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Hybrid Power Systems for Commercial Application in Kenya

Author(s): [1]*Leonard K. Rotich, [2]Joseph Kamau, [1]Robert Kinyua, [2]Jared Ndeda

Affiliation(s): [1]Institute for Energy & Environmental Technology, Jomo Kenyatta University of Agriculture & Technology, Nairobi, Kenya
[2]Department of Physics, Jomo Kenyatta University of Agriculture & Technology, Nairobi, Kenya
*Corresponding author: kipyegonleon@yahoo.com

ORIGINAL ARTICLE

Abstract: The cost, availability and stability of power are parameters that greatly define the quality of energy supplied by a generating system. A hybrid power system with different sources of energy must be properly designed in order to capitalize on the positive features of the deployed resources. Hybrid power system optimization is a process that allows for deliberate attainment of desired output from a power system. In this paper, a learning institution, East African School of Aviation (EASA) was selected as a case study for investigating the outcome of harnessing local energy resources to serve a commercial consumer in Kenya. A cost competitive hybrid power system was obtained through Simulation and optimization processes.

Keywords: *HOMER, wind energy, solar PV solar thermal, NPC, COE, RES, HPS.*

I. INTRODUCTION

Demand for electricity in Kenya has been steadily growing for the last 5 years. The increasing power demand is not unique to Kenya. Emerging and industrializing economies the world over are witnessing rapid increase in power demand [11]. According to the Ministry of Energy & Petroleum Report [6], access to electricity was at 23% in 2012 and in 2016, it had risen to 55%. This growth has been experienced in the domestic, small commercial and large commercial sectors. This has put stress on the national grid system which has not been upgraded at matching proportions to electricity demand. For this reason, black outs are common leading to loss of productivity time for commercial entities and consequently, their output.
Commercial consumers may consider developing their own power generation systems to meet their energy demands by exploiting local energy resources if the alternative is feasible. High cost of energy from the available market sources like diesel back up and/stand-alone generators is a key contributor to increased cost of power [1]. This is because they are highly affected by the fluctuation of fuel costs and emission of greenhouse gases. Additionally, diesel being a fossil based fuel has finite reserve and its use must be managed to extend its availability [5].

Businesses are tasked with finding ways of reducing their costs on energy by adopting feasible alternatives such as self-generation and implementation of energy efficiency measures where possible. In Kenya, the consolidated energy cost for commercial Industrial class CI1 varies between USD 0.15/kWh and USD0.20/kWh [8]. For sustainable development, electricity generation must involve minimal emission of harmful greenhouse gases to the environment [9]. In the same breath, the cost of generation technology must be affordable in order to keep local economy competitive both regionally and globally.

In order to achieve these desirable outcomes of low cost of electricity and minimal emissions of harmful greenhouse gases, a balance has to be made in the types of generation technologies to deploy. Low cost conventional energy sources are associated with high emissions and negative environmental impact while the relatively clean sources are still riddled with high cost of investment resulting in higher cost of electricity [10]. An optimal mix of available energy resources can ensure both concerns are addressed and at the same time power demand is met. Identifying the need to employ both conventional and non-conventional sources in order to meet modern electricity demand is the basic step in addressing the problem.

Renewable energy resources (RES) like wind, solar, small hydro, biomass, and incineration-gas may be used to generate power. Solar and wind energy resources which are considered in this study are available for free from nature. However, these two suffer from intermittency thus making it hard to derive good quality and stable power from them. This poses challenges to increasing grid penetration of renewable energy [7]. Additionally, conversion technologies for some RES are still expensive as compared to those of conventional energy resources. Energy demand is also variable and this further introduces uncertainties in power system design [2].

Hybrid Power Systems have been designed to utilize several sources of energy to serve a common load with the main aim of diminishing or overcoming the inherent weakness of one source [3]. Optimization and simulation of a Hybrid power System involves defining the operation parameters considered as key in the determining viability of a system [4]. Load conditions must be outlined while the energy resources should be assessed and appraised for suitability. The most viable system that addresses resource intermittency, demand & supply mismatch and gives low Cost of Energy (COE) and Net Present Cost (NPC) is selected.

In this paper, a commercial industrial consumer, East African School of Aviation (EASA) was selected as a case study in order to simulate and optimize a Hybrid Power System for serving a commercial load. The hybrid power system considered composed of Solar PV, Solar Thermal, Wind and Grid.

