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Use of Hybrid PV and Wind Turbine – Grid Connected System in a Local Emirati Home in Dubai-UAE

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Abstract

The Hybrid Optimization of Multiple Energy Resources (HOMER) software is used to assess the economics of using a PV-Wind Turbine (PV-WT) system to provide clean and renewable energy for a typical local home in the UAE. The system is grid connected and thus contains no electricity storage facilities, e.g. batteries. The HOMER software was used to calculate the Cost of Electric (CoE) for different combinations of cost of grid electricity (CGE), interest rates (i%) and PV & wind turbine combinations. The results show that for interest rates of 4% and 6% a hybrid PV-WT system is economically viable for all four values of CGE studied. When the interest rate is raised to 8%, the hybrid PV-WT system is economically viable only viable a viable to the two highest CGE rates studied. The hybrid PV-WT system was not economically viable for all interest rates higher than 8%. This shows that lower interest rates are needed in order to promote the incorporation of renewable energy in UAE homes.

Peer-review under responsibility of the organizing committee of CPESE 2016

Keywords: Residential PVs, Residential windturbine, gris connected renewabl eenergy, UAE

1. Introduction

The world is facing one of its biggest challenges in the form of global warming and climate change. The continuation of the existence of the human race, as we know it now, depends on us tackling this problem quickly and definitively. The recent COPR 21 agreement in Paris is an important step forward toward achieving this goal [1].

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This is the 1st time where 190 countries agreed to set definitive targets that all countries agreed upon. Now comes the hard part of implementing different strategies in order to achieve this. The main issue now is how to cut down of the CO2emissions, which are the main cause for global warming. One of the areas that offer high potential for energy efficiency is the building sector. According to US statistics published in Building Energy Data Book [2], in the year 2009 buildings were responsible for 40% of all energy use and 74% of electrical consumption.

There has been a tremendous increase in use of renewable energy (RE) in the past decade with solar power presenting the highest potential. Many researchers have investigated ways to incorporate different types of RE in buildings as a way to reduce their electricity demand from the grid where electricity is mainly generated using fossil fuels [3-6]. This paper presents similar work in which the potential to integrate RE into existing homes in Dubai-UAE is assessed from both technical as well as economical.

2. Methodology

Researchers have used a wide range of methodologies to study the impact of different types of REs. This includes Mathematical analysis and modelling, case studies, laboratory & filed experiments and computer modelling.While most people would be tempted to apply the experimental mythology [6], the experimental method remains one of the most expensive and time consuming methodologies thus more researchers have been favoringthe use of computer simulation [7]. Computer modelling offers a low cost as well as a quick method of assessing different building and technology configurations with high accuracy. The popularity of simulation is has been aided by the continuous improvement in the accuracy of computer models, both custom made and commercial, as well as the enhanced speed of the required computational facilities. Thus computer simulation was chosen as the methodology in this study.

There is a large number of energy modelling software available each with its own unique features, capabilities sand limitations. Since this research is looking at both the technical and economic aspects of integrating RE the focus was on a software that can do both. The top two such software that can do this are RETScreen [8] and HOMER [9]. HOMER was selected for this research, as it is simpler and faster to use when studying a wide range of configurations.

3. Case study

Figure 1 shows the house selected for use in the current study. This is a public housing villa built by the UAE Ministry of Public Works (MoPW) for local Emirati families. This design is designated as model 717 and was built in several locations in the UAE in the period 2000-2012. The total floor area of the house is 394 m^2. The roof area is 78 m^2. This does not include the area above the stairwell, which is around 15 m^2 nor the area above the attached guesthouse (Majlis) is 34 m^2. Figure 2 shows the local electricity demand for the house [10].

Figure 1.The house used as case study in the current paper [10].

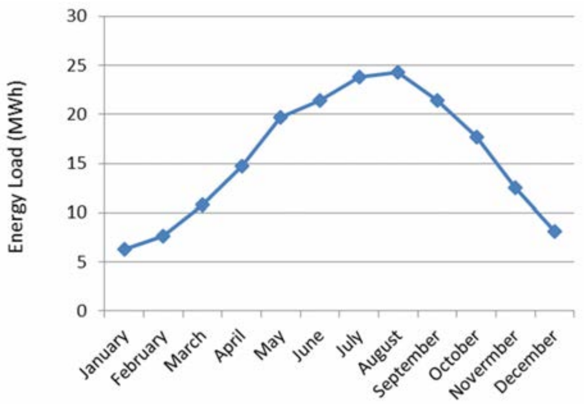

Figure2.The monthly electrical consumption of the house used as case study in the current paper [10].

