Application of Using Hybrid Renewable Energy in Saudi Arabia

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Abstract— **One of the major world wide concerns of the utilities is to reduce the emissions from traditional power plants by using renewable energy and to reduce the high cost of supplying electricity to remote areas. Hybrid power systems can provide a good solution for such problems because they integrate renewable energy along with the traditional power plants. In Kingdom of Saudi Arabia a remote village called Al-Qtqt, was selected as a case study in order to investigate the ability to use a hybrid power system to provide the village with its needs of electricity. The simulation of this hybrid power system was done using HOMER software.**

Keywords- hybrid, renewable energy, HOMER, photovoltaic, wind energy

I. INTRODUCTİON

Renewable energy or "green energy" is defined as the energy generated from natural resources such as sunlight, wind, rain, and geothermal heat, which are renewable. Hybrid power systems usually integrate renewable energy sources with fossil fuel based generators to provide electrical power. They are generally independent of large electric grids and are used to feed loads in remote areas. Hybrid systems offer better performance, flexibility of planning and environmental benefits compared to the diesel generator based stand-alone system. Hybrid systems also give the opportunity for expanding the generating capacity in order to cope with the increasing demand in the future [1-4]. Remote areas provide a big challenge to electric power utilities. Hybrid power systems provide an excellent solution to this problem as one can use the natural sources available in the area e.g. the wind and/or solar energy and thereby combine multiple sources of energy to generate electricity. A village in the Kingdom of Saudi Arabia, called Al-Qtqt, was selected as a case-study to investigate the most suitable combination of power sources for the hybrid power system. A simulation is done using HOMER software [5], and the details of this study are described in this paper.

II. HYBRİD POWER SYSTEMS

Hybrid power systems usually integrate renewable energy sources with fossil fuel, (diesel/petrol) based generators to provide electrical power and traditional diesel system acting as back-up in case of lack of the primary source [2]. They are generally independent of large centralized electric grids and are used in remote areas. In these systems, it is possible for the individual power sources to provide different percentages of the total load. For instance, on a cloudy and windy day, when the solar panels are producing low levels of electricity, the wind generator can compensate by producing more electric power. There are generally two accepted hybrid power system configurations:

1. Systems based mainly on diesel generators with renewable energy used for reducing fuel consumption.
2. Systems relying on the renewable energy source with diesel generators used as a backup supply for extended periods of low renewable energy period or in cases of high load demand [1, 4].

A hybrid power system, as the one shown in Figure 1, has the ability to provide 24-hour grid quality electricity to the load. Such a system offers better performance, flexibility of planning and environmental benefits compared to the diesel generator based stand-alone system. The operational and maintenance costs of the diesel generator can therefore be decreased thereby improving the performance of operation. Further, less fuel is used. The system also gives the opportunity for expanding its capacity in order to cope with the increasing demand in the future. This can be done by increasing either the rated power of the diesel generator, renewable generator or both of them.

The advantages of using renewable energy sources for generating power in remote areas are obvious. The cost of transported fuel is usually expensive for such locations. Further, using fossil fuel has many concerns on the issue of climate change and global warming. The main disadvantage of a standalone power system using renewable energy is that the availability of renewable energy has daily and seasonal fluctuations which results in difficulties in regulating the output power to cope with the varying the load demand [3].

