER optimum configurations of appropriate power stations were suggested in the Plan depending on energy resources available in specific locations (Indradip and Chaudhuri, 2008). Analysis has been done for single home user as well as combination of 10 and 50 home users to get the most economic and technical viable options (James and James, 2005) HOMER models each

individual system configuration by performing an hourly time-step simulation of its operation for a one year duration. The available renewable power is calculated and is compared to the required electrical load (Dalton *et al.*, 2009).

Sudan lies between latitude 3°N 23°N and longitude 21° 45'E and 39°E This large area enjoys a variety of climates, from desert regions in the north to tropical in the south and makes it a favourable environment for all activities of the integrated agricultural investment from production to processing industries. Sudan is a relatively sparsely populated country (UNESCO, 2004). Khartoum climate region in the summers are invariably hot (mean max. 41°C and mean min 25°C) with large variation; low relative humidity averages (25%). Winters can be quite cool. Sunshine is very prevalent. Climate is a typical desert and rain is infrequent and annual variation in temperature is large. The fluctuations are due the dry and rainy seasons. Two main air movements determine the general nature of the climate. First, a very dry air movement from the north that prevails throughout the year.

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Khartoum is located at 15.38 latitude and 32.28 longitudes. Energy planners have long envisioned large utility-scale solar power plants covering large expanses of desert (Alnaser *et al.*, 2004). While this vision has many favorable attributes, the economics require careful investigation. Ground-mounted PV systems require the allocation of land which must be acquired and prepared to accept the PV system. The cost of land and the cost of site work can be considerable (Anonymous, 1996). In Sudan and many other develop countries; the lack of available large open tracts of land has effectively precluded the grid connected PV option as afforded to develop in Sudan. As interest in solar electricity increases, there is a growing consensus that spread PV systems that provide electricity at or near the point of use will be the first to reach prevalent commercialization (IEA, 2002). this study find that HOMER is Hybrid Optimization Model for Electric Renewable, (HOMER) is design optimization model that determines the configuration, dispatch and load Management strategy that minimizes life-cycle costs (Steven, 2005).

This study describes the designing and implementation process for hybrid system in Khartoum capital of republic of Sudan that took about 12 months, starting from january2009and HOMER. Simulation tool has been at length used in order to compare and optimize the electrical demand to the electrical energy that the system is bright to supply, on an hourly base.

MATERIALS AND METHODS

Hybrid power system: HOMER simulates the operation of a system by making energy balance calculations for each of the 8,760 h in a year. For each hour and compares the electric and thermal demand in the hour to the energy that the system can supply in that hour and calculates the flows of energy to and from each component of the system. For systems that include batteries or fuel-powered generators. HOMER also decides for each hour how to control the generators and whether to charge or discharge the batteries. HOMER performs these energy balance calculations for each system configuration. It determines whether a configuration is feasible. The system cost calculations account for costs such as capital, replacement, operation and maintenance, fuel and interest. System in HOMER Information about the load, resources, economic, constrains, controls and other component that have been used in HOMER are given below shown in Fig. 1.

Electric load material: A typical load system, shown in Table 1, for single home in the remote areas has been considered for the analysis. Monthly average hourly load demand (Sudanese perspective) has been given as an

Table 1: Appliances for single home user

Appliance	Quantity	Capacity (W)	Maximum use h day ⁻¹
Florescence light	4.2	10.0	4
B/W TV	1.5	15.0	4
Radio/Cassette	1	5.5	5