4. HOMER modelling and data analysis

In addition to the electricity consumption profile in Figure 2, local solar radiation and wind data are required as input to HOMER [11]. Several configurations were assessed by HOMER based on the most economical configuration of grid power, PV panels located on the villa's roof, two types of wind turbine located on top of the stairwell and a DC/AC converter; no battery storage was considered since this is a grid connected system. The area available for the PV panels was limited to a maximum of 70 m^2, this is the roof area (78 m^2) less 10% for circulation. Information as to the PV's technical data (power production and size) as well as costs was obtained from the GoGreenSolar supplier website [12]. The wind turbine data for two size turbines was obtained from the Luminous Renewable Energy website [13]. The turbine, if any, will be located at the top of the stairwell in order to increase the height of the turbine's hub. With increased height, the wind's speed increases and the wind turbulence decreases, both of which enhance the productivity and reliability of the wind turbine.Figure 3 shows the technical schematic of the configurations studied.

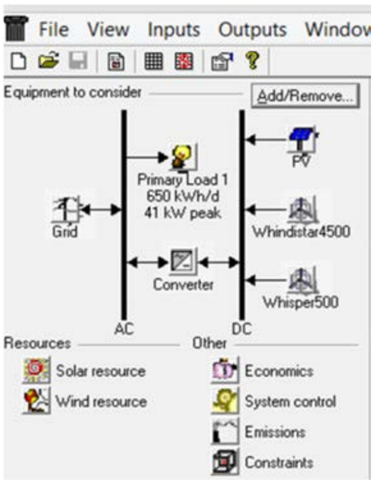

Figure3.The technical equipment considered in this study.

Following is a summary of the HOMER input for these elements:

- Cost of grid power (AED/kWh):0.295, 0.345, 0.385, 0.405; 1 USD = 3.67 AED. This covers the 4residential electricity slaps used by the Dubai Electricity & Water Authority (DEWA) in Dubai including the current 0.065 AED/kWh fuel surcharge cost [14]. There is no limit on the amount that can be bought from or feedback to the grid; DEWA implements the net-metering system with no cashback to the consumer should the net balance be on the consumer's side.

- Cost of PV panels: 5500 AED/kW$_p$ [12]. Possible total capacity of the PV panels considered: 0, 1, 2, 3, 4, 5, 6 and 7 kW$_p$(limited by the available roof space). The panel lifetime is 25 years.
- Cost of wind turbines: 26800 AED for the Whisper 500 (W500) turbine (3.3 kW DC design capacity) and 34865 AED for the Windistar 4500 (W4500) turbine (4.5 kW DC capacity) [13]. Possible combinations included no turbines, 1*W500 or 1*W4500; since the wind turbine is to be located on top of the stairwell there is no room for more than one turbine at a time. The lifetime for both types of turbines is 15 years.
- Cost of the converter: 1313 AED/kW [12]. Possible sizes considered: 0, 1, 2, 3, 4, 6, 8, 10, 12, 14, 16, 18, 20, 25, 30 kW. The lifetime for the converter is 15 years.
- The annual interest rates considered: 4%, 6%, 8%, 10% and 12%, based on the range of consumer interest rates charged in Dubai-UAE at the time of this research.

Based on the above data HOMER was used to simulate and assess more than 7000 possible combinations looking first for combinations that are able to meet the load requirements of the villa (technical constraint) then identifying the most economical viable configuration for each combination of grid electricity cost and interest rate. The analysis is based on a project life of 25 years, with replacement of wind turbines and converters as needed. The economicviability is based on the overall Cost of Electricity (CoE, AED/kW) for each configuration that is technically viable. In addition to the CoE, the HOMER analysis also provides the breakdown of the electricity provided from the RE(s) vs grid power. Figure 4 shows the breakdown of the power provided by the grid, PVs and wind turbine for the case of grid power cost of 0.405 AED/kWh and interest rate of 4%. This is the most RE favourable combination in this study still only 12 % of the total energy is provided by REs (5% by PVs and 7% by wind turbine).

