Renewable Energy Solution for Electrical Power Sector in Yemen

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Abstract- Yemen is one of the least developed countries in the Middle East. Since more than 23 years, Republic of Yemen is going from darkness to darkness in the field of electricity power sector. It is considered as one of chronic problem in the country since 1990 up to now. The next 10 years Yemen meets a huge and serious problem in electrical power sector more than ever. Renewable Energy is considered as one of optimal solutions for power sector in Yemen which is called Solar, Wind and Geothermal energies. The objective of this work is to study and analyse existing status of power sector in Yemen and introduce the advantages of renewable energy resources. In depth study about solar and wind energy is presented in this paper. Renewable energy could enhance electrical grid system in Yemen and generate the green energy for Yemeni rural areas to serve: education sector, lightening homes, and medical clinics, etc. The importance of this paper is to illustrate the features of clean energy to enhance the power sector in Yemen and propose solutions to develop this sector.

Keywords Clean energy, Yemeni power sector, solar irradiation, solar and wind energies, electrification of rural areas, reduce the pollution.

1. Introduction

Yemen is situated between 13N-16N latitude and 43.2 – 53.2 longitude at the south west of Asia. Yemen is surrounded with the Red Sea from the west and by Arab Sea and Indian Ocean, from the south see Fig. 1. The country consists of three major zones: costal, rugged foothills and mountainous areas. Population is approximately 24.3 (UN, 2010), capital Sana'a, area approximately 536,869 sq. km, Yemeni's population is growing at an annual rate of 3.5%. Major language Arabic, and with a per capita of: US $1,494 per a year (World Bank, 2012), low level of electrification and infrastructure in general. In the power sector, Ministry of Electricity (ME) is responsible for the formulation of policies and plans of electricity development, including the control and licensing of private and industrial auto-generation. The Yemen Public Electricity Corporation (PEC), a semi-autonomous part of ME, is responsible of electricity generation, transmission and distribution through several grids [1, 2]. The Yemeni population has the lowest access to electricity in the region, with only 51.7% having access. Just a little number of the rural population are connected to the national grid system and have some access from other sources, typically a diesel generator that operates only a few hours in the evening.

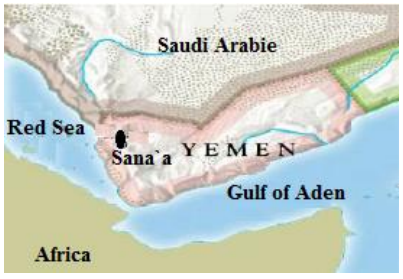

Fig. 1. Location of Yemen.

Several definitions of state are available in the literature, one of these definitions is given by Valadmir Olyanov: "state is a political regime plus electrification all the country". In our case study, the second part of this definition is eliminated or has been forgotten in Yemen for more than 33 years and experts can put here a big question mark (?). This study concluded that the majority of all generating power stations are outdated and exceeded the end of life long time ago. The result, Yemen is going in dark tunnel in power sector and still going up to the moment of writing this study. Renewable

energy technologies poses many long term benefits including energy security, job creation, business opportunities, sustainable development and prevention of global warming [3].

Applications of solar energy in Yemen have been slowly growing since 1975. However, effective utilization of solar energy in Yemen has not made reasonable progress yet mainly due to several barriers as high cost and, they have no idea about this clean energy. Sun energy is considered as one of the most renewable energy generated directly or indirectly from the sunshine. Yemen has 12 months of sunshine and the weather condition is suitable for solar energy. So, Yemen cans use this energy for lightening homes, water heating, solar cooling, education in the rural areas, telecoms stations in the mountainous areas and series of others applications. The main obstacle for solar power energy technology is that it is very expensive contrary to international market and unreachable for the most of Yemeni people. Recently, solar energy is used in some homes in the rural villages, in telecommunications, and TV transmission sectors. First installation of solar panels were in the middle of the 70's. In comparing alternative power generation technologies, the most important measure in the energy is the cost per kilowatt-hour delivered.

