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Lowering Cost of Photovoltaic Systems Using Forecast Dependent Design, Monitoring and Management Methodology

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Abstract

The target of current work is to cut off the cost of solar energy systems by using weather forecasting to predict energy production and implementing energy management measures to optimize the use of energy and reduce the need for energy storage. For standalone systems, this can include reducing the number of PV panels and battery banks, while still ensuring that there is enough energy to meet user needs. The energy management system you describe monitors the power level of the storage elements and adaptively controls switching to minimize the number of panels and battery banks needed. For grid-connected systems, the goal is to calculate the energy produced by the system and use that information to arrive at a zero-balance bill, considering the user's daily and nighttime energy consumption. The proposed energy management procedures are designed to reduce costs by optimizing the use of energy. the percentage of cost reduction has been determined for both types of systems.

Keywords
Solar energy, Lowering the cost, Forecasting, and Energy management .

1. Introduction

The United Arab Emirates (UAE) has a high reliance on non-renewable energy sources, particularly oil, to meet its energy needs. However, there are several reasons why it is important for the UAE to shift to renewable energy:
The UAE has a hot and arid climate, which makes it well-suited for solar energy. Solar energy is a clean, renewable, and abundant energy source that can help the UAE reduce its reliance on fossil fuels. Also, the cost of the renewable energy the cost of renewable energy has been decreasing in recent years, making it more competitive with traditional fossil fuels. And solar energy, in particular, has dropped dramatically over the last decade. The price of solar panels has fallen by more than 85% since 2010, making solar power one of the most cost-effective forms of renewable energy. The cost of building new utility-scale solar power plants is now competitive with the cost of building new fossil fuel power plants in many parts of the world. The cost related highly with the amount of energy must be produced; therefore, the area will need more and more. So, to make the reduction forwarding and make the solar energy suitable for all people by making the system smarter via involve weather forecast and energy management system to increase the cost of PV models.

1.1 Objectives

The project divides into two main stages, the first part is to design the solar system, by two configurations, the stand alone (by take help from the batteries to store energy at the night), and grid-connected (by take help from the main utility grid), design with all necessary devices to make the solar energy system reliable, calculate the cost, find the parameters are affect implementation of the system. The second part are aims to reduce the cost of the system with not have an effect on powering the home that by taking forecasting the weather to know the energy would be used, and control if there any reduction of the energy using Energy Management System (EMS).

2. Literature Review

A series of recent studies has indicated that the design and implementation of a computer-based smart energy monitoring and management system for standalone photovoltaic systems, in study have done by Ali Abou-Elnour, Fahd Morad, Ibrahim Al-Tayasna, and Ossama Abo-Elnor. system has two main components: a monitoring and controlling system and a wireless communication system using LabView, by Ali Abou-Elnour, A. Thabt, S. Helmy, Y. Kashf, Y. Hadad, M. Tarique, and Ossama Abo-Elnor. Also, several studies suggest that to implement the solar energy system by A stand-alone photovoltaic system is designed to operate independently of the electric utility grid and is generally sized to supply certain DC and/or AC electrical loads. The system uses a bank of batteries to store energy in the form of DC power that is produced by the PV modules to be used at night or on days with no sun, also by the book titled Renewable and Efficient Electric Power Systems by Gilbert M. Masters, the renewable energy systems have discussed by the traditional way. In a paper published with title Weather-Based Solar Energy Prediction, this paper discusses the challenges in predicting the energy output of a photovoltaic solar panel system. The literature on design solar energy system with energy management and weather forecast is less consistent. Finally, another promising line of research would be to involve smartness to the solar energy system. This paper addresses aim to design a smart solar energy system, by the control, monitor the consumption of energy based on forecasting the weather, so far lacking in the scientific literature.

3. Methods

The researchers conduct the study by using MS Excel sheet, to calculate how many devises needed for how many times. The study has been done by taking real time devices now a days in the market, the literature has collected from various database like IEEE journal, ELSEVIER.

