Remedy of Chronic Darkness & Environmental effects in Yemen Electrification System using Sunny Design

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Received: 26.10.2016 Accepted: 15.12.2016

Abstract- In terms of Power systems the unstable situation in Yemen needs serious attention. Sometimes it leads to complete darkness and a nearly stops the basic services due to power outages in the country as well as political and financial problems experienced by the country nowadays. Even though Yemen is one of the richest countries in the world in renewable energy sources (solar energy), with over three thousand hours per year clean blue sky. Under the financial and political crisis, Yemen suffers from crisis of petroleum products, which required to generate electric power using diesel generators. This paper aims to provide renewable energy as a suitable solution as well as a clean and environmental friendly energy. It also aims to reduce the use of diesel-generators and presents the effective and efficient use of solar energy as alternative renewable energy for electrification of the necessary government facilities viz. important ministries' buildings, hospitals, schools and universities etc. This will lead to the promotion of health services, education and life-critical services even under the difficult conditions experienced by the country. This study has been used the Sunny Design Web App.

Keywords Yemen power sector, Hybrid Renewable energy, solar irradiation, electrification of Government facilities.

1. Introduction

Yemen is one of the least developed countries in the region. Located in the Arabian Peninsula between 13N–16N latitude and 43.2–53.2 longitude [1]. Yemen is characterized from the countries of the fastest growing population with a low per capita income rate, and low access to the electrical grid in the region. Political and financial problems Caused of the large shortage in the electric power, especially in the recent biennium 2015-2016 AD, and thus stopped most of the main electric generating stations from the service [2], which has led to the absence of the necessary government facilities, hospitals, schools, and universities not to mention residential buildings. It became thinking in finding solutions especially the needed to provide the necessary services for life and the continuation of work in the health sector as well as the educational wheel, has become an urgent necessity, and in the absence of petroleum products because of the crisis. Renewable energy (solar energy) is the best solutions on reality for several problems in multiple countries in general, and an appropriate solution to the problem in Yemen, as a standalone system or a hybrid [3]. For a country under siege and suffering from a severe power crisis, solar energy is considered as a perfect alternative energy source to solve an important part of this crisis, furthermore, the source is eco-friendly. In the last years from 2014 - 2016 AD solar energy systems have seen unprecedented developments in addition to lower price rate dramatically [5].

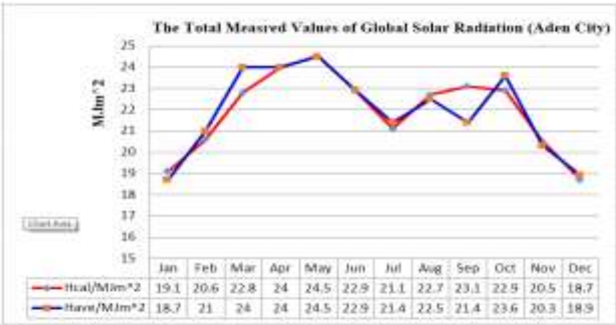

Fig. 1. The total measured of global solar radiation of Aden city

2. Motivation of Paper

To provide an analytical study of the economic feasibility and to find a solution to the chronic problems of the electric power as an example of Al-Wahdah hospital in Aden city [4]. And to produce minimal power for the continuation of minimum services at least, in the state of siege or in the case of the inability to control central stations of electric power generation which located in the scope of the problems.

3. Research Methods

In this paper, we have been used the Sunny Design Web Application[6] to calculate all the needs equipment and analysis the cost effective for the hospital project.

4. Contents of Basic Design

4.1. Calculate the Hospital load profile

Electrical capacity of the hospital building (building B) has been calculated according to the main loads which listed below and are detailed in Table 1. [2, 3].

- Block A (Main hospital ward; 7 storeys)
- Block B (Administration, out-patient clinic, X-ray; 2 storeys)
- Block F (Maintenance and operation section; one storey)
- Own load of the electrical room.

Distribution of the hospital loads according to the current consumption, which is approximately equal to 220 kW are shown in Table 1. [4].