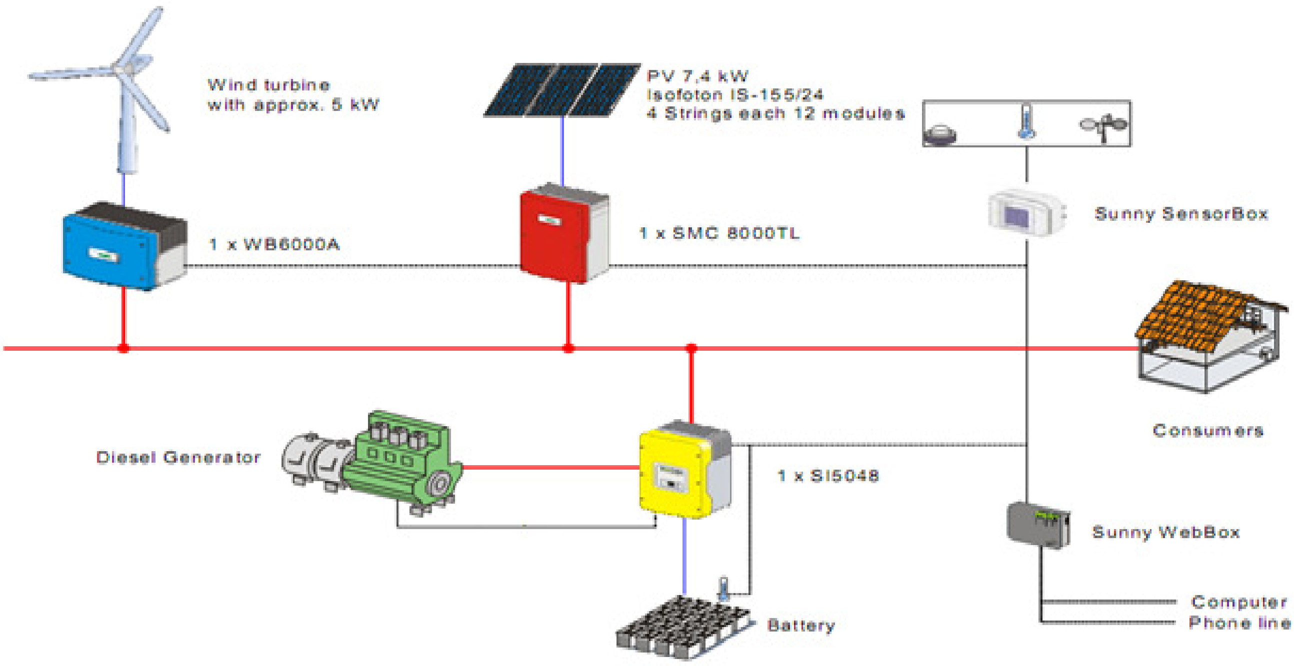


Fig. 1. Hybrid power systems

III. Simulation of Hybrid Power System Using HOMER Software

In order to design a mini-grid hybrid power system, one has to be provided with information for the selected location. Typical information's required are; the load profile that should be met by the system, solar radiation for PV generation, wind speed for the wind power generation, initial cost for each component (diesel, renewable energy generators, battery, converter), cost of diesel fuel, annual interest rate, project lifetime, etc. Then using these data one can perform the simulation to obtain the best hybrid power system configuration. One of the available tools for this purpose is the HOMER software from NREL [3].

A. HOMER Simulation Procedure

HOMER simulates the operation of a system by making energy balance calculations every hour for each of the 8,760 hours in a year. It finds the least cost combination of components that meet the specified electrical and thermal loads. HOMER simulates thousands of system configurations, optimizes for life cycle cost, and generates results of sensitivity analyses for most situations [6]. Thus HOMER helps to perform analysis and answer many design questions such as:

- Which technologies are most cost-effective?
- What size should the components have?
- What happens to the project's economics if costs or loads change?
- Can the renewable sources supply the load?

B. Village Selection

The objective of this study was to select a village in a remote area in the Kingdom of Saudi Arabia to study the feasibility of using hybrid power system to supply the load of the village throughout the year. Al-Qtqt village was chosen for this purpose. It is located at 24°28'36.16"N 46°15'0.86"E and it is about 100 km from Riyadh City.

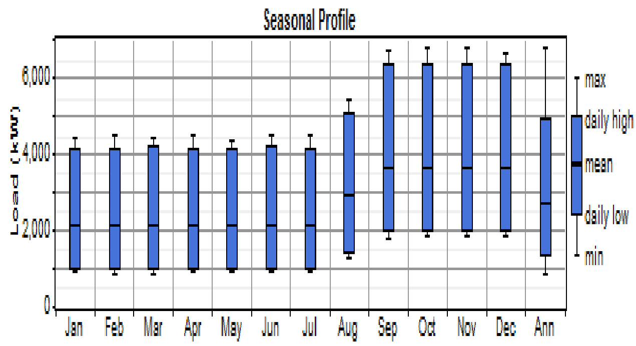


Fig. 2. Annual load profile for this village

Figure 2 shows the load profile for this village [8]. The simulation process of the hybrid power system for the chosen village was analyzed to see if using the hybrid power system will be feasible or not. It is important to note that this village is already connected to the grid and one additional objective was to see the effect of using hybrid power system and to determine if the village can depend on it. For the chosen village, the renewable energy sources e.g. the solar and wind data is given in Table 1 [9].