2. Background

Several types of power energy resources are available in our planet. Each resource has its advantages and disadvantages. Some resources are finite, unsuitable for environment pollutions and risky as nuclear one. Renewable energy introduces itself as green, clean, competitive energy compared to classical finite energy and of course cost-effective. Wind energy depends on wind velocity and its variation from time to time that means it is not constant energy.

Yemen has a great potential with its renewable energy resources especially solar and wind energy. The education sectors should educate and train students and people at schools and universities about clean energy. Non-existing data bank of renewable energy resources in most of the cases hinders the possibility of the utilization of this energy. Creation of renewable energy data bank helps energy analysts who are responsible for developing national programs on renewable energy utilization and users to reach decision that will prove most profitable under actual circumstances.

The technical and economic feasibility study of wind energy utilization in Yemen has not yet fully explored. Several studies were conducted to assess the potential of wind energy in the country. The wind map of Yemen as demonstrated in Fig. 4. Indicates that the state is characterized by the existence of three vast windy regions: along the Red Sea, Gulf of Eden and Indian coastal area, the third region is situated in the mountainous and some desert areas.

The average annual wind speed in sea coastal areas exceeds 16 to 19 kmph. The most suitable area for wind energy potential north-west of the road of Mocha in an area that covers about 300 km^2. This region alone in Yemen could produce 2 GW of clean power. Analysis of data from monitoring stations in the Mocha shows that the average annual wind speed is 7.4 m/s. This area also has other advantages that make it eligible for wind farms. It is an open area without obstacles and there are transport links close by. Yemeni Island of Socotra enjoys high wind speed in the range of 5-12 m/s and monthly; daily solar irradiation ranges from 8–18 MJ/m^2. With the average monthly daily irradiation is between 4 to 5 kWh/m^2 which are considered as high potential for renewable energy applications.

3. PVA Modeling

PV arrays are built up with combined series/parallel combination of PV solar cells, which are usually represented by a simplified equivalent circuit model such as the one given in Fig. 2 and/or by an equation as in (1) [4].

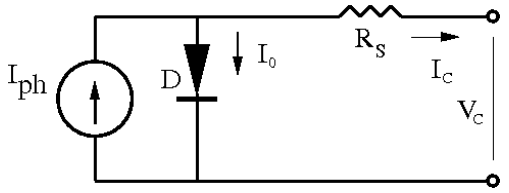

Fig. 2. Simplified-equivalent circuit of photovoltaic cell.

The PV cell output voltage is a function of the photocurrent that mainly determined by load current depending on the solar irradiation level during the operation [4].

$$V_C = \frac{AkT_c}{e} ln\left(\frac{I_{ph} + I_0 - I_C}{I_0}\right) - R_s I_C \quad (1)$$

Where the symbols are defined as follows:

e: electron charge (1.602 * 10-19 Coulombs).

A: curve-fitting constant.

k: Boltzmann constant, (1.38 * 10-23 J/°K).

I: cell output current, A.

Iph: photocurrent, function of irradiation level and junction temperature (5 A).

I0: reverse saturation current of diode (0.0002 A).

Rs: series resistance of cell (0.001 Ω).

Tc: reference cell operating temperature (20 °C).

Vc: cell output voltage, V.

Both k and Tc should have the same temperature unit, either Kelvin or Celsius. The curve fitting factor A is used to adjust the I-V characteristics of the cell obtained from (2) to the actual characteristics obtained by testing. Eq. (1) gives the voltage of a single solar cell which is then multiplied by the number of the cells connected in series to calculate the full array voltage.

Solar power impinging on a normal surface on one bright day with AM1.5 is about 1000 W/m2 is about 1000

W/m2, and it would be lower on a cloudy day. The 500 W/m2 solar intensity is another reference condition the industry uses to report I-V curves.