II. HYBRID POWER SYSTEM SIMULATION AND OPTIMIZATION USING HOMER SOFTWARE

HOMER software is a powerful tool for designing Hybrid Power Systems of different configurations depending on the needs of a designer. In order to carry out simulation and optimization process for a power system, information about a selected site is needed. The basic information required is the Load profile to be served by the power system and the energy resources to be deployed. Other input data needed for successful simulation are economic variables like interest rates, power system components and their costs. This data is then used by HOMER to perform simulations in order to shortlist and rank systems according to their costs. Input data for the site under study are briefly discussed below.

a) Load profile for the site

The load profile was determined by collecting power consumption data over a period of 4 weeks using a power data logger. The data logger was hooked at the mains supply from the grid. The logger measured and recorded cumulative power usage at 5 minutes interval. The data collected was imported to HOMER and used to generate a yearly load profile. Fig 1 represents the average daily load curve.

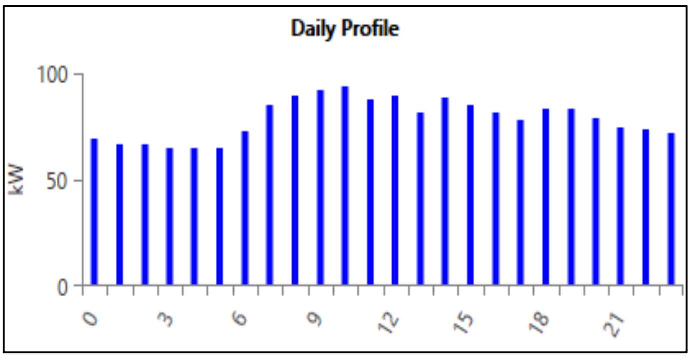

Figure 1 - Daily load Profile for the site

b) Wind and Solar Resources Assessment for the site

Wind speeds and solar radiation data for the site (EASA) were obtained from NASA Surface Meteorological Data. The average monthly wind speed data recorded at 50m above ground for a period of 10 years (July 1983 – June 1993) was obtained. Similarly, monthly averaged values of Global Horizontal Irradiance for a period spanning over 22 years (July 1983 – June 2005) was obtained and used as input for HOMER Simulation. Wind speed and solar radiation values are tabulated below.

Month	Clearness Index	Daily Radiation (kWh/m^2/day	Wind speed(m/s)
January	0.630	6.420	4.610
February	0.655	6.860	4.680
March	0.633	6.660	4.640
April	0.575	5.830	4.700
May	0.562	5.360	4.780
June	0.558	5.110	4.890
July	0.562	5.230	4.920
August	0.565	5.550	5.050
September	0.618	6.370	5.150
October	0.588	6.130	4.890
November	0.547	5..590	4.540
December	0.602	6.060	4.320

Table.1. Solar radiation & Wind speed values for the site.

c) Economic Data input

In order to determine NPC, COE and system costs, economic parameters such as discount rates and price of components must be specified in HOMER. For this study, a nominal discount rate of 10% was chosen. Price of components is obtained from manufacturers while the grid cost of energy is taken from the most recent charges (USD 0.16/kWh). Grid sales are through net metering where credits are settled monthly at USD 0.12/kWh.

III. SCENARIO ANALYSIS

Scenario A: Wind, Solar PV, Grid

This case presents a system condition where the site is connected to the grid and Solar PV and Wind are added to observe the feasibility of resultant system.

Scenario B: Wind and Grid

This case presents a system where Solar PV is not included. This was done to find out the performance of a Wind/Grid hybrid system under prevailing load condition.

Scenario C: Wind/Grid/Solar Thermal

This case presents a system condition with Solar Thermal added to the Wind/Grid configuration in order to observe the impacts of the Solar Thermal fraction to the overall COE. Simulation was done partly with HOMER and partly by hand. Consolidated cost of energy of the system was determined for comparison with the outcome of previous cases.

