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A Feasibility Study of Solar and Wind Hybridization of a Telecommunication Off-Grid Radio Base Station Site

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Abstract : ***In order to expand cellular coverage and grow their market presence, mobile network operators in Kenya have had to deploy a significant part of their radio base station infrastructure in rural and remote areas, most of which are off-grid areas i.e., areas that are beyond the reach of the national electricity grid. The most common way to solve the power problem at these off-grid radio base stations has been to install and run diesel generator sets. Diesel generators have some inherent problems associated with them, which include; high cost of fuel, fuel delivery challenges, fuel pilferage, fuel supply disruptions, fuel price uncertainties, high generator maintenance costs, environmental pollution and system unreliability. Solar and wind are alternative sources of energy that can be used in standalone mode or in hybrid configuration to reduce reliance on diesel generators. The financial analysis and design of renewable energy systems can be challenging, due to the large number of design options and uncertainty in key parameters. Further complexity is added because their power output may be intermittent, seasonal, and non-dispatchable, and the availability may be uncertain. This case study was undertaken to determine the most feasible hybrid power solution for one off grid radio base station site belonging to a mobile network operator in Kenya through use of HOMER Microgrid analysis software tool. The load profile was measured using a digital power data logger and the maximum load estimated. Wind and Solar data was obtained from the National Aeronautical and Space Agency and National Renewable Energy Laboratory data bases respectively. Component costs, operational costs, diesel fuel prices and estimate interest rates were also obtained from both secondary and primary sources. Using this data, several hybrid system configurations were simulated and ranked according to the value of their Net Present Cost. The system with the lowest Net Present Cost is deemed as the most feasible configuration. Results from the study showed that the Solar-Diesel Generator-Battery Bank configuration has the lowest Net Present Cost and would be the most feasible power solution for the study site.***

Keywords – Hybrid Energy, Solar, Wind, Telecommunications, Net present Cost, HOMER

Introduction

According to Communications Authority of Kenya (CAK), (2014) Population coverage of mobile networks in Kenya stands at an average of 79.2%.Within the context of achieving universal access, to mobile communications, Kenya presents a significant growth opportunity for the mobile industry over the coming years. However, the mobile industry in Kenya faces many challenges – both infrastructural and operational while trying to run networks in a cost effective manner. The abysmal grid electricity infrastructure is one of the major challenges that they face. Statistics by World Bank (2015) show that only about 23% of the Kenya population have access to grid electricity. In addition, wherever there is access to grid electricity infrastructure, the supply of electricity is highly unreliable with frequent and long outages.

The reliance on diesel based power alternatives has hugely increased the cost of operations for their existing networks due to the higher cost of diesel power, the need for regular maintenance of power equipment and diesel generators. This has greatly impacted the Return of Investment (ROI) of existing network investments for operators in the country and also hindered network operators from expanding their networks into rural and remote areas.

Therefore, the infrastructural challenges for network operators in Kenya are twofold – one, how to cost effectively power their existing network and two, how to cost effectively expand network coverage to populations currently without access to mobile communications infrastructure. In addition to the infrastructure challenges, network operators also face many operational challenges including the theft of diesel stored at the site.

The poor supporting infrastructure and the operational complexities across Kenya have hugely impacted the Operation Expenses (OPEX) of mobile networks and hence, the cost of services for the end users. Cost-effective energy alternatives and reduced risks of operations have a great implication for increasing the coverage and subscriptions across parts of Kenya. Mobile operators in Kenya have focused on addressing the energy challenges by trying to adopt alternative renewable energy sources, such as solar, wind, biomass and fuel cell, in order to reduce the cost of energy as well as to address some of the operational challenges in powering their tower sites. Kenya is rich in wind and solar resources which could be tapped to alleviate the energy challenges faced by mobile network operators. Designing for renewable energy resources is however very complex due to their intermittency and uncertainty of their availability. Paper based calculations are applicable when designing for a single renewable energy resource but they become impractical for hybrid energy systems where more than one renewable energy resources are involved. There are several software modeling tools that have been developed to help overcome this challenge and make it easy to determine the most technically optimal energy system configuration to adapt. Some of these tools can also be used carry out a financial analysis to come up with the most feasible option.