In PV power, this cost primarily depends on two parameters: the PV energy conversion efficiency and the capital cost per watt capacity. Together, these two parameters indicate the economic competitiveness of the PV electricity. The conversion efficiency of the PV cell is defined, as in Eq. (2) [5-6]:

$$\eta = \frac{electrical\ power\ output}{solar\ power\ impinging\ on\ the\ cell} \quad (2)$$

The objective of this research is to take into account that the renewable energy resources namely wind and solar energies in Yemen as a very good alternative choice to support national grid system and to improve electricity access of rural populations. Yemen is characterized by mountainous areas zones it's higher more than 3600 m Over Sea Level (OSL) and has a long coastline approximately of 2500 Km. In addition, Yemen enjoys high level of solar irradiation and large desert where temperatures exceed 47C° [7] as showing in Fig. 3 [8]. This figure shows the distribution of solar energy at the earth`s surface. Globally, 6500 TW of solar energy are available over the world`s land plus ocean surface if all sunlight is used to power photovoltaic [8]. Readers can remark in this map that Yemeni land is considered as rich of solar irradiation.

Surface downward solar irradiation (W/m2) (global avg: 193; land: 183)

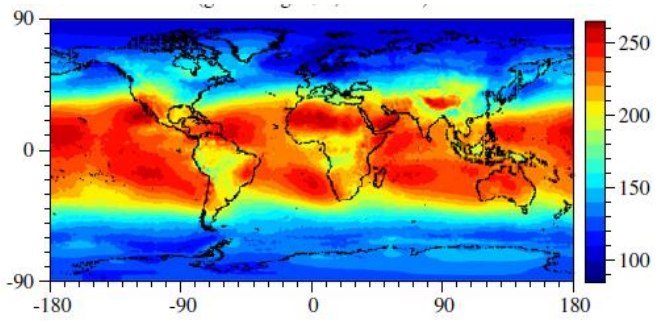

Fig. 3. Map of the yearly averaged downward surface solar irradiation reaching the surface (W/m2) at 1.5 × 1.5° resolution, generated with the GATOR-GCMOM 3-D global model. (Image courtesy of Mark Z. Jacobson).

That means Yemen is one of the regions in the world that has high levels of solar irradiation. All those encouraged indications have motivated us to go-ahead for study seriously renewable energy in this country.

4. Existing Electrical Energy in Yemen

The energy sent to distribution network has reached 6513.1 GWh in December 2012. However the energy sold is 4165.9 GWh, while the total loss ratio in transmitted energy in the same period reached of 36 % [2] as presented in Table 1. That means the total loss ratio of transmitted and distributed energy in national network is so high and unacceptable. The ministry of electricity in Yemen should be finding an solution to avoid this huge loss in energy in distribution network.

5. Related works

Renewable energy is considered as future energy. Several countries had started to use this energy long time ago or thinking about using these green energy resources. Power energy sector in Yemen needs to concentrate on renewable energy because this country has a lot of encouraging resources of this energy. Although some work has been done toward studying and using renewable energy in Yemen, most researches are reported as demonstrated in [1, 7, 9, 10] for example the study developed by Ali M. Alashwal on renewable energy applications in Yemen as in [1]. The author introduces the energy profile in Yemen: oil, gas, wind, and PV applications, and geothermal energy. This paper is concentrating on existing applications of renewable energy technologies. P.V. is used as a power source for different purposes: telecom, TV transmission, water pumping, electrification of rural houses and some other, e.g. clinics, boarding, houses, etc. Solar heaters were introduced in this work.

Abdulah H. Algifri on wind energy potential in Aden-Yemen as in [7], the wind energy resource is very large and widely distributed throughout the world as well as in Aden.Yemen possesses a very good potential of wind energy. In this article number of year's data on wind speed in Aden has been studied and presented. Statistical analysis were carried out from which the annual wind speed was found to be 4.5 m/s and most of the time the wind speed is in the range of 3.5–7.5 m/s.