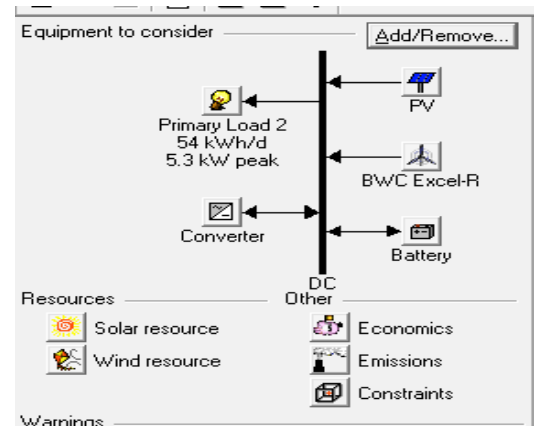


Fig. 1: Schematic diagram of hybrid power system

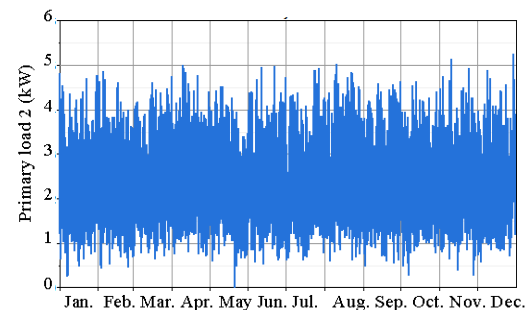


Fig. 2: Primary load 2

input of HOMER and then it generates daily and 2.3 kw day⁻¹ monthly load profile for a year as get in Fig. 2. It has been found that for this system each home user consume energy around (338 W day⁻¹ of Wh day⁻¹) with a peak demand of nearly. The system also gives the opportunity for expanding its capacity in order to cope with the increasing demand in the future. This can be done by increasing either the rated power of diesel generator, renewable generator or both of them (Nayar *et al.*, 1993).

RESULTS AND DISCUSSION

Renewable resources: As hourly data is not available therefore monthly averaged global radiation data has been taken from (NASA, 2008) HOMER introduces clearness index from the latitude information of the selected site and

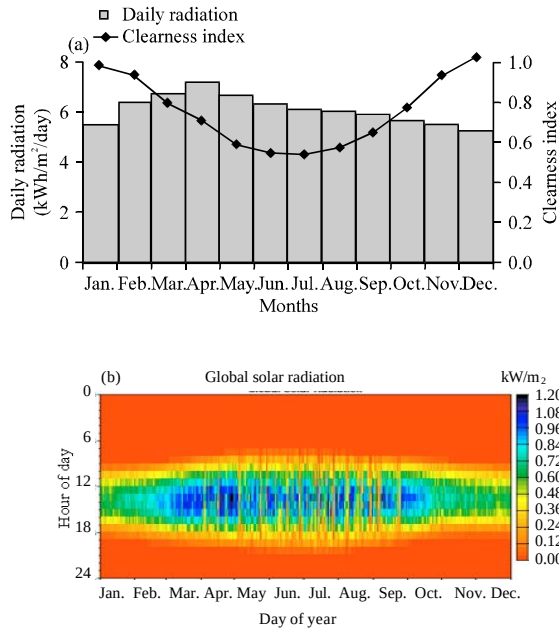


Fig. 3: Solar analysis diagrams (a) global solar radiation and (b) daily radiation-clearness

this index values are shown in Fig. 3. HOMER creates the synthesized 8760 hourly values for a year using the Graham algorithm (Graham and Hollands, 1990) which results in a data sequence that has realistic day-to-day and hour-to-hour variability and autocorrelation (HOMER, 2005). For wind monthly averaged (1999-2007) measured data from (SEI) have been used along with the information of height = 30 m, elevation = 3 m ASL, surface roughness = 0.01 m (Benemann *et al.*, 2000). HOMER create these monthly average data based on the other parameters such as Weibull factor $k = 1.8$, autocorrelation factor (randomness in wind speed) = 0.90, diurnal pattern strength (wind speed variation over a day) = 0.25, hour of peak wind speed = 22 m sec^{-1} to generate hourly data for a year as shown in Fig. 4. (Ahmad and Nayar, 2004) certain of systematic result depend on different location that to get the analysis. Combining the renewable energy generation with conventional wind and PV power generation will enable the power generated from renewable energy sources to be more reliable and affordable (RohintonEmmanuel, 2009).