The main objective of this study, therefore, was to determine the most technically and financially optimal solar-wind-diesel generator and battery hybrid configuration inclusive of battery storage for the mobile network operator remote off-grid radio base station site under the study. The specific objectives of the study include: Establishing the load profile of the off-grid radio base station site; Evaluating the available solar and wind energy resources at the radio base station; Dimensioning the hybrid energy system components for optimal technical operation by matching the energy resources to the site load requirements; Carrying out financial analysis of the hybrid system to determine the most feasible configuration by using HOMER Pro software analysis tool

Materials and Methods

The study was carried out in the following general steps guided by the specific objectives: Estimating the load power; Evaluating the wind and solar energy resources at the site; Sizing the solar array, the wind turbine, the battery bank, the diesel generator and the power converter; Simulating the possible hybrid system configuration; Simulating the net present cost for each hybrid system configuration including for the system which is presently installed at the site; Determining the most feasible hybrid system configuration i.e., the one with the lowest net present cost.

Load profile measurements were undertaken at the radio base station study site located in South East part of Kenya for duration of twenty four hours using Fluke 1735 Power Data Logger. During the load data recording duration it was noted that the generator was running continuously and hence at no point did the backup batteries discharge and recharge. Hence in order to determine the maximum possible load power at the study site, the theoretical maximum battery recharge power was calculated and added to the measured peak load power. This maximum site load power forms the basis for estimating the capacities of the energy hybrid system components.

Wind speed data for the study site location was obtained from National Aeronautical and Space Agency (NASA) surface meteorology and solar energy database. The wind speed is monthly averaged over a period of ten years at a height of fifty meters. The average annual wind speed is 4.644 m/s with a low of 3.933 m/s in the month of December and a high of 5.31 m/s in the month of September. Solar daily radiation data was also obtained from NASA surface meteorology and solar energy database. The average solar radiation is 5.491 kWh/m^2/day with high of 6.224 kWh/m^2/day in the month October of and a low of 4.956 kWh/m^2/day in the month of June.

The maximum peak power capacity of the solar array that can be installed at the site was capped to the available space and the power rating of the panel type chosen for this study. The unobstructed free space available at this site that is suitable for solar panel installation is about 40M^2. Hence the highest number of CS6X-310P solar panels each measuring 1.92M^2 that can be installed at this site is twenty panels. The rated nominal maximum power (Pmax) per panel is 225 kW, which means that the maximum installed power capacity of the solar array would be 4.5 kW.

The selection of the a suitable wind turbine for this site was done through analysis of power curves of several small size wind turbines and matching them with the average wind speed prevalent at the location of the study site. The wind turbine whose power curve showed the best power output at the wind speeds prevalent at the study site location is the Bergey XLR6 with a maximum power output of 6 kW.

The diesel generator was auto sized through the HOMER optimization tool. However, as a rule of thumb, a diesel generator should have enough capacity to cover the peak load, the maximum battery recharge current and inefficiency but be within the limits of the smallest diesel generators available (Danielle Seeling-Hochmuth, 1998)

Battery backup at telecommunication sites is sized to provide power for long enough so as to give sufficient time to operations and maintenance teams to travel to site and resolve the power failure problem. Four hours of battery backup is considered the industry standard for radio base station sites. In the case of the study site the battery bank will not be modelled to operate in back up mode but in cyclic mode so as to help improve on site fuel efficiency. Therefore the determination of the optimal battery bank size was done through system simulation by use of HOMER. Before the simulation was carried out, certain parameters like nominal battery voltage, system voltage, number of batteries per string, maximum discharge current, maximum recharge current, round trip efficiency and battery technology were taken from the battery manufacturer manual and keyed into the modelling tool.

The size of the voltage converter (rectifier) was determined by the peak load size, battery recharge current, covering for converter inefficiency and including module redundancy.