In the paper of Abdo A. Almakaleh [9] a study deals with monthly design values of solar energy for each month and site is presented for different collectors configurations. These designed values will enable the design to concentrate the efforts to achieve good social and economic benefits and to promote the utilization of solar energy in Yemen. Finally we quote the study developed by Faher Hayati and Abdulsalam Alkholidi as in [10] on utilization of solar power energy in telecom and TV transmission sectors. This study illustrates the exploitation of PV energy in transmission stations in radio relay link line of sight in the mountainous areas and rural telecommunications where grid system is unavailable and so tough to install generators for a couple of reasons: the first one is the road to these transmission stations doesn't exist in some locations. The second reason, the stations are in highlands and difficult to transport the diesel and repair if there is a failure. So, PV energy is a good alternative choice in highlands areas. Readers who are interested in the solar energy in Yemen should consult the references sited in [9].

Table 1. Electrical energy loss in distribution network in Yemen from 2006 to 2012

Year	The energy sent to distribution Net (GWh)	Energy sold (GWh)	Energy lossed in distribution network (%)
2006	4838.6	3624.42	25.2
2007	5640.7	4088.73	26.2
2008	6074.7	4497.74	25.9
2009	6280.7	4644.00	26.1
2010	7091.7	5036.18	28.9
2011	5664.2	4078.5	28.0
2012	6513.1	4165.9	36
Source: Ministry of electricity			

6. Green Energy Can Save Yemen

After having studied and analyzed the total availability of electricity sector in Yemen. The data presented about existing power sector is absolutely not encouraging. As we mentioned above, currently all energy generated in national grid system in Yemen is nonrenewable resource supply. Indeed, several solutions are proposed to solve the chronic problem of power sector and to meet the increasing demand of energy. Last decade we have heard a lot of projects in the Yemeni local media to setup renewable energy projects but until now nothing has implemented. This work proposes several solutions to utilize renewable energy to enhance and develop Yemeni power sector as follow:

1. Geothermal energy refers to the energy deep within the earth, but it needs huge investment while Yemen is poor country. This source is an infinite energy resource but could be used in volcano regions and setting up could be expensive. According to a study completed in 1980s, some Dhamar governorate region as Al-lissi Mountain and Hamam Ali could produce 125 – 250 MW of geothermal energy.
2. Electricity energy generated by gas but the majority of this gas available in the country has been bought for famous international oil company by 3.2$/Cu M, while the price in the world market is about 15$/Cu M (chronic corruption in the country).
3. Generate the power energy using Coal but the last is not available in Yemen and the ministry of electricity should buy it from international market. This energy is not friendly to the environment. An available cheap source of energy, but for least developed countries environmental impact has less priority in economic development.
4. Generate the electricity energy by using renewable energy resources as wind and solar power energies.

The benefits of using renewable electricity are reduction in emission, reduction in energy loss, reduction in power lines and equipment, lower capital cost as lower capacity equipment can be used (such as transformer capacity reduction of 50 kW per MW installed) [5]. Yemen is rich in renewable resources, such as wind, solar and geothermal resources. That means that large power generation projects can be developed in the country, as well as decentralized systems to meet the needs of energy in rural and remote communities. Today's, renewable energy is rapidly developing technology. As a matter of the fact, in this work we will pay attention on solar and wind energies as solution for Yemeni power sector for several reasons:

a) It is an infinite and green energy resource.
b) The **72%** of the Yemeni population living in rural areas where national grid system is unavailable in the majority of villages, only 23% have any access to electricity, about 10%–14% is connected to the national grid system while the remainder is estimated to have some access from other sources, typically a diesel generator or few of population are used some solar panels, but so limit because this technology is still so expensive for those who live in Yemeni rural areas.
c) Yemen has one of the world's highest levels of solar irradiation. Higher solar irradiation availability during all the year months.
d) Yemen has a long coastline and high altitudes arrive of 3677 m ASL which make it a perfect place for generating energy from wind, with an estimated 4.1 hours of full-load wind a day. Wind map in Yemen as demonstrated in Fig. 4 shows that the wind energy, which can be converted into mechanical and electrical energy. It could be a very good alternative to support the electricity power sector. Note that, this energy is unpredictable, energy source.

In the following subsections, we will study and analyze solar and wind energy resources in Yemen as very serious solutions for least power sector.

