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Feasibility Study of Solar Energy Integration for Electricity Production in Kuwait

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***Abstract*— This paper introduces a feasibility study for integrating green energy to produce electricity in Kuwait. Solar energy is a great choice for Kuwait because of its location and desert weather that guarantee a high solar radiation level. The study focused on the usage of solar energy within a grid connected system, with two examples of houses and parking lots. The proposed feasibility study was applied on 300,000 houses and 23,000 parking areas as a first phase, it showed how Kuwait can financially benefit from using such green energy besides its positive impact on Kuwait environment by decreasing the global warming. A second phase would be considering a grid connected system to guarantee high reliability and cover more applications.**

***Index Terms*—Solar Energy, Electricity Generation, Green Energy, Feasibility Study**

I. INTRODUCTION

Since many years, oil and gas have become the main energy recourses to produce electricity in Kuwait. These resources have many disadvantages toward environment and human health in addition to their depletion. There are severe side effects from burning oil, and one of these effects is that it releases gases such as CO_2, NOx….etc Therefore, Kuwait signed on a convention including other countries aiming to reduce the global warming and greenhouse effect. Kuwait can get advantage from its long sunny day, nine months' summer period in using solar energy, Fig (1) shows sun radiation level all over the year in Kuwait [1]. In the meantime, there are couple of small solar energy projects in Kuwait including round 4000 solar panels on different governmental buildings with 100 Kw capacity per building, another project is using the roof of two schools in producing round 350 MW of electricity using solar panels that are being distributed on a 1000 m^2 area.

So far the hugest solar energy project in Kuwait is still running with a total investment of 7.5 billion US $ and an expected production of 2000 MW [2], this project should be considered as a step towards relying on renewable energy sources in producing electricity following other developed countries that rely on different renewable sources [3] to meet their increasing needs of electricity

This research paper will propose a feasibility study for solar energy usage in Kuwait according to the collected data. The study aims on finding and proposing a way that shows how Kuwait can use the solar energy source efficiently to produce electricity, reducing by that its dependence on oil and gas. The study is divided into two main parts: the first part is concerned by implementing a standalone system for residential loads, one typical Kuwait house was used as a model and the study extended to include 12000 houses, for a period of 25 years, taking into consideration that each year there are 12000 new houses.

In the second part of the study more standalone system is introduced to be implemented in parking areas, where the implementation of a solar system in these areas in terms of cost, electricity production and CO2 emission is studied.

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II. PROBLEM STATEMENT

Electricity production in Kuwait is increasing rapidly, the price of one Kw is 0.045~0.06 Kuwaiti Dinar (KD), the Kuwait government is paying 3 billion KD yearly to financially support people living in Kuwait by 95 % of both Electricity and water costs [4]. This project aims at satisfying three main issues. The first one is related to the strategic decision that was stated by his highness Sheikh Subah AlAhmad AlSubah aims to fulfill 2% of the nation's supply by the end of 2015 and 15% of the nation's supply by 2030 [5]. The second issue is related to the GCC objective to reduce CO2 emissions which have been increasing rapidly in the last years as seen by Fig. (2) [6]. The final issue is directly related to the decreasing level of oil reserve in the world in general and in Kuwait specifically, and the increasing consumption of these natural resources each year, without forgetting their negative impact on the environment.

A. Methodology

The applied methodology was defined based on 8 steps as shown in Fig. (3), where literature review covered Kuwait electricity production based on non-renewable sources, as well as case studies for solar energy production [7, 8]. In the fourth step, real, technical, financial and metrological data are collected. Full analysis is done in the fifth step to help developing the framework and proper methodology of implementing the solar panels to houses rooftops and parking lots. Finally, the proposed methodology was evaluated taking into consideration several factors including cost of producing 1 KWh, number of oil barrel burned, and carbon dioxide emissions.