TABLE I. THE SOLAR RADIATION & WIND SPEED READINGS FOR THE VILLAGE

Months	Clearness Index	Daily Radiation (kWh/m2/d)	Wind Speed (m/s)
January	0.633	4.310	3.000
February	0.658	5.205	3.000
March	0.639	5.930	3.600
April	0.616	6.422	3.600
May	0.643	7.091	3.000
June	0.678	7.596	3.700
July	0.654	7.254	3.500
August	0.661	7.010	3.500
September	0.691	6.660	2.500
October	0.675	5.598	2.200
November	0.661	4.646	1.100
December	0.626	4.033	2.800

IV. CASE STUDIES

Figure 3 shows the general configuration of the Hybrid system investigated. When designing the system, different scenarios and conditions need to be considered to simulate all possible cases. Each selected case examines the system under a specified set of conditions.

Case 1: Solar Plus Grid without any constrains

This case represent the current condition of the system where the village connected to the grid and the solar is added to the system to see the feasibility of the solar usage but without any constrains imposed.

Case 2: Solar and Wind Plus Grid without any constrains

In this case the wind was also added to the system and the specification in HOMER software was still without any constrains. This was done to see the effect of adding a wind turbine to the system

Case 3: Solar and Wind Plus Grid but with constrains

This case represents the same system as the previous case, but it was required that the system should use a Minimum Renewable Fraction. The Minimum Renewable Fraction was varied from 0 % to 50 %. If a wind turbine was removed from the system, then it translates to the case of solar plus grid but with constrains.

Case 4: Diesel, Solar and Wind without Grid and any constrains

This case represents the ideal condition for the system where the village is off the grid and the system depends only on the hybrid power plant without any constrains of using a specific portion of renewable energy in the output power from the power plant.

Case 5: Diesel, Solar plus Wind without Grid but with constrains

This case is similar to case four but constraints were imposed to use a pre specified percentage of renewable energy in the output power.

V. RESULTS AND DISCUSSION

The simulations of different cases shows that there are only two main cases i.e. case 3 and case 4 which are of interest. This is due to the fact that the other cases produce only one output, which is the grid, and this is due to not using any constrains in HOMER software. It is important to note that tariff of electricity are very low in Saudi Arabia. Therefore, if there are no constraints, grid supply will be the most economical for the consumer. For case 3 and case 5 the optimal system types are shown in Figure 4 and Figure 5.

As shown in these figures, the optimal system of the village is the solar and grid only (without wind) because the wind turbines are not feasible for wind speed of less than 3 m/s. In most cases, the wind speed in this village is close to this minimum. Thus one will not expect much contribution from the wind turbines in the hybrid system.

To obtain the optimal percentage of minimum renewable fraction from economical point of view there are various output costs that must be considered. These are plotted versus the minimum renewable fraction in Figures 4a, 4b whereas Figure 4c provides the CO_2 emission values.

From the curves of Figure 4 it is clear that a minimum renewable fraction (Min. RF) of 15%-35% provides the optimal range for costs and emission. Further, from Figure 5a we can note that at 30% Min. RF, the total cost for the system is minimum. Although the cost of energy increases with the increase of Min. RF, the emissions decrease. Table 2 includes a summary of the costs for the system when the Min. RF is 30%. Here the optimal system consists of solar and diesel. To obtain the optimal percentage of minimum renewable fraction from economical point of view there are various output costs which are plotted versus the minimum renewable fraction as shown in these figures

The curves show that the range of 10% -30% of Min. RF gives the optimal range for the costs and emissions.

In Figure 5a it is shown that, at 0% ,the best choice economically is the diesel only system. However, as shown in Figure 5b and Figure 5c at 20% the system will use more renewable energy, the emissions will be less than the lower values for Min. RF and the COE will be slightly higher. Table 2 summarizes the costs for 20% of minimum renewable fraction, while Table 3 shows a summary of emissions.

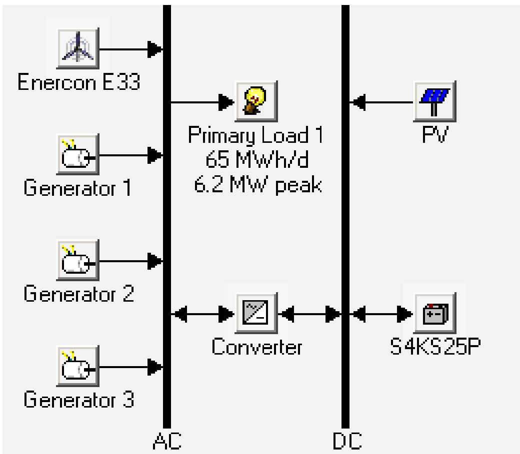


Fig. 3. Hybrid power system configuration

VI. CONCLUSIONS

To reduce the emissions from traditional power plants, by using renewable energy, and to decrease the high cost of supplying electricity to remote areas, hybrid systems are of considerable importance. Hybrid systems are one of the most promising applications of renewable energy technologies in remote areas, where the cost of grid extension is high. Since the price of fossil fuel increases with the distance of the location, hybrid energy systems could be an appropriate technology to reduce fuel consumption and environmental hazards.