Table 1. Load List of Hospital

Name	Cap. W	Qty.	Cons. kW	All Cons. kW	Operating Day/h
Light	80	200	16	80	8:00-13:00
Air Con.	2200	57	125	627	8:00-13:00
X-Ray1	38000	1	38	912	24h
X-Ray2	22800	1	22.8	527	24h
Fan	100	70	7	35	8:00-13:00
Refrig.	330	14	4.62	110	24h
Others	1320	4	5.28 4	26	8:00-13:00
Comp.	120	10	1.2	6	8:00-13:00
dental device	200	2	0.4	2	8:00-13:00
Amount			**220**		

In summary, electric power consumption in block B may increase to 600kW, 220kW represents the current consumption amount, 280 kWh depends on the renovation of block A plus CT scanner, and about 100kW due to the renewal of block B [2,3].

4.2. Define the load profile by using Sunny design web App

By using Sunny Design Web App, we can define our load profile here and optionally add specific loads. Fields marked with an asterisk (*) are mandatory[6]. The load can be assigned to different seasons as shown in Fig. 2.

Fig. 2. Determine the date of season in the Sunny Design Web App

After we have selected the breakdown of the seasons we must enter the daily consumption according to the load list of hospital in Table 1. and enter the average weekly profile by seasons as shown in Fig. 3. and Fig. 4 respectively [5, 6].

Fig. 3. The daily load profile

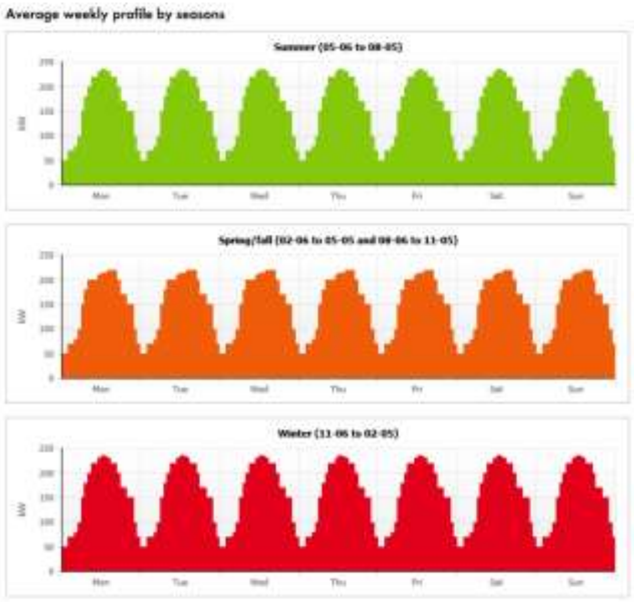

Fig. 4. Average weekly profile seasons

Table 2. Average seasonally profile

	Summer	Spring/ Fall	Winter
Min power requirement	50 kW	50 kW	50 kW
Max. power requirement	236 kW	236 kW	236 kW
Ave. daily requirement	3,771 kWh	3,771 kWh	3,771 kWh
Energy requirement	347 MWh	683 MWh	347 MWh

4.3. Configure the Gensets

According to the data that we have gotten [3, 7] about generator details, it's diesel generator and its capacity is 500KVA as shown in next details

4.4. Calculate the capacity of the PV system of Hybrid Renewable Energy

As we mentioned previously that the electricity from the public grid parked completely during the crisis experienced by the country. Therefore, electricity is generated in all the hospitals and some of the necessary government buildings currently by using diesel generators. Because of what we are seeing in the development of solar energy systems, as well as a decrease in its prices, this study has suggested using a grid off hybrid system. According to Table 1., which shows the capacity of the load in first stage of the hospital project, we have been adopted 250 kW as a capacity of solar power system. By using Sunny Design Web software[6], which there is a copy Online and Offline application can be downloaded on the computer .The entering data to the program begins by choosing the type of system (here we have been selected hybrid type system) and then steps of entering project data as follows:

- Enter Project Data
- Location
- Temperature Settings
- Profitability
- Electrical Connection of the Inverter
- Cable sizing
- Finally, Line Losses

The type of PV system designed is 1040 x .SMA SMA Demo Poly 240 (PV array 1) with Azimuth angle: 0 °, Tilt angle: 10 °, Mounting type: ground mount, peak power: 249.60 kWp and the PV design data is shown in Table 3. [6].