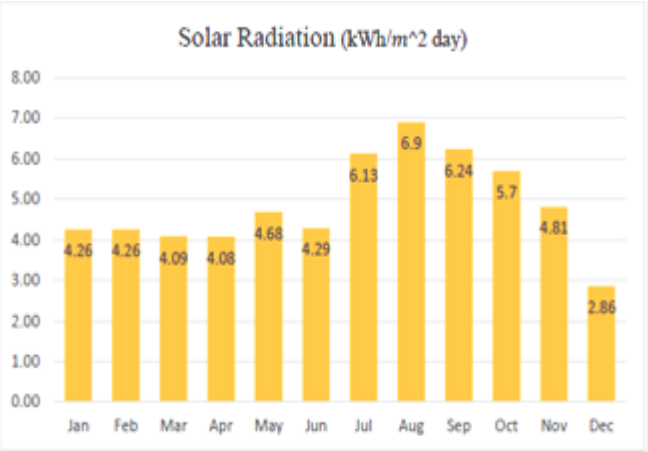

Fig. (1) Solar Radiation in Kuwait

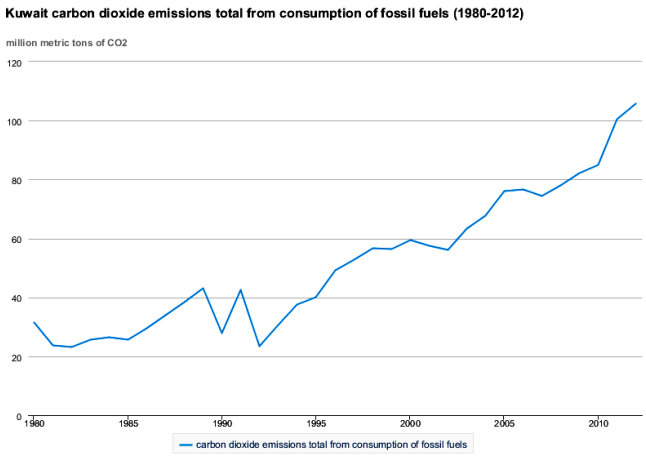

Fig. (2) CO2 emissions levels in Kuwait

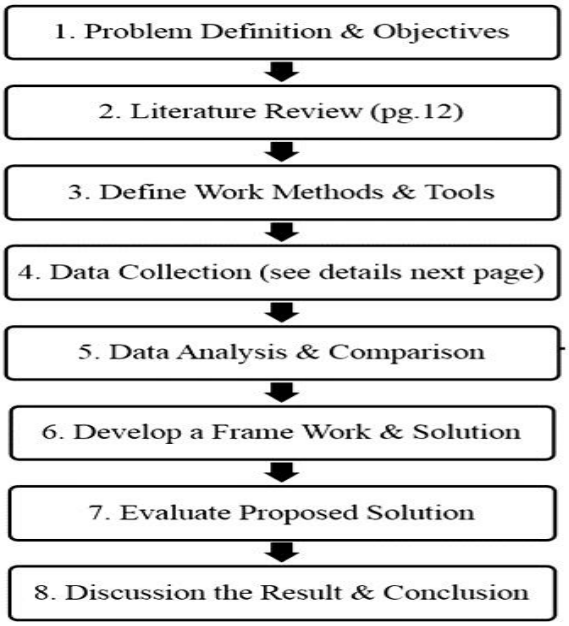

Fig. (3) Methodology flow

III. CASE STUDY

A. *Case Study of 1 House*

The implementation of solar panels within a grid connected system is being studied, a house rooftop with a maximum space of 150 m^2 will be used for solar panels mounting. This solar system insures 24% of local consumption of the house. Photovoltaic (PV) array, inverter, breakers, meters are all being used to guarantee reliable load feeding as shown in Fig. (4). PV panels absorb sunrays and generate DC electrical power. DC power is not suitable for most of the households, so an inverter is used to convert it into AC power taking into consideration the working frequency of the main electrical grid. In case the PV system is generating extra power than the house can utilize, the surplus is sent out over the grid to supply other loads. However, if the PV generated power is not sufficient then the needed power is drawn from the grid as usual and that can be computed via a two way electrical energy meter [9].

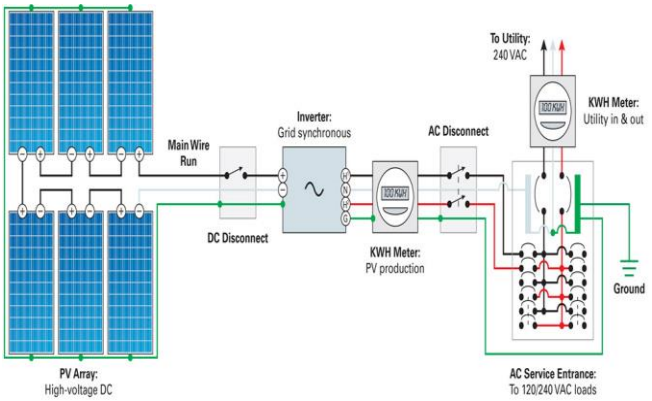

Fig. (4) – Proposed PV system

Table-1- shows the needed data for each of the proposed PV system components. The cost of implementing this solar system for the whole 150 m^2 is 21,375 KD, including the cost of 60 panels, installation cost, inverter cost, mounts, racks, wiring, and maintenance