4. Implementation

Implement the stand-alone system with the main parts (PV, battery bank, voltage regulator, and invertor), while for the grid connected (PV, invertor and connected onto the main utility grid).
The grid connected has special design by connect the PV into the government grid, that make the user produce more energy to get benefit from selling the electricity.
The design of each system as shown in Figure 1 shows the stand-alone system and the second Figure 2 shows the grid connected system, then the power will be produced and the cost are depending highly to the needed of the system, this study has been done for house applications.

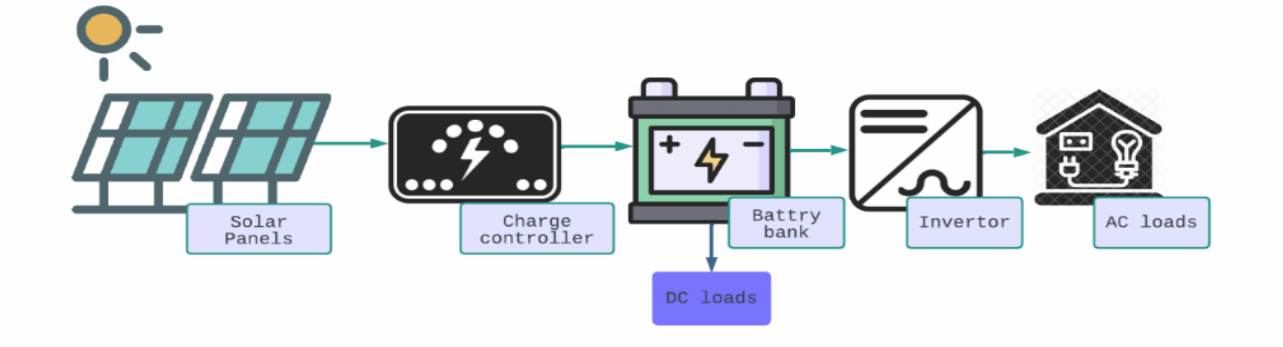

Figure 1. Stand-alone system

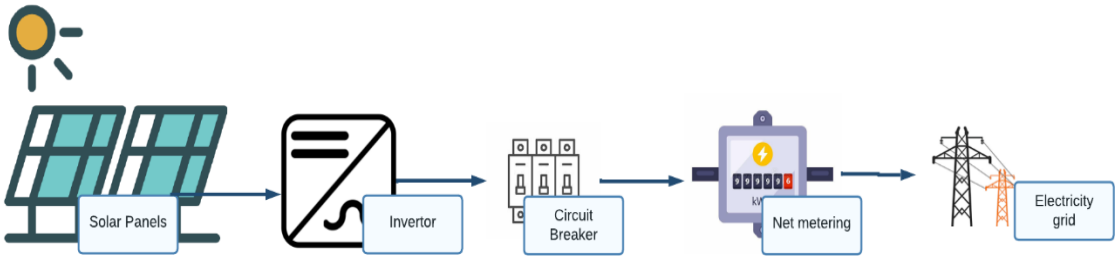

Figure 2. Grid-connected system

The design starts by calculate how many energies needed? For our case study in the Table 1 shows tabulated the loads, power, consume hours and energy

Table 1. Example of home's load

	Load	Hours	Power (watt)	Energy (kWh)
1	TV	2	58.6	0.1172
2	Light	10	12	0.6
3	Air condition	8	1000	24
4	Kettle	0.5	180	0.09
5	Coffee maker	0.3	850	0.255
6	Dishwasher	1.5	1200	1.8
7	Microwave	0.5	800	0.4
8	Air Frayer	1	1500	1.5
9	Toaster	0.3	700	0.21
10	Food processor	0.2	800	0.16
11	Refrigerator	24	150	3.6
12	Hair dryer	0.5	2200	1.1
13	Washing machine	1.5	400	0.6
14	Heater	0.5	1200	0.6