Photovoltaic module: The cost of PV module including installation has been considered as 220 SP/W for Sudan (Anonymous, 1998). Life time of the modules has been taken as 25 years and these are tilted at 21° with no tracking mode (ISE, 2008). As of this analysis we get the continuous of energy depend on the life time of a hybrid

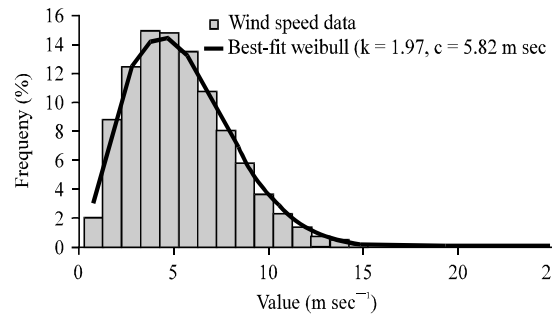


Fig. 4: Daily wind speed

power system which has an ability to provide 24 h grid quality electricity to the load. This system offers a better efficiency, flexibility of planning and environmental benefits compared to non renewable energy (Steven, 2005) find that PV Calculates the electric behavior of large and in homogeneously light up PV arrays that obtained the scale of Photovoltaic Module should become more gorgeous as costs of usual supplies increase (Dalton *et al.*, 2009). Capacity shortage and fraction of excess electricity, cost of useful energy varies from 24 to 39 kWh which is comparable to solar home system (Shafiuzzaman, 2005) that mean the scale of solar system the one of the main factor of design the hybrid system.

Wind generator: The load demand is very low for a single home system and the price per kW turbine cost is very high for low capacity wind turbine compare to that of high capacity ones. Low capacity wind turbine is not much available (Awea, 1999); research and development are going on to improve the technology and designing low capacity turbine with low cut-in speed at around 2.5 m sec^{-1} . For these analysis a 3 turbine with a capacity of 0.5 kW has been considered Fig. 5. The cost of the turbine with tower and installation has been considered as 96000 SP/turbine. For the load higher than 1 kW, turbine from Southwest Wind power, (model: W175, capacity: 3 kW) has been considered at the cost of 200000 SP/turbine with tower and installation. Options analysis was done for only PV and wind that acquired after 2007 power demand including reverse system is supplied by using mini-grid connected hybrid power system with quite a few power options: PV/wind. HOMER optimum configurations of appropriate power stations were suggested in the Plan depending on energy resources available in specific locations. Total 35 power stations have been proposed in the Plan. All of them are of hybrid types with Wind and battery bank (Indradip and Chaudhuri, 2008) for a 400 W capacity of Wind Home System (three home users) in coastal areas at a speed of

Table 2: HOMER details results

Home	Load	PV module (kW)	Wind generator (quantity)	Battery (quantity)	Initial cost SP	Total NPC	COE (SP/Wh)
Single	338 Wh day ⁻¹	0.15	0	2	61,890	98,470	49.5
20	115 kW Peak 6.8 kWh day ⁻¹	1.0	1	16	780,000	841,480	25.8
30	2.3 kW peak 10.1 kWh day ⁻¹	2.0	1	24	978,890	1,463,300	23.8
40	3.5 kW 13.5 kWh day ⁻¹	2.5	2	24	2,188,330	1,999,590	24.7
50	4.6 kW 16.9 kWh day ⁻¹	3.5	2	8	1,567,220	1,940,985	20.1
	5.8 kW						