Table 3. PV Design Data

Name	Value
Total number of PV modules	1040
Peak power	249.60 kWp
Number of PV inverters	20
Nominal AC power of PV inverters	300.00 kW
AC active power	300.00 kW
Active power ratio	120.2 %
Max. available PV energy*	499.61 MWh
Energy usability factor	100 %
Spec. energy yield*	2002 kWh/kWp
Line losses (in % of PV energy)	----
Used PV energy	332.85 MWh
Used PV share	66.6 %
PV share of the energy supply (total)	24.2 %
PV share of the energy supply (during the day)	36.5 %

After defined the load, configure the PV and Generator [8–10], the public scheme of the hybrid system is shown in Fig. 5.

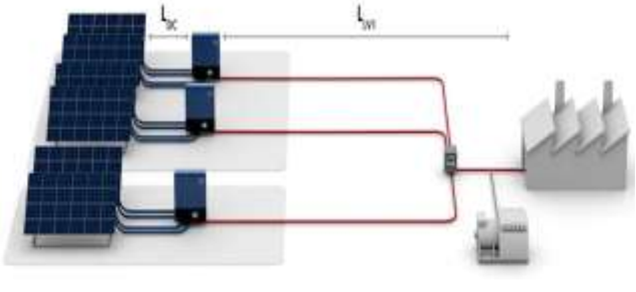

Fig. 5. Hybrid (PV/Diesel) power system structure

5. Details of Energy Supply

In this design, the hybrid system consists of three main components:

5.1. Diesel Generator (Genset)

Diesel generator that is configured by the amount of fuel consumption, efficiency and the capacity of the electricity produced compared to the amount of fuel consumed[12, 24] Fig.6.

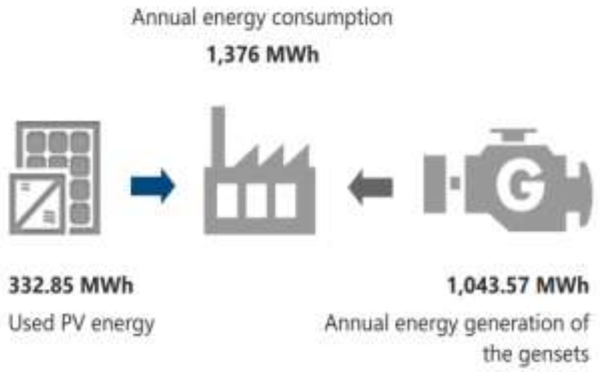

Fig. 6. Annual energy consumption & Annual energy generation

5.2. Photovoltaic (PV)

Solar energy is used as the base-load power source. The size of the PV cells matrix depends on several points[6, 8, 9]:

- Load profile.
- The renewable fraction in the hybrid system.
- Work hours
- The daily amount of solar radiation.

5.3. Inverters

The PV arrays produce direct current (DC) at a voltage that depends on the design and the solar radiation [10–12]. The DC power then drops to an inverter, which converts it into standard AC voltage. The inverter size is rated based on the selected PV size.

Table 4. Annual energy and fuel consumption

Name	Value
Annual energy consumption	1,376 MWh
Annual energy generation of the gensets	1,043.57 MWh
Fuel consumption per year (approx.)	426,055 L
Used PV energy	332.85 MWh
Annual fuel savings potential (approx.)	83,211 L
PV share of the energy supply (total)	24.2 %
PV share of the energy supply (during the day)	36.5 %

6. Energy Yield and Performance Ratio of PV Systems

For investors and operators alike, there are two fundamental questions: How much electricity does the system generate? And how well does the system perform [2, 9,13]?. The yearly sum of global irradiation, that hits the module is specific to the location and should be obtained from databases, measurements, or - in the first instance - from an irradiance map. It is measured in [kWh/m2]. The target yield is the theoretical annual energy production (on the DC side of the module), only taking into account the energy of incoming light and the module's nominal efficiency [18].