6.1. Solar Energy

Let us start this subsection with this famous proverb "the sun is God gift, so let's use it". Solar cells, also called photovoltaic (PV) power technology uses semiconductor cells (wafers), convert sunlight directly into electricity. PV gets its name from the process of converting light (photons) to electricity (voltage), which is called the PV effect. Today, PV widely used namely, in house lightening, heating and in telecommunications and TV transmission sectors, etc. The annual average of daily sunshine hours is between 7.3 and 9.1 hours/day [9]. Even in winter time the solar irradiation is very high. The prospect of solar energy in Yemen is very bright where the average solar irradiation is 18-26 MJ/m^2 - day with over 3000 hours per year clear blue sky [11, 12]. The majority of Yemeni people are living in remote and mountainous areas where they are interesting to use solar power energy. The strength of the solar irradiation and sun-shining in Yemen is expected to be the highest category of the world, while the weather practically, divided into two seasons in most areas of the country: spring and summer.

The maximum and minimum temperature measured in Yemen [13, 14] for all year months are presented in Table 2.

Table 2. Average maximum and minimum temperature for winter and summer in C°.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Max	25.3	25.9	28.5	27.2	29.8	31.6	30.1	30.3	28.8	25.7	23.9	24.1
Min	6.2	9.6	11.1	11.0	11.9	14.1	14.8	15.2	13.4	7.2	3.4	2.0

The previous table shows that the average temperature during all the year months is high even in December (24.1 C°) and January (25.3). According to presented in Table 3, we can generate the solar power energy during the year to supply a lot of rural zones in solar energy and keep the rural areas clean and calm. The following Table 3 shows the trend and patterns of solar irradiation in Yemen, for more data of solar irradiations in two cities in Yemen refer to [9]. This high of solar irradiation level lead to the conclusion that the north part of the country will be an ideal region for applications of solar energy in Yemen.

For more details information about solar irradiation in Yemen, we invite the readers to refer to reference (9). In conclusion, study shows that Yemen is one of the ideal places for the applications of solar power energy.

Table 3. Solar irradiation in governorates (Taiz, and Seiyun).

Station	Taiz	Solar Irradiation		City: Seiyun	Solar Irradiation	
Latitude(N^o)	14.75	Global	Extraterrestrial	Lat. 15.98	Global	Extraterrestrial
Month	Design Day	MJ/m^2	kWh/m^2	Design Day	MJ/m^2	kWh/m^2
January	17	17.24	8.45	17	17.33	8.12
February	47	19.16	9.31	47	17.92	9.06
March	75	22.13	10.12	75	19.34	9.98
April	105	20.78	10.61	105	22.86	10.61
May	135	21.82	10.68	135	23.45	10.80
June	162	20.05	10.61	162	20.94	10.78
July	198	17.88	10.60	198	20.31	10.74
August	228	19.27	10.57	228	19.51	19.51
September	258	18.05	10.24	258	20.64	20.64
October	288	22.37	9.51	288	19.64	19.64
November	318	20.24	8.63	318	17.63	17.63
December	344	17.26	8.15	344	15.74	15.74

6.2. Wind energy

Wind energy has become the least expensive source of new electric power that is also compatible with environment preservation programs. Many countries promote wind power technology by means of national programs and market incentives [5]. Wind power is developing rapidly in global level especially in developed countries namely in Austria, Japan, Germany, Norway, Netherland, Canada, USA, UK and Spain. But, this green energy resource doesn't see the light in Yemen until nowadays. The generous areas of wind zones in Yemen are located on sea breezes and in mountain valley-wind. According to Fig. 4 [13], Yemen has a long coastal strip of over than 2500 km with a width of 30-60 km along. Average annual wind speeds (measures at 10 *m* height) exceed 8 *m/s* at most of the coastal sites. There is a good potential for wind energy potential at sites on the coastal strip, in addition to the offshore area. There is also great wind energy on Yemeni islands and inland hills and mountains areas [11].