Results and Tables

The load power profile in Kilowatts is as shown on the graph on **Figure 1**. The power spike that appeared at 3:58 pm was a result of an electrical disturbance due to tripping of a battery circuit breaker that happened inadvertently when the researcher caused a short circuit at the rectifier output terminals.

The power flow is steady until at 6:37 am the next day, but thereafter declines sharply from 0.72kW to 0kW within two hours. Oliver Blume *et al*, 2010 state that base station energy consumption is only moderately correlated to traffic load. Josip Lorincz *et al*, 2012 also state that traffic load variations have small influence on the power consumption of base stations.

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The 0kW recorded can be explained from a research carried out by Josip Lorincz *et al*, 2012 about modern measures that have been put in place to improve base station energy efficiency. In their research paper titled “Measurement and modelling of base station power consumption under real traffic loads”, they state that, “at the network level, one of the most important approaches for reducing energy consumption is dynamic management of network resources, which allows shutting down of entire base stations during a low traffic load. In such a scenario, neighbouring base stations must provide coverage and take over the traffic load of those base stations that are turned off”

Turning off a base station is achieved by implementation of gradual/partial shutdown of power amplifiers before finally switching of the entire base station. The base station power amplifier is the most energy hungry component, consuming 60% to 80% of base station power. Rising traffic levels trigger a wake-up mechanism that must remain operable in the switched-off base station. Based on these assumptions it was deduced that the study site base station switches off temporarily at 8:37 pm due to low cellular traffic conditions on that part of Mombasa road and subsequently neighbouring base stations begin take up any little study site traffic that is detected. At 1:54 pm the study site load power begins to raise, an indication that the cellular traffic has gone up to a sufficient level as to trigger the wake-up mechanism of the base station.

The study site has a 600AH back up battery bank that did not discharge during the site load measurement period. The recharge current of the battery bank was obtained from the manufacturer recharge characteristics graph for Narada batteries and added to the measured site current in order to calculate the realistic maximum load demand expected at the site.

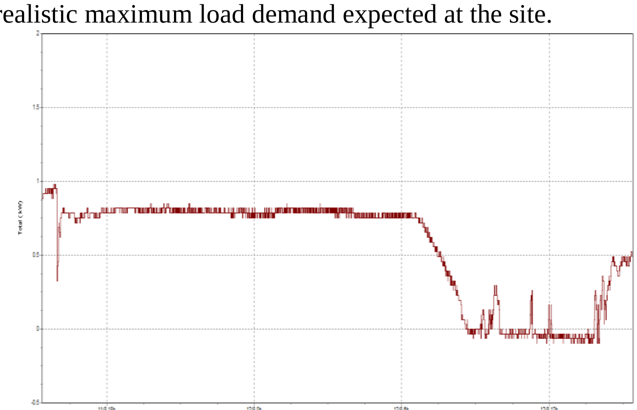
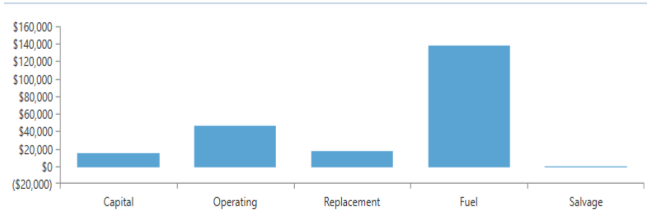


FIGURE 1 A TWENTY FOUR HOUR LOAD PROFILE OF THE STUDY SITE

The Fluke 1735 Data Logger was set to average the load power measurements every thirty seconds but for purposes of entering the data into the HOMER micro grid analysis tool, hourly load power averages were used.

The existing site consists of an 11 kW diesel generator and a 600 AH battery bank for back up. The Net Present Cost (NPC) simulation for the existing site energy system was done and the results show that the study site has a NPC of 219,078 US$. The NPC breakdown per cost type is shown on **Figure 2**.