Therefore, for the same energy have been construct stand-alone and grid-connected, the answer is based on many parameters that will highly affect the number of (PV, batteries, invertor, and the voltage regulator), the parameters are concludes into 3 categories:

- Manufacturing parameters: or the market, and it is depending on the performance of the equipment and devices, also the brand, the type of material, etc.
- Geographic parameters: the second category is geographical factors: these parameters are related to the location where we are going to implement the system, so for example peak hours, radiation and saving days.
- Special parameter: related to the great connected model this parameter are depends on the government and the rate of tariff will put

5. Results and Discussion

The finding are discussed in the part 4, therefore, if there any changes of the type of the part, that leads to fluctuate the cost, even where the system will implement, this parameter highly affect the number of PV and batteries, since the power generated from the sun not high, so when the system will construct in countries close to Ecuador, so will reach more energy as Figure 3 shown, and this clear in Figure 4: which displays the relation between the number of PV and batteries in different irradiance, clear that the irradiance will increase leads to increase the number of devices, in Figure 4.A shows the number of battery only for stand-alone.

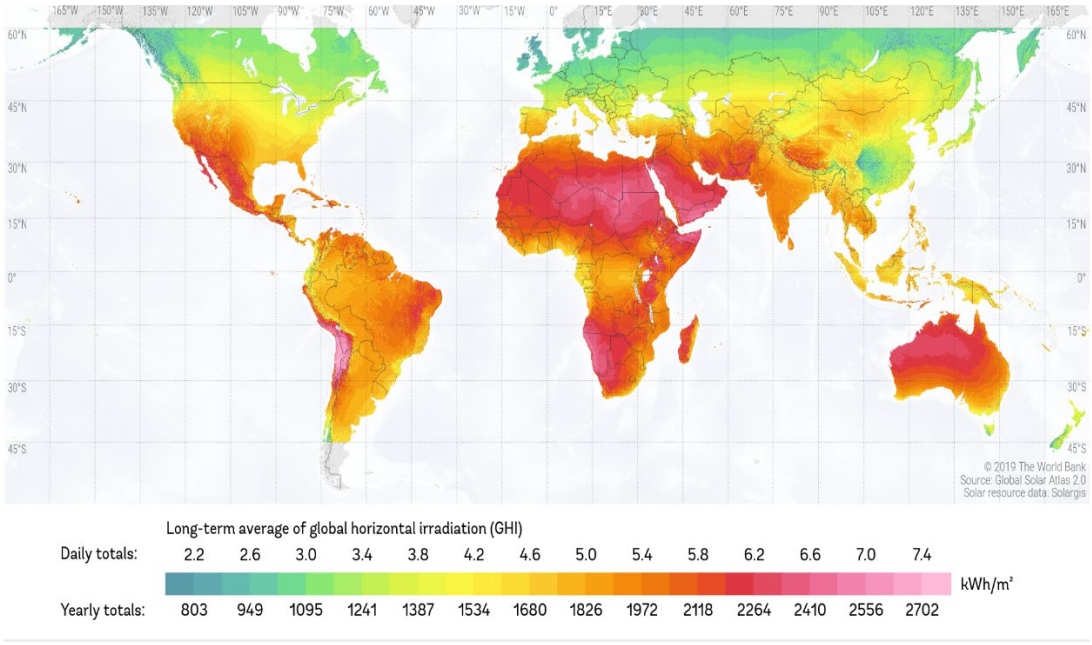

Figure 3. Displays a solar radiation map

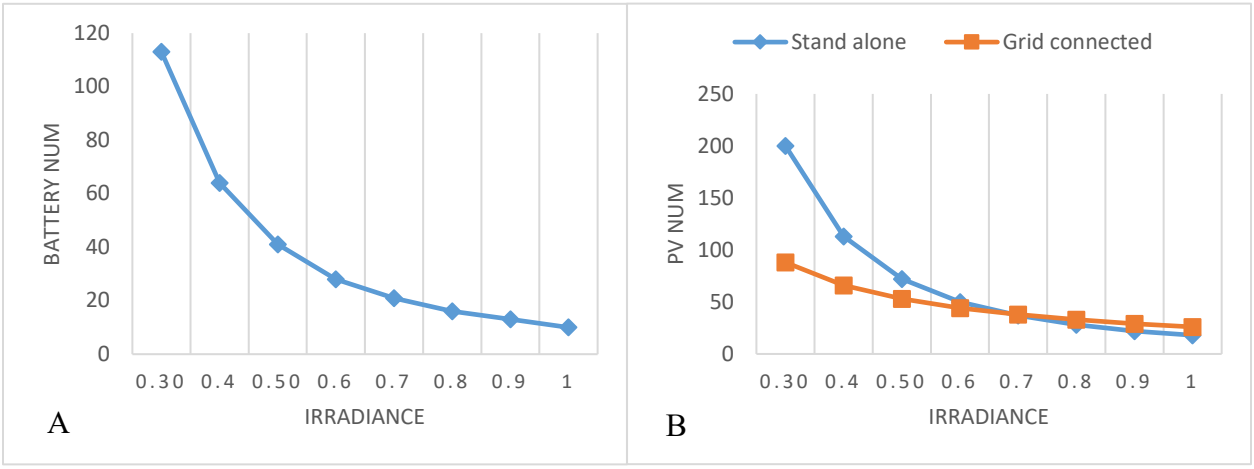

Figure 4. Display the relations between the number of PV and the number of batteries in different irradiance

Must mention that the irradiance are not controlled, otherwise, other parameters founded that to affect the cost, with respect to the prices available in the market, by study 3 types in UAE market as documented in Table 2 the results as shown in Figure 5, the grid connected need more number of PVs, that's make the person invest on generate the energy, and will be source of money for the person, to sell the extra KWh production. also, clear that the unity cost of 1 PV will be higher with respect to the performance, and when use the lower performance means more arrays needed that leads to higher cost as Figure 6 display.

Table 2. Different type of PV

#	Type	Power (watts)	Price (AED) per unit	Efficiency
1	Polycrystalline	105	175	15%
2	Monocrystalline	270	410	20.23%
3	Monocrystalline	550	750	21%

