Journal of Natural Sciences and Mathematics
Qassim University, Vol. 10, No. 2, pp 95-103 (July 2017/Shawwal 1438H.)

Solar Mini-grids for Sudan Rural Areas: Case Study, Arquit Village

N. Ibrahimi[*] , R. Abdelgadir[2] and R.ALI***[2]**

Majmaah university

2. Ministry of Science and Technology

National Energy Research Centre

*E-mail: *n.ibrahim@mu.edu.sa*

*** ratiebahaj@yahoo.com*

****Remond2009@windowslive.com*

Abstract: The objective of this work is to evaluate the potential of alternative energy technologies to increase electricity access in rural areas of Sudan . one of these alternative energy technologies is renewable energy mini-grids .One of the rural areas in Sudan is Arquit village, Sinkat area, Red Sea state; we suggest building 7.5 MW solar system minigrids at Arquit village. In Arquit village, the maximum and minimum electricity productions of from solar energy are expected during March, and December respectively. In Summer the days are longer for solar electricity production , while in the winter months, October to February, production of solar electricity does not take place after 5 a.m. Therefore, energy storage is needed to fill the gap in supply during the summer and winter months, or using wind energy for electricity production.

Keywords: Arquit village, solar energy, mini-grid, National Energy Research Centre.

1. Introduction

The key of economic growth and development of any society is the energy. The rural electrification over much of the developing world is slow. Many countries in Africa are lower than rural population growth [1]. Many difficulties faced Rural electrification programs , which :

1.The low population densities in rural areas result in high capital and operating costs for electricity companies.

2.People in rural areas are poor and their electricity consumption is low.

3. Most of the local populations are farmers which cause difficulties over rights of way for the construction and maintenance of electricity lines [2].

In Sudan around 37% of household houses connected to electricity national grid. 66.4% of population they don`t have access to electricity [3] , most of them are in rural , whereas the rest depend on diesel generators source of electricity [4],In Red Sea State 18.4% of household houses connected to electricity national grid,, and 13.6% the source of electricity comes from diesel generators [3].

1.2. Mini-Grid

Is village electrical distribution system severed by generators. Power in Mini-Grid is provided by diesel generator. The benefits of using a mini-grid are: Minimal contribution to global warming [5], [6], improved environmental quality and public health [7], renewable energy resource [8], economic benefits [9], [10], more stable energy market [11], [12]. Mini-grid operator models describe the organizational structure of mini-grid implementation and operation. The four main mini-grid operator are the utility, private sector, community and hybrid models.

We have selected Arquit village, Sinkat locality, Red Sea state as case study.

The objective of this research is to investigate the potential of using solar system Mini-Grid, in rural areas in Sudan.

2. Technical Analysis

2.1. Study Area

Arquit is a village in Sinkat locality, red sea state southwest to Port-Sudan city. The coordinates of the village are: 36° 06' 39" E, 18° 46' 41" N. It lies about 160 km from Port Sudan city, the capital of the state. The population is estimated to be 6947 people according to the Sudan census of 2008 [13] . Most of people activities is in agriculture, even the women in the houses they cultivate fruits (grapes, prickly pears, citrus and pomegranate). IN the village there are : two primary schools, one for boys and one for girls, mixed Secondary School, Health center, two hotels, four mosques Table .1, one well (Donky) for different purposes (drinking, irrigation, etc.), and private farms planted with citrus fruits such as grapes and pomegranates in small and medium scales.

The source of electricity in the village consists of 30 diesel Generators, with capacities 3, 5 and 7 KW.