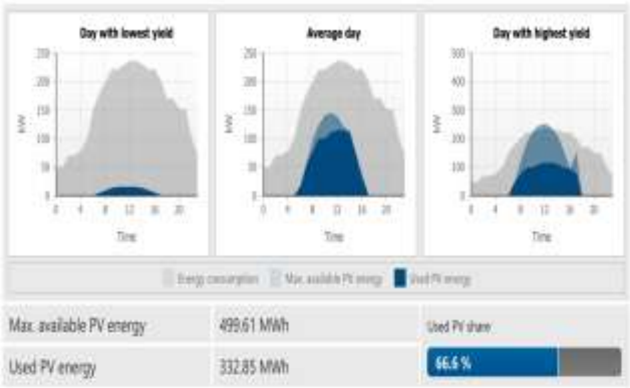

Fig. 7. Information on the PV yield

7. Details of Fuel and CO_2 Savings Potential

In addition to economic costs resulting from fuel consumption [16], there are other effects produced due to carbon dioxide emissions and the resulting climate change. Therefore, it was necessary to search for alternative energy working on diminishing the use of fuel and thus reducing global warming.

Table 5. Fuel/ CO_2 emission savings potential

Name	Value
Fuel savings potential per year	83,211 L
CO_2 emission savings potential per year	222 T
Relative fuel / CO_2 emission savings potential / year	16.3 %

The Fuel/ CO_2 emission savings potential per month [5, 7] is shown by Fig. 8.

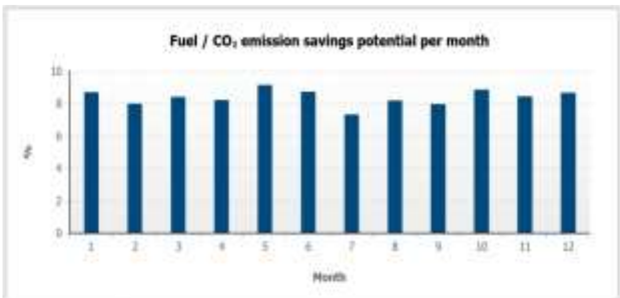

Fig. 8. Fuel/ CO_2 emission savings potential per month

8. Profitability of the Hybrid System

PV/diesel hybrid systems guarantee an efficient and continuous supply of energy by ensuring that both of the power generators (diesel and PV system) operate side by side.

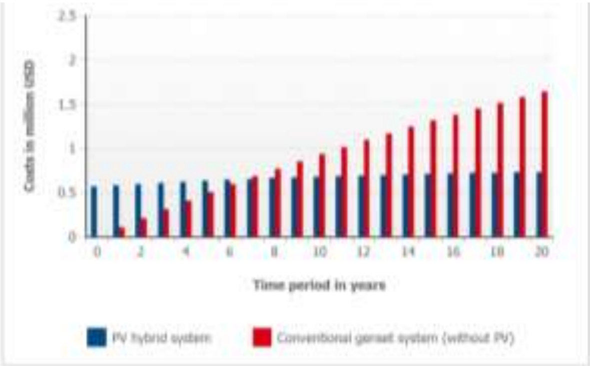

Fig. 9. Cost comparison (discounted cash flows)

By integrating photovoltaic in existing diesel systems, the use of fossil-fuels and therefore your costs- are greatly reduced [5, 6, 11]. Sunny Design Web App is using to evaluate the off-grid energy supply system by analyzing the load profiles while taking the Diesel Genset topology into consideration. It provides recommendations for optimizing the energy efficiency [9, 18, 19]. By simulate the impact of integrating a PV system with the goal of saving as much diesel as possible, while at the same time ensuring profitability on the investment in PV.

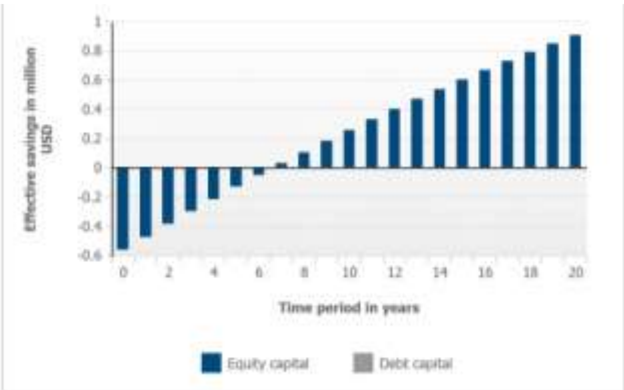

Fig. 10. Effective savings

Depending on the consumption profile it is possible to achieve > 30% diesel savings. The investment in PV-diesel-hybrid systems is highly profitable with amortization periods of less than 7 years as shown in Fig. 10. [5, 13].