Fortunately, the availability of meteorological data about the wind velocity for all the year's months is presented in Table 5 for three big cities in Yemen (Sana'a, Aden and Taiz) obtained from Civil Aviation and Meteorology Authority (CAMA) [12,14]. From wind resource map in Yemen that contains enough data about the wind velocity in various regions in the country. So, this work cans depict a good point of view of wind energy resources in the Yemen.

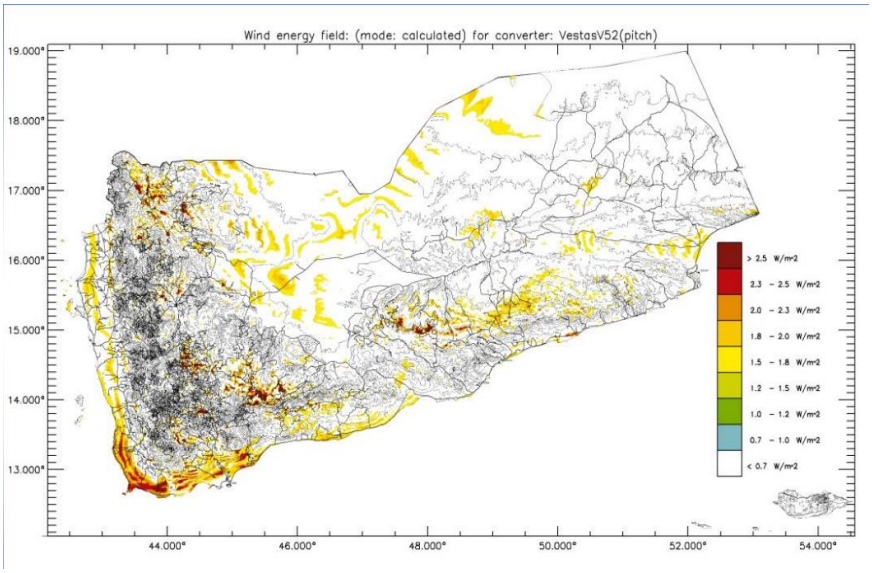

Fig. 4. Wind resource map in the Republic of Yemen.

Table 4. The data of wind velocity (km/hr) obtained from (CAMA) for Year 2003.

Wind Velocity (km/hr)	Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
	Sana`a	15. 6	17.4	15.2	15.2	14.8	16.1	17.6	16.5	18.9	16.9	16.3	14.8
	Aden	20.6	18.5	20.9	20	13.3	18.3	21.3	20.5	14.6	16.7	20	19.1
	Taiz	12.4	14.6	16.1	17.2	17.0	18.3	21.7	17	17	14.4	14.4	13

Table 5. Economical potential of wind energy resources in Yemen.

Wind Energy	Governorate	Economic Potential (MW)
Coastal areas: Taiz, Hodeidah, Lahej and Eden.	Taiz	5125
	Hodeidah	5094
	Lahej	2540
	Eden	475
Highlands: Ayban Mountain and Dhamar	Ayban Mountain	4813
	Dhamar	1152
Estimated total generated energy from wind farms in Yemen		**19199 MW**

Table 4 introduces the wind velocity km/hr during all year's months in three big cities in Yemen. You can observe that the maximum wind velocity in the capital Sana'a during the month of September exceeds 18.9 km/hr and the minimum wind velocity in the same city reaches 14.8 km/hr in May and December. In Aden, the maximum wind velocity recorded in July was 21.3 km/hr and in March 21 km/hr. The minimum wind velocity in the same city reached to 13.3 km/hr during the month of May. Taiz city is considered as one of the richest areas in Yemen concerning the wind velocity namely in Mocha coastal areas and Arrous Mountain which surround the city of Taiz. The maximum wind can exceed 21.7 km/hr in July and the minimum wind velocity is in December. Practically, wind energy application experienced in Yemen is not in existence, where the PEC is planning to implement wind farm in governorate of Taiz (Lat: 13.7° N, Lon: 44.1° E, and Elev.: 1385 m), about 100 km from this big city. This area is called Al Mocha situated on the Red sea coastal area. It shows that the average annual wind speed of 7.4 m/s. This project is estimated to product 65 MW of wind energy to enhance a national grid system. PEC had installed an experimental wind turbine in this position. Until now, it is difficult to estimate when wind energy project will be completed, and operated.