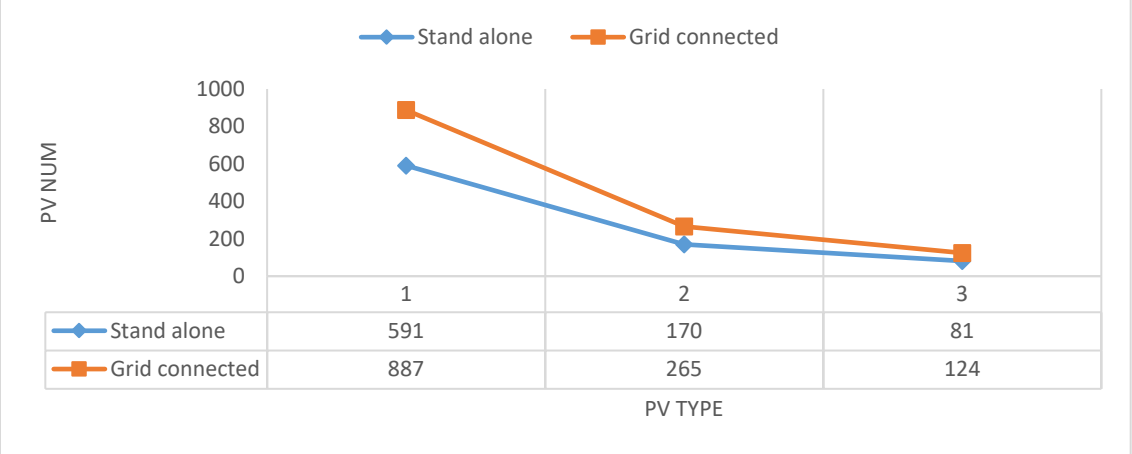

Figure 5. Relation between number of PV in both system

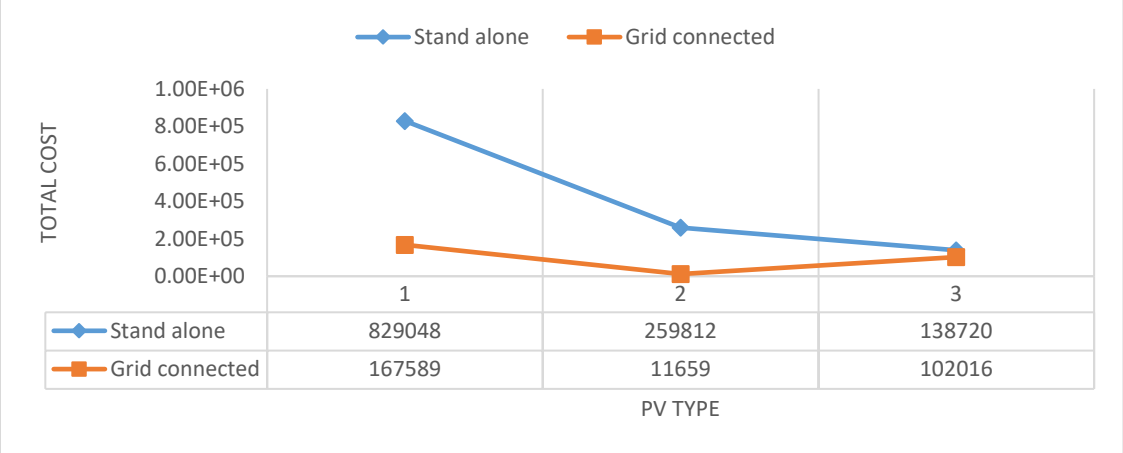

Figure 6. Total cost in both system

For the stand alone, the number of battery bank take the same action of the PV, from the Figure 7 and 8 we can say we get the same relation.