Applications of hybrid systems range from small power supplies for remote households providing electricity for lighting or water pumping and water supply to village electrification for remote communities. HOMER Software can be used to analyze and simulate the possible alternatives to decide for the best choice.

A village in the Kingdom of Saudi Arabia was selected for the study described in this paper. The load profile of the village as well as the solar emission and wind speed data were used as the inputs to the software. . Different scenarios and conditions were considered to cover possible states of the system in the village. Five case studies were designed and simulated. The output of the simulation helps to choose the optimal case for the system and the optimal percentage of Minimum Renewable Fraction. It is shown that the optimal case is the solar and grid combination and it represent a system connected to the grid with the addition of using renewable energy. The chosen percentage of Minimum Renewable Fraction, considering cost and emissions, was 30%.

TABLE II. SUMMARY OF THE COSTS

Cases / Costs	Case 3	Case 5
Total Capital Cost($)	20,200,000	16,602,000
Total NPC($)	55,482,580	35,107,348
Total O&M Cost($/yr)	2,543,109	43,464
Total Fuel Cost($/yr)	0	1,086,972
Total Ann. Cost($/yr)	4,340,220	2,746,333
COE($/kWh)	0.184	0.116

TABLE III. EMISSIONS OF GRID ONLY SYSTEM & HYBRID POWER SYSTEM

Pollutant	Emissions (kg/yr)	
	Grid only System	Hybrid Power System
Carbon dioxide	14,943,271	10,713,995
Carbon monoxide	0	0
Unburned hydrocarbons	0	0
Particulate matter	0	0
Sulfur dioxide	64,786	46,450
Nitrogen oxides	31,684	22,716

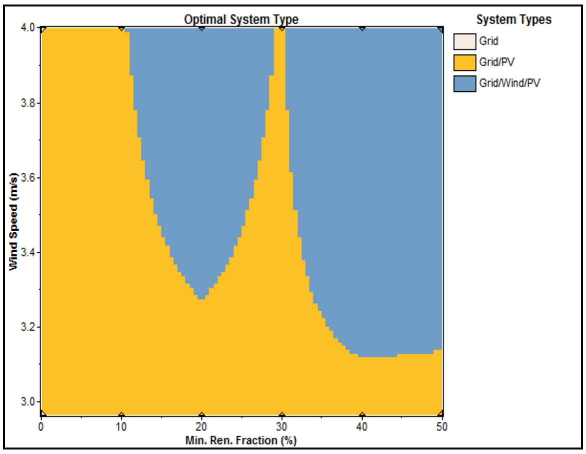


Fig. 4. Optimal system type

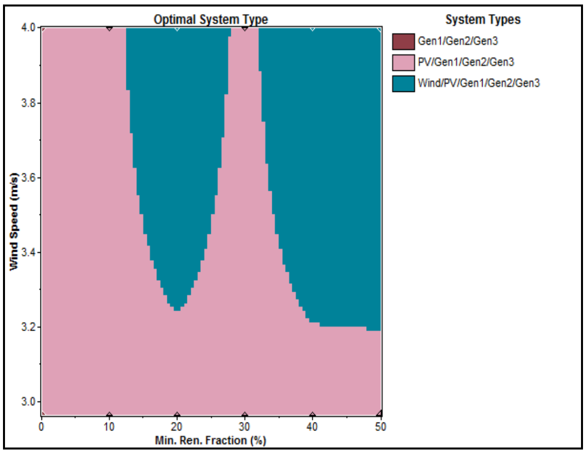


Fig. 5. Optimal system type

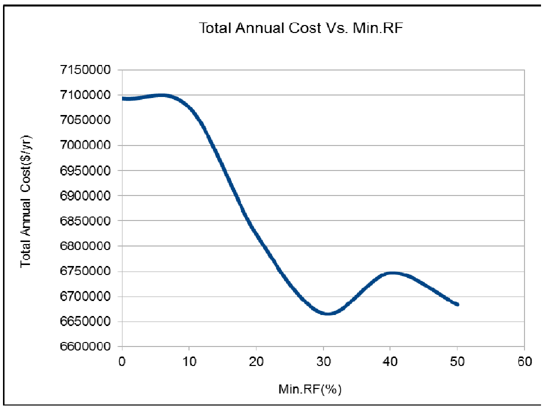
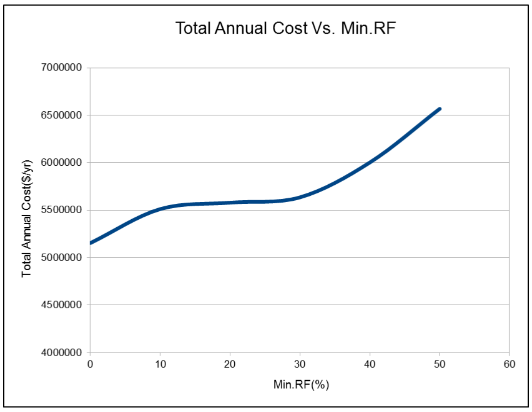