6.3. Analysis and Outcomes of this Study about Wind Energy

After long time study of wind energy resources in Yemen, the study confirms that this type of energy is available in different areas of the country. The highly promising locations of this energy resource are situated in good locations wherever the high voltage transmission line are already installed as in the Mocha, Ayban Mountain, Aden Coast, Lahej, Hodeida and Dhamar. Table 6 shows the economic potential of wind energy resources for different governorates in Yemen [15].

Table 5 illustrates that the wind energy resources in Yemen is very promising to be used and PEC should think seriously to invest at this clean energy resources. According to ministry of electricity in March 2012, theoretically Yemen could generate 17000 to 19000 MW of wind energy. That means not only Yemen will be rich in electricity but it will have the ability to export it to the neighbors. In fact, to arrive to this number of energy generation cited above PEC should open the electricity power sector market to the investors not only in Yemen but for international level. This study recommended PEC to put a short term plan to generate

electrical energy from wind farms during three to five years to generate 2000 MW to avoid *catastrophe situation* in electrical power sector in Yemen in 2 years by the end of 2015.

7. Sound Levels for Different Observed Locations

The wind power systems components are: the wind power system comprises one or more wind turbine units operating electrically in parallel. Each turbine is made of the following basic components: Tower structure, rotor with two or three blades attached to the hub, shaft with mechanical gear, electrical generator, Yaw mechanism such as the tail vane, sensors and control [5]. Yemeni main cities are characterized by availability of highest mountains or located near the sea coast for example as Sana'a is characterized by Ayban Mountain about 2900 m ASL, Nokom Mountain, and series of other mountains. Taiz is characterized by Arrous Mountain about 3000 *m* ASL and series of other mountains. Eden is characterized by Shamssan Mountain and the majority of Yemeni cities are surrounded by the highlands as Mokalla, Ibe, Hajah, Dhamar, and Dhalea. So, we are interested in calculating turbine sound levels to avoid the noise which is generated by wind farms. According to American Wind Energy Association (AWEA) literature [16].

The AWEA rated sound level is calculated at a distance of 60 meters from the rotor hub and excludes any contribution of background sound. As the distance from the turbine increases, the background sound becomes more dominant in determining the overall sound level (turbine plus background). Background sound levels depend greatly on the location and presence of roads, trees, and other sound sources. Typical background sound levels range from 35 dBA (quiet) to 50 dBA (urban setting). Equation (3) can be used to calculate the contribution of the turbine to the overall sound level using the AWEA rated sound level. Equation (4) can be used to add the turbine sound level to the background sound level to obtain the overall sound level [16].

$$Turbine\ sound\ level = L_{AWEA} + 10\log(4\pi 60^2)\ 10\log(4\pi R^2) \quad (3)$$

Where:

L_{AWEA} is the AWEA rated sound level in (dB).

R is the observer distance from the turbine rotor center (m).

$$Overal\ sound\ level = 10log\left(10^{\frac{Turbine\ level}{10}} + 10^{\frac{Background\ level}{10}}\right) \quad (4)$$

Table 6. Overall sound levels at different locations for an AWEA rated sound level of 40 dBA.

Distance from rotor center (*m*)	L_{AWEA} = *40 dBA*				
	Background noise level (dBA):				
	30	35	40	45	50
10	55.6	55.6	55.7	55.9	56.6
30	46.1	46.4	47.0	48.6	51.5
50	41.9	42.4	43.9	46.6	50.6
70	39.2	40.2	42.4	45.9	50.3
100	36.6	38.3	41.3	45.5	50.2
150	34.1	36.8	40.6	45.2	50.1
200	32.8	36.1	40.4	45.1	50.0