With a peak output of 15 Kw, and considering 40 % of the PV working hours with almost ideal conditions regarding sun, dust and rain the implemented system is supposed to generate a sum of 52560 kWh yearly. Table-2- shows the detailed cost for the PV system for one house in KD, taking into consideration that the shown prices were provided by the end of 2015

TABLE-1
SOLAR SYSTEM COMPONENTS AND COSTS

	Main Needed Data
Panels Type	Photovoltaic
Panels Brand Company	DM Solar
Panels Efficiency	14%
Panels Size	2.5 m^2
1 Panel Cost	75 KD
Panels Installation Cost	150 KD
Inverter Brand Company	Solectron Renewables
Inverter Cost	38 KD
Mounts, Racks and Wiring Cost	85 KD
Maintenance per Year	30 KD

TABLE -2-
TOTAL COST FOR 1 HOUSE

Description	Cost in KD
60 Panels	4,500
Installation of 150 m^2 of Panels	9,045
Inverter Cost for 150 m^2 of Panels	2,280
Mounts, Racks, and Wiring	5,100
Maintenance per Year	450
Initial Cost for One House	21,375
Cost of 150 m^2 of Panels	4,500
Installation of 150 m^2 of Panels	9,045
Inverter Cost for 150 m^2 of Panels	2,280
Mounts, Racks, and Wiring	5,100

One barrel of oil is equivalent to 1,628 kWh, which means that 1 kWh is equal to 0.00061 barrel of oil equivalent [10]. Hence, the result will be 1.345×10^6 barrels of oil to be burned to satisfy the yearly needs of one house from electricity. However after applying the grid connected PV system, the number of oil barrels that should be burned is reduced to 1.022×10^6 barrels per year. Therefore, for one

house, the number of barrel saved per yearly is equal to $1{,}345\times10^6$ barrels. Taking into consideration that the life cycle of the solar panels is 25 years, so each house will save about 8.075×10^6 oil barrels. For saving of taxes under Kyoto Protocol, each house will save around 10000 KD in the 25 years period. In addition, the saving of CO_2 per house will be 2,175 short tons.

B. Case Studies for 12,000 and 300,000 Houses

Following the same steps for the one house case study and considering that the Public Authority for Housing Welfare in Kuwait is trying to cover almost 12,000 houses every year, the study is one more time applied on the cases 12,000 houses and 300,000 houses.

Fig. (5), shows the increasing cost for supplying 12000 with electricity along 25 years using fuel [11]. Tables 3 and 4 are showing the total cost and savings for the 12000 houses case while Tables 5 and 6 are showing the same for the 300,000 houses case. Finally, the cost per kWh using solar = Total cost of the project for 25 years/Total production for 25 years kWh cost = 32,130 KD /1314000 kWh = 0.024 KD

Comparing the result to the cost of kWh using fuel, which is 0.045-0.060 KD, the cost using solar is cheaper than using fuel.

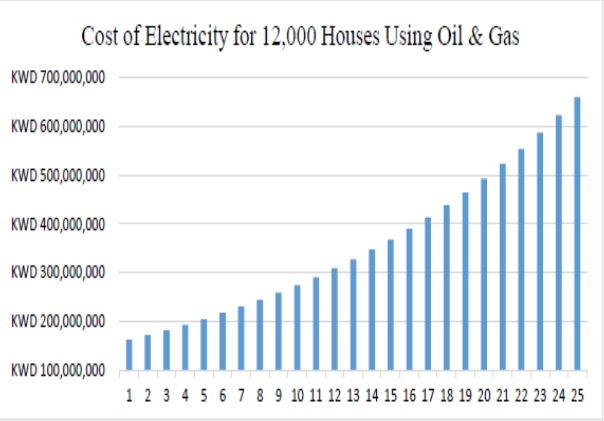

Fig. (5)-Accumulated Cost of Electricity for 12,000 Houses Using gas and oil for a period of 25 years.

C. Case study of Parking Lots

In this study, an on grid system will be implemented as mentioned previously with the same materials that are used in Table 1. The structure of the idea is to implement one solar panel within each 12.5 m^2. The panel can produce 1250watt (1 m^2 produces 100 watt).

Table 7 shows the technical aspects and detailed cost for implementing the solar system in one parking lot. The study is concerned with 6 different parking lots as follows: Kuwait University (KU), Ministries zone, Ministry of Water and Electricity, Scientific Center, Entertainment City and Kuwait Airport. Each parking lot contains parking spaced stated in Table-8-, where each parking slot requires one solar panel.