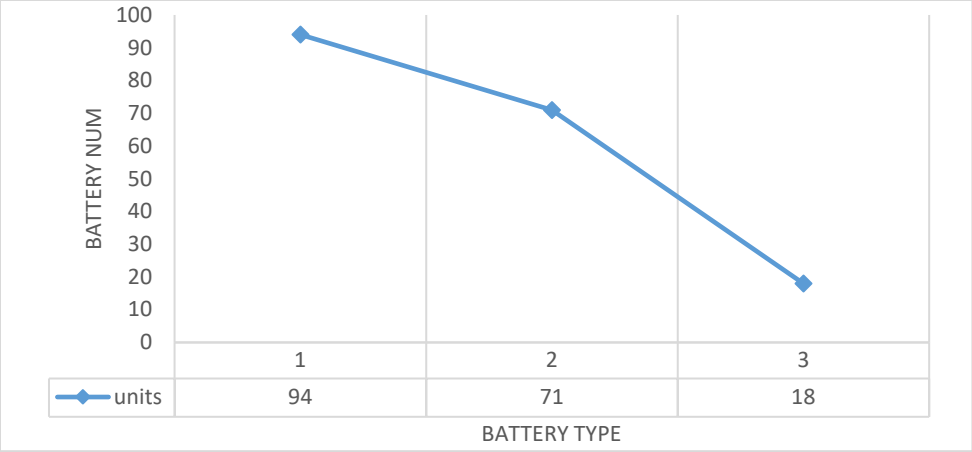

Figure 7. Relation between battery type & battery number

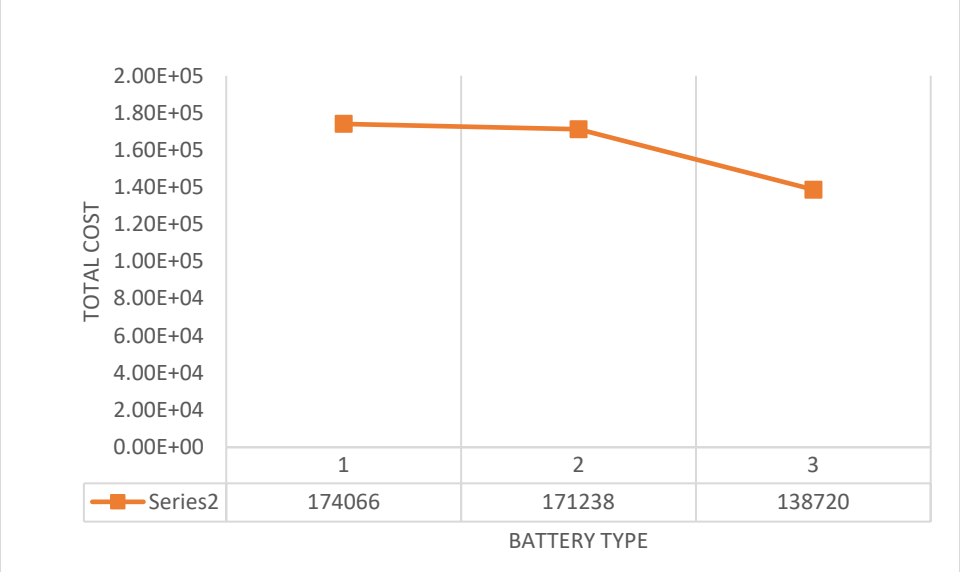

Figure 8. Total cost of battery

Must mentioned that all the results have done under fixing the other parameters (the irradiance, peak hours, saving days, sell and buy cost, etc.).

We can conclude that, pick devices with higher performance will make the total cost less, also, the cost of grid-connected normally lower than the cost of stand-alone, and that results of investment with the electricity and there some equipment does not include like the battery and voltage regulator.

The total cost will be 174066 AED with battery type 1, and with type 3 is 138720 AED, so the cost when choose the expensive equipment will reduce total cost by 20.31%. for the cost of 1KWh generated by the system for the type 1 is 0.68 and for type 3 0.54, the percentage of reduction is 25.9%.

The number of days that energy can be stored in a standalone system depends on several factors, including the size of the storage system, the amount of energy being generated and consumed, or in other world the location the system will be implemented, and the efficiency of the system. In general, larger storage systems and systems that are more efficient will be able to store energy for longer periods of time. The larger battery bank needs huge investment, the

Figure 9 show the relation between saving days and the number of component, and Figure 10 shows the relation between the cost and saving days.