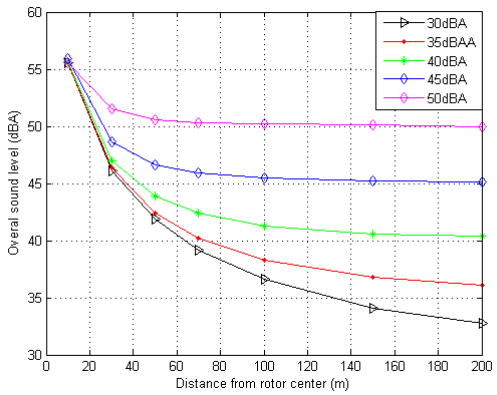

Fig. 5. Overall sound levels at different locations for an AWEA rated sound level of 40 dBA presented in Table 6.

The consequences presented in the previous Table 6 and Fig. 5 illustrate the overall sound level at different locations 10, 30, 50, 70, 100, 150, 200 meters distance from rotor center respectively. These results show that the sound level decreases when the distance increases from the rotor center.

8. Analysis

According to the World Bank, Yemen has the lowest level of electricity connection in the Middle East, with only 40% of the population having access to electricity. Rural areas are particularly badly affected. Industrial concerns, hospitals and hotels have their own back-up generators. Yemen's electricity infrastructure is outdated and insufficient to meet the country's needs [17]. Yemen's difficult security environment complicates the exploration, production, and transport of energy from generating power plants to electrical substations. The government should develop a renewable energy sector in different areas in Yemen to minimize the gap in energy production. The energy lossed in distribution network is reach of 36% in 2013. According to PEC engineers the losses in energy in distribution network (Region IV) in Sana`a on 20 October 2013 is reached of 40%. That means Yemen is considered as the first country in the world in energy loss. Annually in the rural areas, Yemen is losing the forest cover because people need to cut the trees for firewood and heating. So, a

lot of square meters of soil are lost every day. Renewable energy generation can help protecting forests loss. Finally, we note that the utility of solar energy in the rural areas in Yemen where the average solar irradiation is 450-550 cal/cm2 is more economically than wind energy. Because the rural houses are located in remote areas where it is economically justified to use solar energy rather than other sources of electricity.

9. Conclusion

This article provided a brief introduction to the Yemeni profile and background. Further the availability of electrical energy sector in the Republic of Yemen was presented. Chronic problem of Yemeni electrical power sector is illustrated. In addition, the potential of renewable energy resources in Yemen were presented namely: solar and wind energy. According to wind map and data cited in this work shows that Yemen is one of the richest countries in the world concerning solar irradiation and wind speeds availability, where all the regions in the country are characterized by availability of these two interesting resources. The number of irradiation and wind data collection is limited due to soothe difficulty to obtain this data for three reasons: unavailability of data bank about solar and wind resources, weakness of cooperation with researchers from academic establishments, and economic reasons where this work is individually researched without any sponsoring. Finally the priority to develop the wind energy according to the Yemeni wind atlas and wind map as presented in Fig. 4 are: Taiz, Hodaydah, Abyan, Lahj, Dhamar mountainous area, and Aden.

10. Recommendations for Government and Investors

1. Clean government sector from chronic corruption.
2. Reform energy sector.
3. Put short and long term plans to develop power sector according to scientific study.
4. Encourage the investment in the country and remove all the barriers.
5. Ensure least cost supply option.
6. Eliminate or reduce taxes of solar energy technology.
7. Development, implementation and expansion of the rural electrification program using solar energy resources.
8. Create special association to help the Yemeni people use renewable energy.
9. Encourage Wind-PV hybrid systems in rural areas.
10. Attract international agencies (lenders and donors) to invest in PV technologies for rural electrification.
11. Transform of energy from renewable energy system to grid.
12. Adapt a serious step to manufacture locally of solar components.
13. Advertise on TV and public media in general about importance of utilization solar and wind energy resources.
14. Encourage engineers to work in field of solar energy by initialize mega and pioneer projects supported from the government.
15. Support and finance the research field studies and cooperates with Yemeni Universities.
16. Support investors and people who already have installed solar systems and back them up.

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