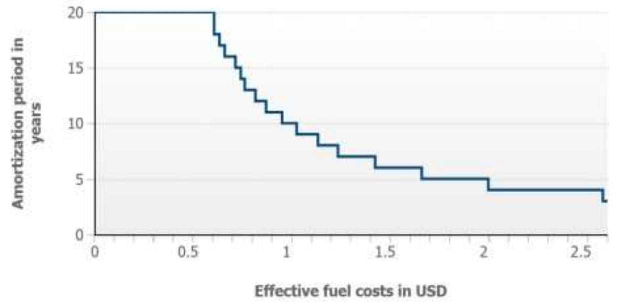

Fig. 11. Sensitivity analysis

The following tables detailed the PV/Diesel of costs and financing of the hybrid system[21, 22, 23].

Table 6. Costs of the PV system

Name	Value
Specific investment costs of the turnkey PV system (CapEx / kWp)	2250 USD/kWp
Inverter share of costs	10 %
OpEx PV/year as % of CapEx	3 %
Analysis period of profitability in years	20

Table 7. Financing of the PV system

Name	Value
Equity ratio of investment costs	100%
Annual interest rate	4.0 %
Credit period in years	10

Table 8. Gensets operating costs

Name	Value
Effective fuel costs	1.30 USD/L
Average energy efficiency	2.45 kWh/L
Energy generation costs (pure fuel costs)	0.53 USD/kW
Annual increase in fuel costs	5 %

Table 9. Discounting of future cash flows

Name	Value
Cash flow discount rate	8 %

Table 10. Investment costs

Name	Value
Investment costs of the turnkey PV system (CapEx)	561,600 USD
Expected amortization period in years (approx.)	7 Years
Net present value using discounted cash flow (approx.)	903,813 USD
Net present value using nominal cash flow (approx.)	2,857,182 USD

9. Conclusion

The Sunny Design Web software has simulated for four different system configurations, namely, PV Project, PV Project with self-consumption, PV Project without Grid connection and PV Hybrid project. The hybrid PV/diesel system using PV array size of 250kW gives 16.3 % fuel / CO_2 emission savings potential per year. The use of hybrid PV/diesel system will significantly reduce CO2 emission for environmental point of view.

The graphs in Fig.9 and Fig.10 explain that the cost of PV System is constant throughout until twenty years whereas the cost of Genset is initially very less and increasing from the seventh year of its operation. Therefore, it can be concluded that the PV cost will remain same and maintenance cost is increasing with time for Genset. Moreover, the maintenance and running cost is also high for the same period of time if Genset is utilized. The cost may go up to three times of the installation of a solar energy system whose estimated value is approximately $ 1.5 million. Therefore, it is recommended to use the PV systems for all applications.

In this paper, this has been presented in analytical study of the central hospital in the south of Yemen, and therefore it can be implemented on a similar project in the central hospital in the north of Yemen to deal with urgent medical conditions. It can also be applied to appropriate educational facilities and government buildings as well.

References

[1] M. H. Al-Buhairi, “Monthly and Seasonal Investigation of Wind Characteristics and Assessment of Wind Energy Potential in Al-Mokha, Yemen,” Energy Power Eng., vol. 4, no. 3, pp.125–131, 2012. (Article)

[2] M. Hadwan and A. Alkholidi, “Solar power energy solutions for Yemeni rural villages and desert communities,” Renew. Sustain. Energy Rev., vol. 57, no. January, pp. 838–849, 2016. (Article)

[3] F. Alkadasi, W. A. Climate,& K. Khoday, United Nations Development Programme “Prospects of Solar Energy in Yemen,” no. January, 2014. (Policy Note)

[4] C. Agency, Ministry of Planning and International Cooperation “Final Report of The Preparatory Survey on the Project for Japan International Cooperation Agency,” no. August, p. 229, 2010. (Report)

[5] Jamil Abdul-Aziz, , Abdo A-Nagi, , Abubaker A.R. Zumailan “Global solar radiation estimation from relative sunshine hours in Yemen”, Renewable Energy, Volume 3, October 1993 , Pages 645-653 (Article)