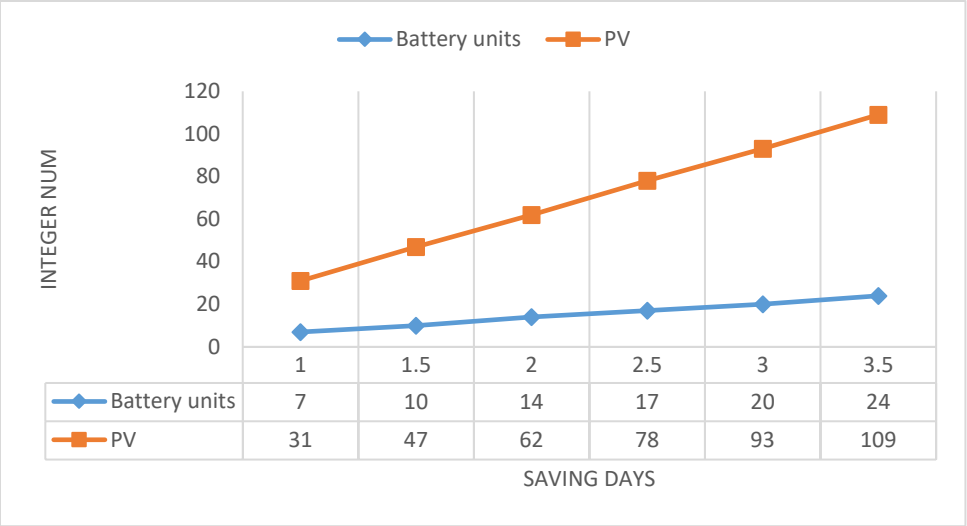

Figure 9. Relation between the saving days and the number of components

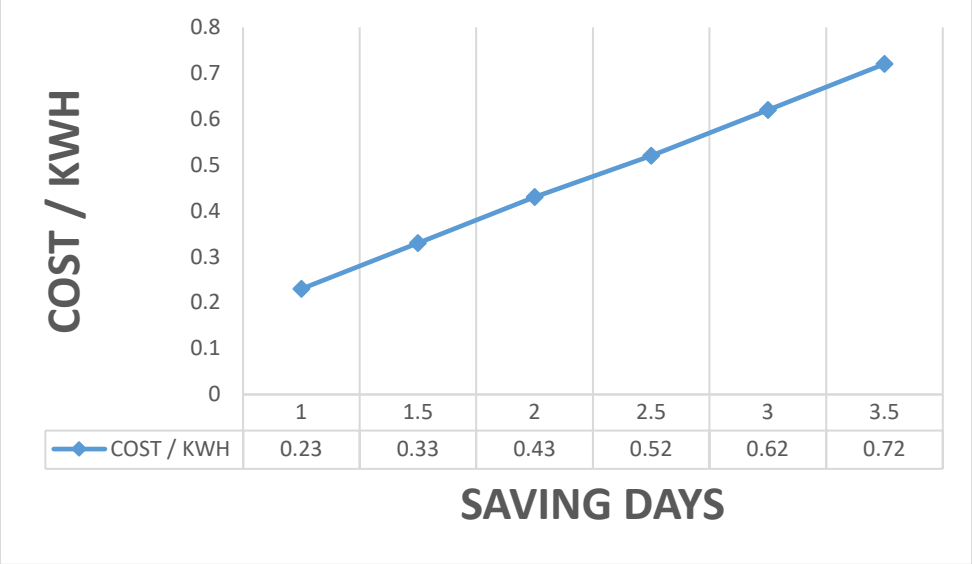

Figure 10. Relation between the saving days and the total cost

The saving days affect highly the cost on the system, so in UAE if taking 2 days will make the cost per 1 KWh 0.43 AED, but on other hand the system could implement the system by 1 saving days only, so the cist will reduced to 0.23 AED, the percentage of reduction is 46.5%,, the Table 3: shows tabulate the whole reduction percentages with respect to 1 day, we can conclude that by reduce the saving days will reduce the cost dramatically.

Table 3. relations between saving days and the cost/KWH with the percentage of reduction

Saving days	COST / KWH	Percentage of reduction
1	0.23	0%
1.5	0.33	30.3%

2	0.43	46.5%
2.5	0.52	55.7%
3	0.62	62.9%
3.5	0.72	68.1%

So, by construct system with minimum number of saving days, which is in uae 1 day, and take in consideration the weather, since Weather conditions can have a significant impact on the generation of solar energy. For example, cloudy or overcast weather can reduce the amount of sunlight that reaches solar panels, resulting in less electricity being produced. Similarly, heavy snowfall can accumulate on the panels, shading them and reducing their effectiveness. On the other hand, clear, sunny weather can lead to higher levels of solar energy production. Additionally, temperatures also play a role, as high temperatures can cause solar panels to become less efficient.
There are a variety of ways to mitigate these effects, including using techniques such as "tracking" to orient solar panels towards the sun, and using "cleaning robots" to remove snow and debris from the panels.

Additionally, location plays a key role in the effectiveness of solar energy, as areas with high levels of sunshine and low levels of cloud cover will generally be more suitable for solar energy production than areas with less sunshine and more clouds. This why places like deserts, tropical areas and some Mediterranean countries are more suited for solar energy generation.