TABLE I Main Institutes in Arquit Village

No.	Institute	No.	Institute
2	Primary schools (girls, boys)	1	Youth club
1	Secondary school (mixed)	1	Well (drinking and irrigation purposes)
1	Kindergarten	1	Market
2	Khalwa	2	Bakery
6	Mosques	2	Mills
1	Health center		

Fig(1) : location of Airquait village

2.2. Current Installed Capacity

The current installed capacity in of Airquait now is 300KW, most of which from diesel, and there no access of electricity in the village , however, there are two standalone solar system in ,and one solar vaccination Refrigerator in the village the systems are not in use since batteries are no longer work But solar vaccination Refrigerator is operate, According to, the real Capacity needed of Airquait village in 7.5 MW. Table (2)

2.3. Solar Generation

Arquit village one of the villages where electricity is not access, they depend on diesel generators as a source of electricity. the solar radiation had a mean annual value of 225 W /m2,[14], [15].) give an estimate of 263 W/ m2, which was favored by for their calculation of the heat balance of the Mediterranean and Red seas. [16], its suitable area to implement (solar) mini grid to provide electricity to whole community included institutes and schools in the village .Table (1I). .

There are no any challenges involved in the implementation of solar minigrids in Sudan , This is first Proposal. For quality of solar resource data , Currently, there is satellite data available on all the regions in Sudan, but there is a lack of ground data that validates actual resource data.

Resource assessment such as : resource assessment such as : locations and the amount of renewable power generation potential for those locations must provided. The most importat data is renewable resource assessment which participation the impact of renewable energy project. [17] .

2.4. Energy Needs

As mentioned earlier, the current installed capacity of 0.3 MW mostly from diesel generators, all of it meets basic power demand such as lighting for a period of five hours a day year round, mostly during the evening hours of 6–10 p.m. .The typical usage of electricity in the village households are for lighting, operation of televisions and, and charging of cell phones. A few households also use fans, refrigerators, and computers, among other electrical appliances . The capacity of the energy needed 7.5MW . Table(2), for growth range more renewable may integrating into the grid especially wind energy. The village power -Minigrid distribution is showmen in figure (2) .

3. Methodology

To carry out the results for study, we visits **the site .**collecting data from the village's population. networks, modeling and simulation of the mini grid network using software cost optimization using HOMER Energy software was performed

Table II. Capacity needed of Airquait village

Appliance	Number	Wattage	Working Hours	Energy (kWh/day) Read more
light	10000	30	5	1500
Fans	6100	50	5	1525
TV	3000	120	5	1800
Computers	100	100	3	30
Refrigerators	1000	100	12	1200
Charging point	3100	100	3	930
Receivers	3000	30	5	450
Total				7435

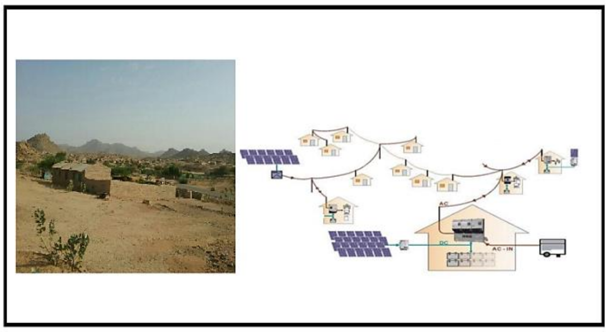
The annual solar radiation in the area is 6.76 (kWh / m2 / day To determine the total kilowatt-hour output of solar PV, a customized weather file was created from Clima Temps.com Fig.(3) [15].The total kilowatt-hour output from standard PV crystalline silicon panels for Arquit village shown in table (2)below.

Table III. Site Details and PV System Specifications

Arquit village	Site location
18° 46' 41" N	Latitude
36° 06' 39" E	Longitude
7500 KW	System size/capacity
1119	Number of panels (14.5 ft2 each)
Ground	Mounting surface
130	Rated panel power
96%	Panel efficiency
33°	Panel tilt

4. Suggested Technical Configuration

As illustrated in Figure 4, a Mini-Grid of 7.MW system can be built to address the electrification needs of Arquit villages



8

Figure(2) Arquit village power -Minigrid distribution

Arquit village needed for energy is about 7.5MW , which needed for households and commercial establishments [18].

Mini grids systems system 7.5 MW builds in outside the village in 1119 panels.