Component	Capital ($)	Replacement ($)	O&M ($)	Fuel ($)	Salvage ($)	Total ($)
11kW FG Wilson	$6,600	$10,567	$29,548	$138,736	-$7.26	$185,445
Narada REX-600	$2,400	$3,638	$9,602	$0.00	-$98.94	$15,540
Converter	$7,000	$4,016	$8,001	$0.00	-$924.29	$18,093
System	$16,000	$18,221	$47,151	$138,736	-$1,031	$219,078

FIGURE 2 NPC SIMULATION RESULTS FOR EXISTING POWER SYSTEM AT THE STUDY SITE

Estimates of component capital costs, installation costs and operational costs were also entered into the HOMER tool. A typical power system schematic incorporating all the components is shown in **Figure 3**.

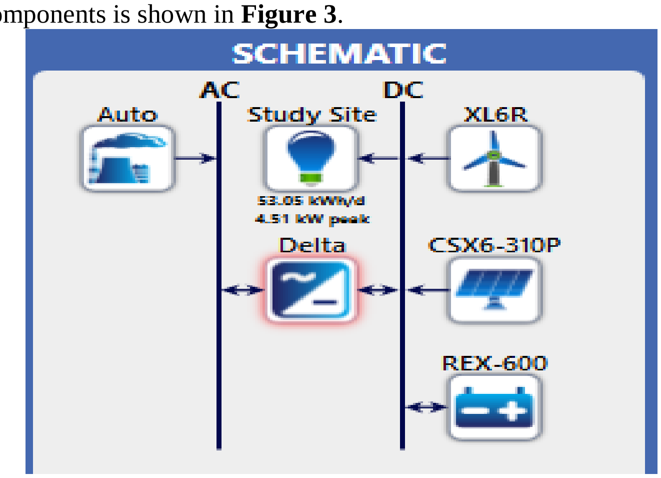


FIGURE 3 HYBRID POWER SYSTEM SCHEMATIC INCORPORATING ALL COMPONENTS

After all the parameters are entered into HOMER, a simulation was run to give the NPC ranking of the feasible hybrid power system configurations. The results of the simulation are as shown on **Figure 4**.

Architecture						Cost			
CSX6-310P (kW)	XL6R	Auto (kW)	REX-600	Delta (kW)	Dispatch	COE ($)	NPC ($)	Operating cost ($)	Initial capital ($)
4.50		5.30	24	6.00	CC	$0.433	$134,037	$6,888	$23,810
		5.30	48	6.00	CC	$0.552	$171,186	$9,903	$12,710
4.50	1	5.30	48	6.00	CC	$0.662	$205,188	$6,091	$107,710
	1	5.30	24	6.00	CC	$0.749	$232,156	$8,770	$91,810

FIGURE 4 NPC SIMULATION OF THE STUDY SITE POWER SYSTEM INCORPORATING SOLAR AND WIND ENERGY RESOURCES

The simulation results show that the configuration consisting of 4.50 kW solar array, 5.30 kW diesel generator, 24x600AH battery bank and a 6.0 kW rectifier-solar controller system had the lowest NPC value of 134,037 US$. The results also show that there are a total of three possible configurations that give a NPC value which is lower than that of the existing site energy system. The NPC comparisons are summarized in the graph shown on **Figure 5**.

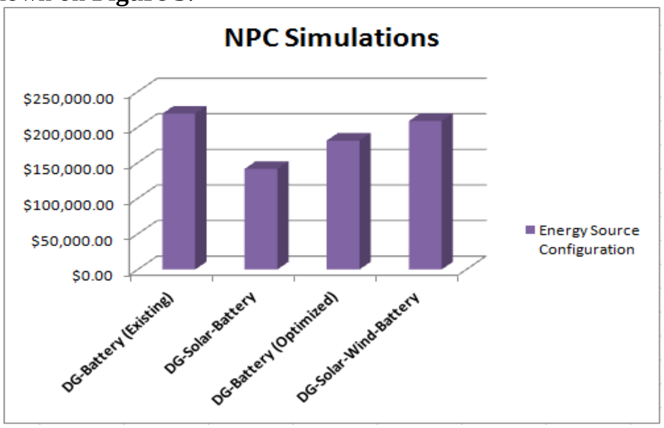
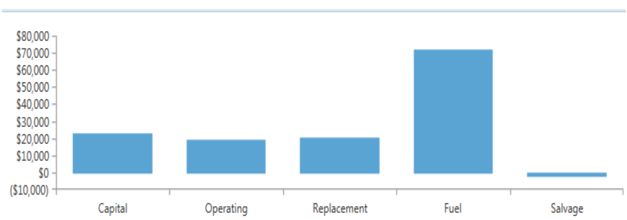