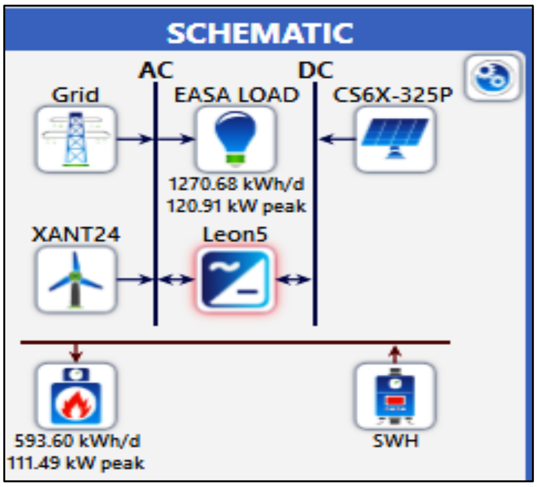

Figure 2 - Hybrid system configuration for the site

IV. RESULTS AND DISCUSSION

Simulation results for scenario A was a hybrid system composed of wind and grid, which is similar to the configuration of scenario B. The most optimum system was made up of 3 XANT M24 (95kW) and the grid. The NPC and COE for the system were USD 804135 and USD 0.0878 respectively while the renewable fraction was 54.1%.

Scenario C was a hybrid system comprising 3 XANT M24 (95kW), solar thermal and the grid. For this scenario, the total load was divided into two parts, AC primary load of 1270.68kWh/day and a thermal load of 593.6kWh/d. The thermal fraction of the total load was estimated by assuming that all the thermal needs for the site was for meeting hot water demand. The hot water demand was met by designing and sizing a Solar Water Heating (SWH) system ideal for the site. The various costs and other operating characteristics of the two main scenarios are tabulated below.

Costs (USD)	Scenario 2	Scenario 3
Total NPC	804135	587711
Total OUSDM	422113	64605
Total ANN	74324	54316
Capital	345000	455476
COE (USD/kWh)	0.0878	0.0601

Table 2 - NPC and Annualized costs for the Systems

V. CONCLUSIONS

Hybrid power system can provide energy at competitive rates compared to prevailing electricity tariffs when proper designing is done. Emission levels associated with power generation from fossil based fuel plants can be reduced by utilizing hybrid renewable energy systems to meet demand. It will be feasibly attractive for commercial consumers to invest in generation of power to meet their onsite demand if their overall costs are reduced.

For the case study reviewed in this paper, two main scenarios; scenario B and scenario C presented positive results for hybrid power system use to meet specific demand of such a consumer. Both cases presented lower cost of energy than the grid tariffs currently incurred by consumers of this scale. Scenario B which composed of wind and grid had a COE of USD 0.0878/kWh while the scenario C which included solar thermal had a COE of USD 0.0601/kWh. This is much lower than the grid tariff which currently ranges between USD 0.15/kWh and USD 0.20/kWh.

Solar PV did not feature among the most feasible hybrid systems because the cost of solar PV per installed kW is still high compared to wind and the grid. Despite solar resource being abundant in the site, the nature of the load being high even during the night when solar is off contributes to reduced suitability of solar.