5. Results

The Hybrid Optimization Model for Electric Renewable (HOMER) : HOMER is an optimization model for designing hybrid electric power systems. HOMER has been in development at NREL since 1994. Assessing the least cost mix of supply technologies is a difficult analytical problem. This depends on the quality of the various resources, the costs of equipment, labor and fuel, and the site-specific description of the daily and seasonal variations in the loads, as well as the options for simple load management. The HOMER is a screening model that is useful for feasibility and sensitivity analysis. HOMER can model any combination of: • wind turbines • photovoltaic panels • diesel generation • battery storage Comparisons can also be made between the optimal hybrid system and grid extension. HOMER provides hourly energy flows through each component, the impact of several simple load management strategies, and economic information such as the cost of energy and net cost of the system (Figure (3)).

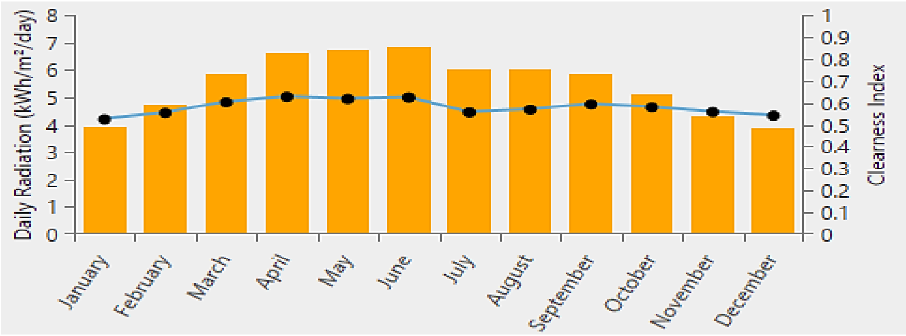


Figure (3) Monthly Average Solar Global Horizontal Irradiance(GHI data)

Architecture			Cost				System	PV		G10			1kWh LA		
1kWh LA	BDI 3P (kW)	Dispatch	COE ($)	NPC ($)	Operating cost ($)	Initial capital ($)	Ren Frac (%)	Capital Cost ($)	Production (kWh)	Capital Cost ($)	Production (kWh)	O&M Cost ($)	Autonomy (hr)	Annual Throughput (kWh)	Rectifier Mean Out (kW)
300	300	CC	$0.000409	$55,663	$910.24	$43,896	100	122	20,669	43,750	10,498,367	438	0.0020	192	0.001
300	300	LF	$0.000409	$55,663	$910.24	$43,896	100	122	20,669	43,750	10,498,367	438	0.0020	192	0.001
350	300	CC	$0.000409	$55,663	$910.24	$43,896	100	122	20,669	43,750	10,498,367	438	0.0023	223	0.001
350	300	LF	$0.000409	$55,663	$910.24	$43,896	100	122	20,669	43,750	10,498,367	438	0.0023	223	0.001
400	300	CC	$0.000409	$55,663	$910.24	$43,896	100	122	20,669	43,750	10,498,367	438	0.0027	254	0.001
400	300	LF	$0.000409	$55,663	$910.24	$43,896	100	122	20,669	43,750	10,498,367	438	0.0027	254	0.001
450	300	CC	$0.000409	$55,663	$910.24	$43,896	100	122	20,669	43,750	10,498,367	438	0.0030	286	0.002
450	300	LF	$0.000409	$55,663	$910.24	$43,896	100	122	20,669	43,750	10,498,367	438	0.0030	286	0.002

Figure (4) the cost of the hybrid system

From figure (4) , it is best use hybrid system (solar – wind) for three reasons :economically, the location of Arquit in high area which , and the speed of wind up to 4.5m/s [13].