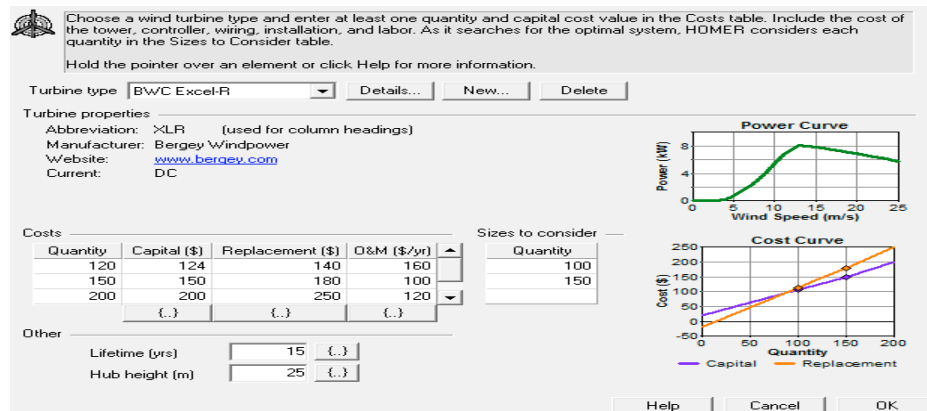


Fig. 5: Wind turbine input

5 m sec⁻¹ the IRR, payback period and benefit-cost ratio are found to be around 16%, 8 years and 2, respectively. Results show that considering energy consumption, environmental effects and remote accessibility most of the coastal regions are viable for wind home system (Shafiuzzaman, 2005), that obtained to the scale of project depending on the suitability for individual locations of the project of wind type of hybrid system.

Battery with control: As the system considered the DC load only, battery and controller were also form as a main part of the performance evaluation of 10 kW PV power system (Sasitharanuwat and Rakwichian, 2007). For isolated battery from Trojan Company (Model: Trojan T-105, nominal V: 6V, nominal capacity: 225 Ah) has been used at a cost of 10,000.00 SP/battery with charge controller. optimized Homer found for Algiers are composed of PV systems, wind generators and batteries, (Malika, 2009). On the basis of local inspections and analysis with the HOMER model, the following design specifications were found to be optimal for a solar penetration of about 25%: PV capacity of 12 kWp, battery capacity of 108 kWh (50 batteries, 360 Ah, 6 V) and 12 kWp converter at Maldives (Van Sark *et al.*, 2004).

Constraints and economics: The project life time has been considered to be 25 years and the annual real interest rate has been taken as 4% (IEA, 2002). As the system has been designed for single and also for multiple home users like 10 to 50 but the load consumed by the user is low so operation and maintenance cost has been taken 500 SP/year. There is no capacity shortage for the system and operating reserve is 10% of hourly load. Analysis shows that the cost of energy (KWH) is low for the system which is the combination of 50 homes (Roaf and Fuentes, 1997). Table 2 shows the load demand for each combination of homes with system architecture and financial summary.

Dalton *et al.* (2009) found that as the result of optimization a modeling for design a hybrid system using Homer software that Modeling demonstrated that, at 2004 prices, the NPC of the grid/RES hybrid configuration is comparable with the grid-only supply and resulted in a RF of 73%, a payback time of 14 years and a reduction in greenhouse gas emissions of 65%. Optimization modeling also showed that whilst a RES-only configuration can potentially supply 100% of power demand, at present electricity prices which have nearly quadrupled since 2004, and predicts that a configuration of 3 Vests WECS (1.8 MW), an 800 kW converter and 3500 batteries

provides the lowest NPC after 20 years at \$19.1M and (Shafiuzzaman, 2005) found as result that payback period and benefit-cost ratio are found to be around 16%, 8 years and 2, respectively. Results show that considering energy consumption, environmental effects and remote accessibility most of the coastal regions are viable for wind home system.

Van Sark *et al.* (2004) found the system simulations showed that with a daily load of 207 kWh day⁻¹ the combination of a 12 KWp, PV system with a battery backup capacity of 108 kWh would be optimum, given the most suitable strategy for the use of two differently sized diesel generators now present. Future demand growth can be accommodating by only a slight change in diesel generator operating strategy. These hybrid system which was design is topologies need higher early resources cost but it has less total net present cost, as a result of higher efficiency operation for the pv generators. Reducing solar radiation and wind power also means less emission from the system as shown by the PV/wind system. In addition, the hybrid system rewardables also consider providing enough electricity for domestic using as needed by people in this particular remote area.

CONCLUSION

This study could be summarized from the analysis that the project life time has been considered to be 25 years and the annual real interest rate has been taken as 4% as the system has been designed for single and also for multiple home users like 10 to 50 but the load consumed by the user is low operation and maintenance cost.

It will be better to use wind-pv combination system for 50 homes instead of single home system. The overall cost of energy would be low if the turbine cost decreases in Khartoum.

The simulation results display that utilizing renewable generators such as PV and wind generator reduces the operating costs using at third class of housing at Khartoum state.

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