So, the weather plays vital role to generate the power, but the system must construct once a time, and it will be with respect to the average of each parameter, so, choose the brand of each equipment, know the purpose of using the system, the location too. After fix all parameter, and by make the saving days 1 day, will check the energy day by day, if there any changes, the system will take action to stop the unnecessary loads by the priority.
The way of control the energy will be by energy management system, to monitor, control and act.

5.1 Priority

The energy efficiency of appliances can play a significant role in determining the overall energy consumption of a household. Turning off appliances when they are not in use can help to reduce energy consumption and lower electricity bills.
Additionally, some appliances consume more power than others when they are in standby mode, also known as vampire power. These appliances can still use a significant amount of energy even when they are turned off, so completely unplugging them is the most efficient way to stop energy consumption.
Some examples of high energy consuming appliances are:

- Refrigerators: They consume energy 24/7, to keep the food fresh.
- Air conditioners: They are energy-intensive appliances that can consume a lot of power when in use.
- Televisions and home entertainment systems: These devices consume a significant amount of energy even when in standby mode.
- Laundry and dishwashers: While in use, these appliances are energy intensive.
- Computers and chargers: Even when not in use they consume some power.

In addition, the energy for each appliance as shown in Table 1, so by the Equation one the system will calculate the difference between amount of energy in the day, and the energy the solar energy constructs it.

$$E_{av} - E_r = \sum E_i \qquad 1$$

Where E_{av} is the energy needed to power the system, E_r is the real energy the system will generate it, and E_i is KWh must ne save them. The real energy will be found it by the weather forecast.

5.3 Proposed Improvements

The system of reducing the energy is based on the weather of the day, are more specific on the energy will reach to power the house, therefor to be the whole system user friendly by build an application based on mobile phone, to check by the costumer the energy generated, if there need to save energy or not, if yes, which appliance will w turn it off? All of those will be answered by the application. the Figure 11 shows a proposed message will send it by the application to check the plane of consume the energy.

Figure 11. Messages from the application to user

6. Conclusion

From the result of the analysis in the case study, the following conclusions were drawn:

1. The two ways of construct the system are stand-alone solar system and grid-connected solar system; the stand-alone from the name added storage device like the battery ad voltage regulator, while in grid-connected those two-equipment cancelled from the system, but that does not mean the cost pf grid-connected will be always lower than the stand-alone.
2. The cost of implanting the system are depends into many factors, and they are divided into 3 main categories (Manufacturing parameters, Geographic parameters, Special parameter), so the location will be construct the system affect, the type of the devices will affect also, the lifespan of the PV, invertor, and other devices, and for the grid-connected the tariff of the electricity will affect the total price too.
3. Weather forecasts play vital role of generation the energy, will make the user more aware of the way of consuming the energy, or to be controlled automatically by sensors using energy management system to control, monitor the power.

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Biography

Prof. Ali A. Elnour Prof. Dr. Ing. Ali Abouelnour obtained the Ph. D. from the technical university Hamburg Harburg, Germany. His research interests include modeling and simulation of semiconductor devices, wireless healthcare monitoring systems, and energy management systems.

Maryam Al Nuaimi is from the United Arab Emirates, specifically from the Emirate of Fujairah. She graduated from Madhab Secondary School in 2016 and completed her academic career at the United Arab Emirates University for two years. She then moved to the University of Science and Technology in Fujairah in 2019 to complete her studies in electrical engineering in the renewable energy branch. Maryam also underwent a training program at the Fujairah Police General Headquarters. Maryam will graduate with a bachelor's degree in electrical engineering by the end of Spring 2023 semester, she is looking forward to completing her master's degree in Engineering Management in the near future.

Maram Hussam who graduated from high school in 2019 and she is now at the end of her university studies, she's currently studying an engineering major in the field of renewable energy, and now in her last semester at the University of Science and Technology in Fujairah. In a few months she will be graduating and doing a master's degree.

Raghed Melhem is a student in University of Science and Technology of Fujairah in college o Engineering and IT, studded Electrical engineering/ Renewable and power engineering, planned to graduate by the end of this semester (Fall 2022/2023)