Table 1.Summary of the results of the optimal configurations for different grid electricity cost (AED/kW) and annual interest rate (i %) combinations.

Annual interest rate (i %)	Grid electricity cost (AED/kW)			
	0.295	0.345	0.385	0.405
4	1, 1, 0, 4 0.295, 8%	7, 1, 0, 8 0.340, 12%	7, 1, 0, 8 0.376, 12%	7, 1, 0, 8 0.394, 12%
6	0, 0, 0, 0 0.295, 0%	1, 1, 0, 4 0.344, 8%	7, 1, 0, 8 0.381, 12%	7, 1, 0, 8 0.399, 12%
8	0, 0, 0, 0 0.295, 0%	0, 0, 0, 0 0.345, 0%	0, 1, 0, 4 0.384, 7%	1, 1, 0, 4 0.403, 8%
10	0, 0, 0, 0 0.295, 0%	0, 0, 0, 0 0.345, 0%	0, 0, 0, 0 0.385, 0%	0, 0, 0, 0 0.295, 0%
12	0, 0, 0, 0 0.295, 0%	0, 0, 0, 0 0.345, 0%	0, 0, 0, 0 0.385, 0%	0, 0, 0, 0 0.385, 0%

Table 1 summarises the results of optimal configuration for each combination of grid electricity cost (AED/kW) and annual interest rate (i %). The results for each configuration are shown in two lines. The first show the PV capacity used (kW$_p$), number of the W4500 wind turbine, number of the W500 wind turbine, converter capacity (kW). The second row shows the overall CoE (AED/kW) and the % of total power provided by the renewable energy system(s) for the configuration. For example, the 1st entry in Table 1 (grid electricity cost of 0.295 AED/kW and 4% annual interest rate) is: 1,1,0,4 and 0.295, 8%. This means this configuration is made up of PVs with a capacity of 1kW$_p$, 1 * W4500 wind turbine, 0 * W500 wind turbine and a converter with a capacity of 4 kW. The CoE for this configuration is 0.295 AED/kW and 8% of the total energy is provided by the renewable energy resources (1 kW$_p$ PV + 4.5 kW W4500 wind turbine). For simplicity, configurations that are totally grid dependent (i.e. does not include any PVs, wind turbines or converters and thus 0% renewable energy contribution) are shaded with light grey. The configurations which benefited most of the use of the PVs &/or wind turbines, i.e. resulted in tangible reduction in the CoE, are shaded with light green.

The data in Table 1 show that the Windistat 4500 is the most viable of the three renewable systems studied. This is interesting, as most would expect PVs to be the most intuitive choice in a sunny country such as the UAE. The edge of the W4500 over the W500 and PVs is mainly due to economics, i.e. the amount of electricity it can produce per unit cost of the turbine.

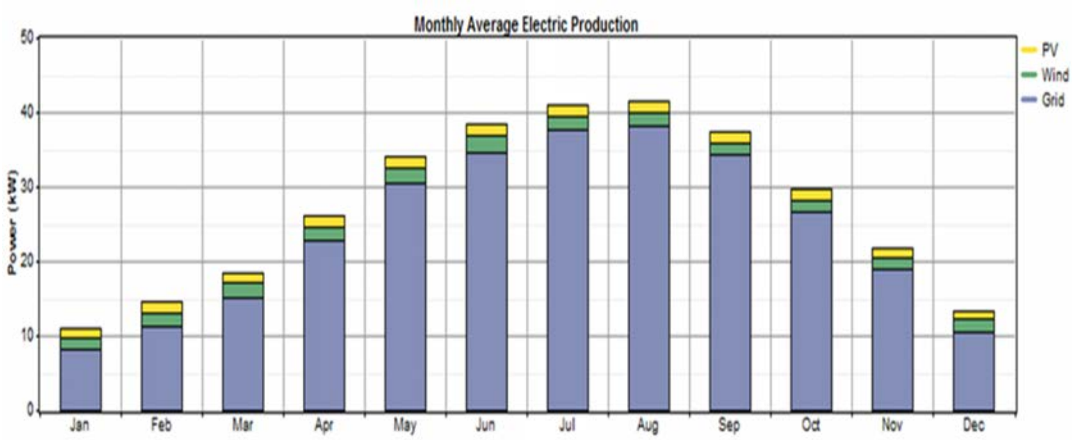

Figure 4. The monthly breakdown of the source of the electrical energy provided for the case of grid power cost of 0.405 AED/kWh and interest rate of 4%.