This paper has considered the village-level electrification in Arquit village and analyzed the viability a solar mini-grid system for the Arquit village Sinkat locality, red sea state southwest to Port-Sudan city. The analysis the possibility of using solar minigrids

In Sudan around 37% of household houses connected to electricity national grid. While 66.4% of population they don`t have access to electricity , most of them in rural , whereas the rest are still depend on traditional source of electricity such as diesel generators

In Red Sea State 18.4% of household houses connected to electricity national grid, where 13.6% the source of electricity comes from diesel generators. solar minigrids have the potential of development of rural communities in Sudan such as north's Sudan and red sea . many studies shows that using solar mini-grid technology can yield solid returns for the investor and provide villages with inexpensive, reliable electricity.

Recommendation

To e encourage and developing solar energy project there are many important things must be done : land banks , the location , financial, and costs for the companies

We need to with NERC to identify villages and regions that would be suitable for mini-grid development Gathering data on the energy demand and load variances in each region

Developing a land bank for identifying land that is available for renewable energy development .

Because the location of Arquit in high area considered a mountainous area, altitudes 2200 meters above sea level, beside the speed of wind up to 4.5m/s (13) From the data there is a possibility to implement RE mini grid in this area because the source of wind; Strong wind regimes appear especially in the mountainous areas at the north eastern border of the country.

Acknowledgment

This research was supported by NERC. We are thankful the Director of NERC Prof. Sami Mohamed Sharif who provided financing support, insight and expertise that greatly assisted this research.

We have to express our appreciation to the Dr. Ratiba A. Agadir the Registrar of NERC for sharing their pearls of wisdom with us during this research and for the valuable guidance and advise her willingness to motivate us contributed tremendously to finish this research.

Finally, we would like to express our heartfelt thanks to Arquit community for their response, and friends who guided us and provided technical and moral support for the successful completion this research.

REFERENCES

[1] Meeting the Challenge of Rural Electrification in Developing Nations: The Experience of Successful Programs. Draft for discussion. Washington D.C.: World Bank, ESMAP. Barnes, Douglas. 2005

[2] User Financing via Micro finance Institutions (MFI) and Utility Bills.AEI Workshop June 2009.

[3] Workshop finding of household energy situation in Sudan February 28th 2013.

[4] Change (O. Edenhofer, R. Pichs-Madruga, Y.Sokona, K. Seyboth, P. Matschoss, S. Kadner, T. Zwickel, P. Eickemeier, G. Hansen, S. Schlömer,

C. vonStechow (Eds)).Cambridge University Press, Cambridge,United Kingdom and New York, NY, USA,.

[5] Intergovernmental Panel on Climate Change (IPCC) “IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation” 2011,1075 pp. (Chapter 9).

[6] National Renewable Energy Laboratory (NREL).“Renewable Electricity Futures Study.2012” Volume 1,pg. 210.

[7] Machol, Rizk “Economic value of U.S. fossil fuel electricity health impacts. Environment International”2013, 5.

[8] “Renewable Electricity Futures Study”2012

[9] The Solar Foundation, Solar Energy Industries Association (SEIA); “Solar Industry Data, National Solar Jobs Census 2011” 2011

[10] Navigant Consulting “Job Creation Opportunities in Hydropower.” 2009

[11] Geothermal Energy Association “Green Jobs through Geothermal Energy. Dan Jennejohn October 2010

[12] U.S. Solar Market Insight, Shayle Kann, , December 2015

[13] 5th Population and Housing Census in Sudan – An Incomplete Exercise A DRDC Report, February 2010

[14] Solar Adds 14.8 Gigawatts of Capacity in Record 2016, On Track to Triple in Size by 2022.

[15] Ministry of Electricity and Dams, “Wind Assessment Report”, 2012 .

[16] A multi-model assessment of last interglacial temperatures The Red Sea: The Formation, Morphology, Oceanography and Environment of a Young Ocean Basin ,**Rahul**, Najeeb M.A., **Stewart**, Ian C.F. (Eds.)

[17] Assessing the Potential for Renewable Energy on National Forest System Lands-agency of the United States government

[18] renewables – Made in Germany 2011 / 2012