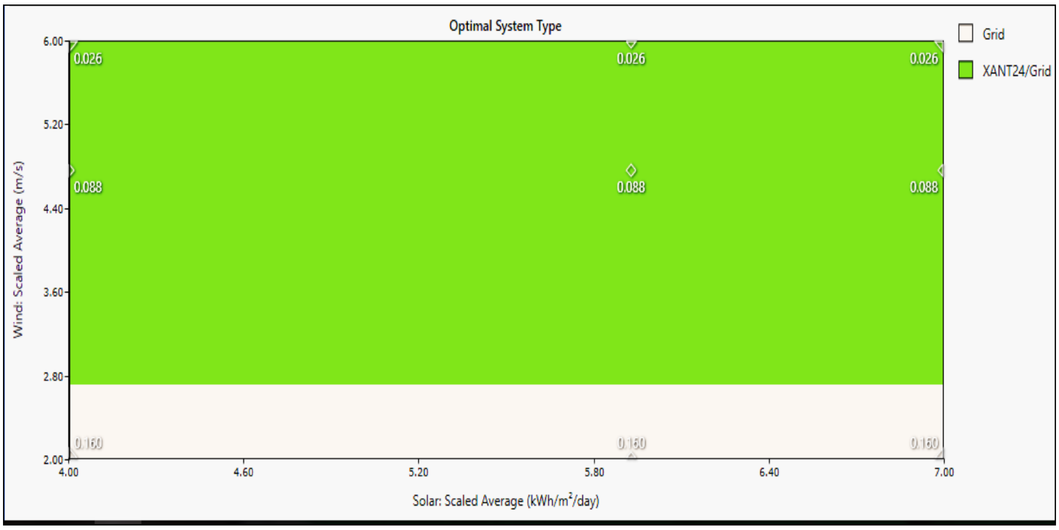

Figure 3 - Optimal System sensitivity results with COE superimposed

According to the figure 3, it shows sensitivity analysis carried out by inputting different values of the average wind speed and solar irradiance search spaces revealed that solar PV would still have not made it to the most feasible system for meeting the load. When price range of grid purchases is used for sensitivity analysis, similar results are obtained.

As shown in figure 4 below, the COE of the optimal system increases linearly with increase in grid purchase price. It is however worth noting that the COE of system configurations with solar PV was still lower than the grid tariffs. Where installation practicalities limit the use of wind, solar PV can still be used to meet part of the load competitively.

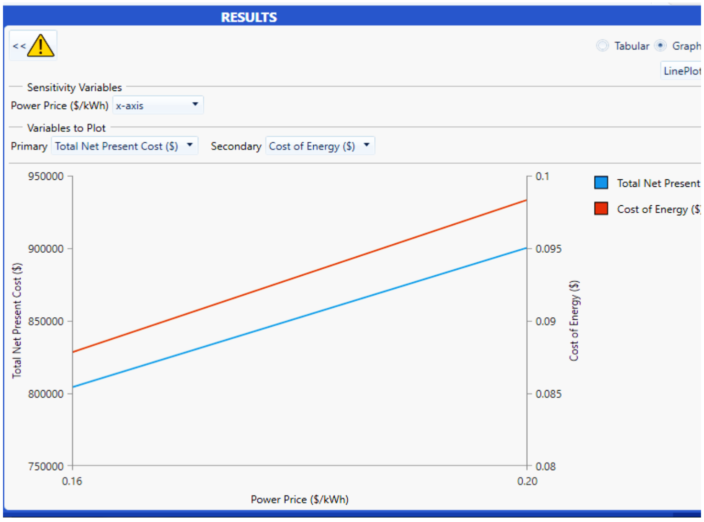

Figure 4 - COE of the optimal system increases linearly with increase in grid purchase price

VI. DECLARATION

All authors disclosed no conflicts of interest.

REFERENCE

[1] Amy R., Stoner R. and Pérez-Arriaga I. (2016). "Prospects for grid-connected solar PV in Kenya." A systems approach. Applied Energy, 161 P 583–590

[2] Eisa A. & Soltan H., (2011). "A methodology for Electric Power Load Forecasting". Alexandria Engineering Journal, 50 P 137–144.

[3] El-Tous Y. & Sandro A. H., (2014). "Photovoltaic / Wind Hybrid Off-Grid

[4] Lukuyu M. & Cardell B. (2014). "Hybrid Power Systems Options for Off-Grid Rural Electrification in Northern Kenya."Smart Grid and Renewable Energy 5 P 81-106

[5] Thomas Covert, Michael Greenstone & Christopher R Knittel, (2016). "Will We Ever Stop Using Fossil Fuels?"MIT Center for Energy and Environmental Policy Research. Ministry of energy, Kenya, (2016).

[6] Development of a Power Generation and Transmission Master Plan, Kenya. P 1-246.

[7] Chow C. W., Belongie S. & Kleissl J., (2015). "Cloud motion and stability estimation for intra-hour solar forecasting''. Solar Energy, 115 P 645–655

[8] Energy Regulatory Commission-International Finance Corporation, ERC-IFC, (2015). "Kenya Market Assessment for Off-Grid Electrification". P 1-126

[9] Sandeep Kumar & Vijay Kumar G., (2013). "A Hybrid Model of Solar-Wind Power Generation System". IJAREEIE. 2, Issue 8

[10] Timmons D., Jonathan M., & Brian R. (2014). "The Economics of Renewable Energy". Global Development and Environment Institute Tufts University Medford, MA 02155. Retrieved on 5.04.2017 from http://ase.tufts.edu/gdae

[11] International Energy Agency, (2011). World Energy Outlook. P 1-106