Fig. 4a. Total Annual Cost vs. Min. RF



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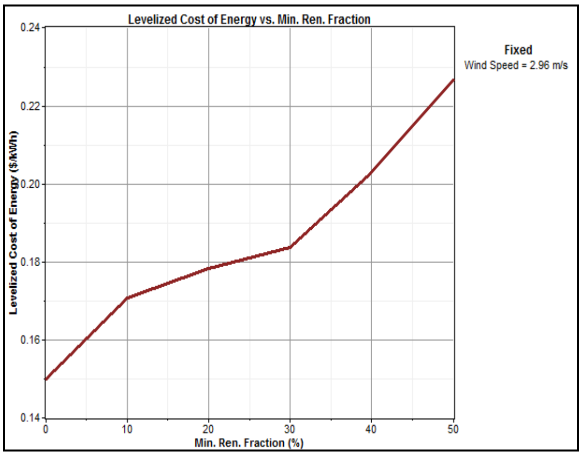

Fig. 4b. COE vs. Min. RF

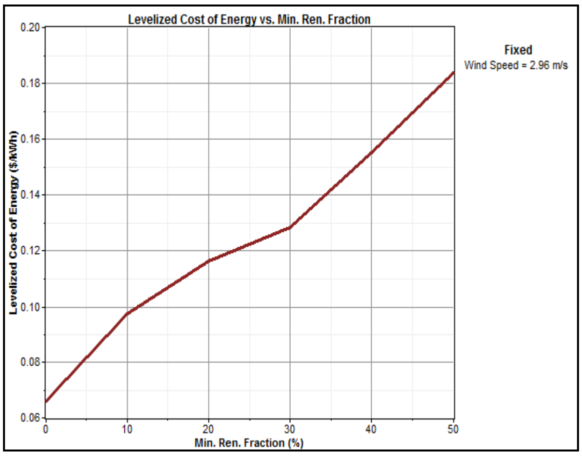

Fig. 5b. COE vs. Min. RF

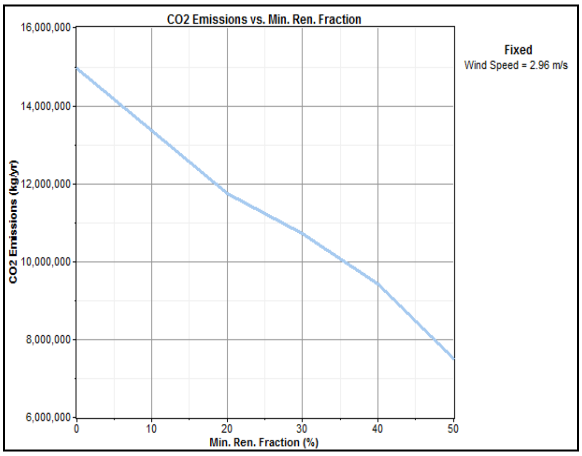

Fig. 4c. CO2 emission vs. Min. RF

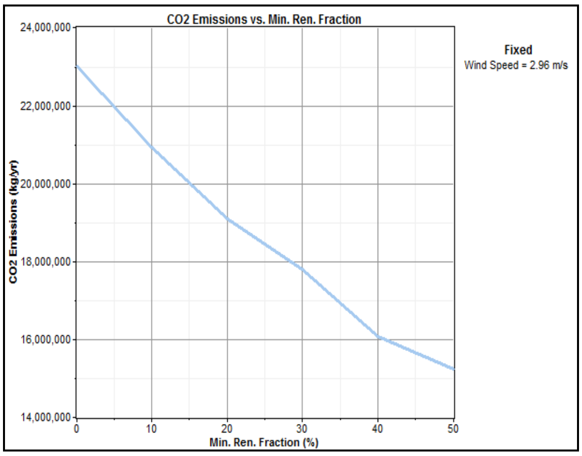

Fig. 5c. CO2 emission vs. Min. RF

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