Table-9- shows the initial implementation cost and the overall maintenance cost for the six parking lots in 25 years, so the total cost for 25 years for all areas is 61.5×10^6. Furthermore, the total expected amount of produced electricity for 25 years is calculated as given in Table-10-

TABLE -3-
TOTAL COST FOR 12,000 HOUSES IN 25 YEARS

Description	Cost in KD
150 m^2 of Panels for 12,000 houses	54×10^6
Installation of 150 m^2 of Panels for 12,000 houses	108.5×10^6
Inverters Cost for 150 m^2 of Panels for 12,000 houses	27.3×10^6
Mounts, Racks, and Wiring for 12,000 houses	61.2×10^6
Maintenance per Year for 12,000 houses	5.4×10^6
Initial Cost for 12,000 houses	256.5×10^6

TABLE -4-
MONEY SAVING IN 25 YEARS

Description	Cost in KD
Fuel cost	98.550×10^9
Solar energy cost	74.898×10^9
Savings	23.652×10^9

TABLE -5-
TOTAL COST FOR 300,000 HOUSES IN 25 YEARS

Description	Cost in KD
Fuel cost	2.463×10^{12}
Solar energy cost	1.872×10^{12}
Savings	0.591×10^{12}

TABLE -6-
SAVINGS FOR 25 YEARS

Description	Data/Cost in KD
Saving Money for 25 years	0.591×10^{12}
Carbone Emissions Reduction	26.04×10^6 short tons/year
Oil Barrels Reduction	2.324 T
Saving in Carbone emissions under Kyoto Protocol	119.2×10^6

TABLE -7-
TOTAL COST OF 1 PARKING LOT

Description	Data/Cost
Panels Type	Photovoltaic
Panels Brand Company	DM Solar
Panels Efficiency	14%
Panels Size	12.5 m^2
Panels Cost	375 KD
Panels Installation Cost	754 KD
Inverter Brand Company	Solectria Renewables
Inverter Cost	118 KD
Mounts, Racks and Wiring Cost	424 KD
Maintenance per Year	38 KD

TABLE -8-
NUMBER OF PANELS PER PARKING LOT

Parking Lot Location	Number of Parking Spaces/Number of Solar Panels
Airport	60
Scientific Center	1890
MEW	5172
Entertainment City	7892
Ministry Zone	4634
KU	3300
Total	**22948**

TABLE-9-
TOTAL COST FOR ALL PARKING LOTS

Parking Lot Location	Implementation Cost in KD	Maintenance cost for 25 years in KD
Airport	106×10^3	54×10^3
Scientific Center	3.3×10^6	1.7×10^6
MEW	9.2×10^6	4.7×10^6
Entertainment City	14×10^6	7.1×10^6
Ministry Zone	8.2×10^6	4.2×10^6
KU	5.5×10^6	3.0×10^6
Total	$\mathbf{40.3 \times 10^6}$	$\mathbf{21.2 \times 10^6}$

TABLE-10-
TOTAL PRODUCTION IN KWH

Parking Lot Location	Total Electricity Production Per Year for All Panels (kWh)	Total Electricity Production for 25 Years (kWh)
Airport	262×10^3	6.55×10^6
Scientific Center	8.2×10^6	207×10^6
MEW	22.6×10^6	566×10^6
Entertainment City	34.5×10^6	864×10^6
Ministry Zone	20.2×10^6	507×10^6
KU	14.4×10^6	361×10^6
Total	$\mathbf{100 \times 10^6}$	$\mathbf{2.5 \times 10^9}$

The Cost of 1 kWh (average for 25 year) is calculated where it is the total cost for 25 years divided over the total electricity production. Consequently, it equals 0.025 KD, which is lower than the cost of producing electricity using fuel.

IV. CONCLUSION

Kuwait is one of the leading countries in oil and gas production, throughout the last years, electricity production in Kuwait relied on nonrenewable sources. This paper introduced a feasibility study of integrating PV panels within a grid connected system for producing electricity in Kuwait. The study was concerned with houses and parking lots, it targeted implementing the PV system for 300,000 houses. The study also considered implementing the PV system for six parking lots. Results showed the capability of saving both fuel and money on the basis of long term investment of 25 years. Other gained benefit is less CO2 emissions for much clean environment. The study gave a lot of promising data showing great benefits for further application of the proposed system allover Kuwait.

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