Still for most grid cost & interest rates, the most economical configuration did not include any renewable systems. This is partially due to the relatively low cost of electricity in Dubaiand the relatively high cost of renewable energy systems. High interest rates also discourage investing in renewable energy resources, which tend to have high initial coast and low running costs versus traditional electricity generation systems, which have lower initial costs, but higher running costs mainly for fuel. Thus the higher the annual interest rate the less important future saving become. This shows that small scale, building installed/integrated, renewable energy systems are still not in a position to challenge fossil-based grid electricity. The cost of small-scale renewable energy systems still need to drop well below today's levels in order to become a strong economic competitor to the grid. This will take time. In the meantime, governments wanting to promote small-scale renewable energy systems can help by providing loans at low interest rates, as seen for most combinations with i=4% in Table 1. This is supported by Figure 5, which shows the optimal configurations as a function of grid power cost and interest rate.

Table 1 also includes another important piece of information about the use of PVs & wind turbine. The maximum renewable energy contribution does not exceed 12%. This is mainly a spatial limitation of the villa which does not allow more than a 7 kW_p PV system to be installed along with a single W4500 wind turbine. The use of other spaces, e.g. the roof of the Majlis and/or the garden can provide more space for additional renewable energy systems. However, such locations are not as efficient as the roof of the villa and stairwell; the secondary locations are susceptible to shading and/or safety issues, which would reduce the productivity and thus the cost effectiveness of PV and/or wind turbines located there.

5. Conclusions

HOMER energy and economic modelling software was used successfully to predict the technical viability and economic feasibility of adding renewable energy systems, PVs and wind turbines, to a villa in the UAE. The study showed that at low interest rates and high grid electrify cost, the use of renewable energy resources is a feasible activity, both technically and economically. Under such situations, the renewable energy systems can provide upto 12% of the total electricity consumption of the villa. This percentage is limited by the available useful villa-space that can be used to install the PV panels and wind turbine.

The study also shows that the cost of small-scale renewable energy systems need to drop further to make such systems attractive at interest rates that are more nominal. In the meantime, government subsidies/ guarantees can be used to promote renewable energy systems until such lower costs are achieved.

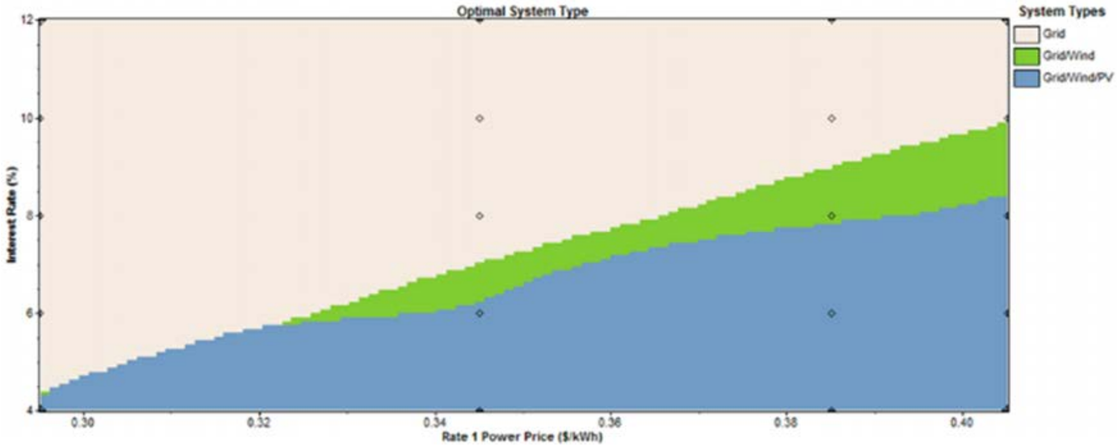

Figure 5. The optimal configurations as a function of gird power cost and interest rate.

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