[6] “Sunny Design Web - SMA.” [Online]. Available: http://www.sunnydesignweb.com/sdweb/#/Home. (WebSite)

[7] M. A. M. Ramli, A. Hiendro, and H. Bouchekara, “Performance Analysis of Hybrid PV/Diesel Energy System in Western Region of Saudi Arabia,” Int. J. Photoenergy, vol. 2014, pp. 1–10, 2014. (Article)

[8] A. S. Rawea and M. Alwajeeh, “Al-wahdah Hospital - Aden City - Yemen Public Electricity Corporation Project,” pp. 1–8, 2016. (Studying)

[9] Alireza Rezvani , Maziar Izadbakhsh, Majid Gandomkar J. Electrical Systems 11-1 (2015): 11-26 “Enhancement of hybrid dynamic performance using ANFIS for fast varying solar radiation and fuzzy logic controller in high speeds wind” 2015. (Article)

[10] D. Arcos-Aviles, J. Pascual, L. Marroyo, P. Sanchis, and F. Guinjoan, “Fuzzy Logic-Based Energy Management System Design for Residential Grid-Connected Microgrids,” IEEE Trans. Smart Grid, vol. 3053, no. c, pp. 1–1, 2016. (Article)

[11] E. F. Camacho, T. Samad, M. Garcia-sanz, and I. Hiskens, “Control for Renewable Energy and Smart Grids,” 2011. (Article)

[12] “PV-diesel-hybrid systems save diesel and are highly profitable.” [Online]. Available: http://www.kraftwerk-rps.com/solution/pv-diesel-hybrid/. (WebSite)

[13] UNFCCC and CCNUCC, “Yemen Electricity Distribution Loss Reduction Programme Version: 05 (PoA-DD),” no. July 2011, pp. 1–66, 2012. (Policy Note)

[14] A. V. Anayochukwu, “Simulation of Photovoltaic / Diesel Hybrid Power Generation System with Energy Storage and Supervisory Control,” IJRER Journal vol. 3, no. 3, 2013. (Article)

[15] A. E.-S. a. Nafeh, “Design and Economic Analysis of a Stand-Alone PV System to Electrify a Remote Area Household in Egypt,” Open Renew. Energy J., vol. 2, no. 1, pp. 33–37, 2009. (Article)

[16] K. Manickavasagam, “Intelligent Energy Control Center for Distributed Generators Using Multi-Agent System,” {IEEE} {Trans}. {Power} {Syst}., vol. 30, no, vol. 30, no. 5, p. 18, 2014. (Article)

[17] E. C. Associates and P. Brinckerhoff, “Yemen : Models to Develop the Gas-to-Power Market Final Report,” no. February, 2010. (Power Report)

[18] “Import Energy Yield and Performance Ratio of Photovoltaic Systemscitations into your library using the Mendeley Web Importer | Mendeley.” [Online]. Available: http://www.greenrhinoenergy.com/solar/technologies/pv_energy_yield.php#. (WebSite)

[19] S. Njoya Motapon, L. A. Dessaint, and K. Al-Haddad, “A Comparative Study of Energy Management Schemes for a Fuel Cell Hybrid Emergency Power System of More Electric Aircraft,” Ind. Electron. IEEE Trans., vol. PP, no. 99, p. 1, 2013. (Article)

[20] P. Patel and J. Shrivastava, "Modelling & Performance Analysis of Hybrid Renewable Energy Resources Using Fuzzy Logic Controller," vol. 5, no. 5, 2016. (Article)

[21] Z. Girma, "Technical and economic assessment of solar PV/diesel Hybrid power system for rural school electrification in ethiopia," Int. J. Renew. Energy Res., vol. 3, no. 3, pp. 735–744, 2013. (Article)

[22] H. Suryoatmojo, A. A. Elbaset, F. A. Pamuji, D. C. Riawan, and M. Abdillah, "Optimal Sizing and Control Strategy of Hybrid PV-Diesel-Battery Systems for Isolated Island *," no. 1, pp. 1–6. (Article)

[23] https://cdm.unfccc.int/ProgrammeOfActivities/poa_db/1NM5O6Y38049SXHR7ZGUDWTJFKBPVE/view (Website).