FIGURE 5 THE NPC SUMMARY FOR THE EXISTING SITE CONFIGURATION AND FOR THE THREE CONFIGURATIONS WITH THE LOWEST NPC

The diesel generator-solar hybrid configuration has the lowest NPC and its cost component breakdown is as shown on **Figure 6**.



Component	Capital ($)	Replacement ($)	O&M ($)	Fuel ($)	Salvage ($)	Total ($)
Canadian Solar Quartech Module	$13,500	$0.00	$2,881	$0.00	$0.00	$16,380
Autosize Genset	$3,710	$11,347	$8,132	$72,372	-$989.54	$94,572
Narada REX-600	$2,400	$4,486	$3,841	$0.00	-$713.00	$10,014
Converter	$4,200	$4,902	$4,801	$0.00	-$831.86	$13,071
System	$23,810	$20,735	$19,654	$72,372	-$2,534	$134,037

FIGURE 6 COST COMPONENT BREAKDOWN FOR THE SOLAR-DIESEL GENERATOR HYBRID SYSTEM

Conclusion

The hybrid power system simulation results at this site show that the Solar-Diesel Generator hybrid system has the lowest NPC and is hence the most cost effective energy system configuration. The configuration with a 5.3 kW diesel generator and a 24 string 600 AH battery bank in cyclic operation has the second best NPC. The Solar-Wind-Diesel Generator hybrid energy system has the third best NPC which is also lower than the NPC of the existing site energy system.

All the simulation results show that fuel constitutes the biggest cost component over the operational duration of all the hybrid systems at the radio base station site. The simulation results also show that the diesel generator is the most costly system component to run, chiefly due to its high operations and maintenance cost and the cost of fuel.

References

i. *Seeling-Hochmuth D. (1998). Optimization of Hybrid Energy Systems Sizing and Operation Control. University of Kassel, Hasse, Germany. pp 12-14*

ii. *Blume O et al (2010). Energy Savings in Mobile Networks Based on Adaptation to Traffic Statistics. Bell Labs Technical Journal. 15(2), 77–94*

iii. *Lorincz J et al (2012) Measurement and Modeling of Base Station Power Consumption under Real Traffic Loads. Sensor, Basel, Switzerland. Pp 4*

iv. *HOMER (The Hybrid Optimization Model for Electric Renewables). Available from: http://www.nrel/gov/HOMER.*

v. *Al-Karaghouli, A., Kazmerski, L. (2010), Optimization and life-cycle cost of health clinic PV system for a rural area in southern Iraq using HOMER software. Solar Energy, 84, pp 710-714*

vi. *Nandi, S.K., Ghosh, H.R. (2010), Prospect of wind-PV-battery hybrid power system as an alternative to grid extension in Bangladesh. Energy, 35, pp 3040-3047*

vii. *Taylor R., Hybrid power systems. Retrieved from:http://files.harc.edu/Documents/EBS/CEDP/HybridPowerSystems.pdf on 16 December, 2011, pp 161-169*

viii. *Jose´ L. Bernal-Agustı´n and Rodolfo Dufo-Lo´ pez, (2009).Simulation and optimization of stand-alone hybrid renewable energy systems. Renewable and Sustainable Energy Reviews 13, pp 2111-2118*

ix. *Juhari Ab. Razak, Kamaruzzaman Sopian & Yusoff Ali, (2007), Optimization of Renewable Energy Hybrid System by Minimizing Excess Capacity. International Journal of Energy, 1(3), pp. 77 – 81*

x. *Lambert, T., (2006), HOMER: The Hybrid Optimization Model for Electrical Renewables.http://www.nrel.gov/international/tools/HOMER/homer.htmlpp 71-121*