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PROMOTION OF SOLAR ASSISTED AIR CONDITIONERS THROUGH DEMAND-SIDE PLANNING IN PETROL-EXPORTING COUNTRIES

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ABSTRACT

Solar thermal technologies have a significant footprint in reducing per capita electricity consumption and CO_2 emissions. Demand-side management (DSM) can help the solar energy technologies enter into the market faster under conditions where electricity is subsidized. The purpose of the present study is to investigate the feasibility of designing a utility DSM program using solar-assisted air conditioners in petrol exporting countries. For this reason an experiment was conducted where a solar-assisted air conditioner installed in an office in Erbil was tested against a standard air conditioner. Using the experimental results s DSM program was designed for 100,000 offices with a rebate of US $100 for each installation. It was estimated that the peak could be reduced by 87 MW from 09:00 AM to 06:00 PM which covers the peak demand time during the summer period. An equivalent power unit costing approximately US $138 million would be deferred for 10 years.

Keywords:
DSM, solar-assisted AC, petrol exporting countries, Solar thermal technology

1. INTRODUCTION

As is evident and known, the increase in electrical appliances in homes, offices, companies and shops continuously increases the demand for electricity. The present work focuses in reducing the growing demand for electricity by using the demand-side management (DSM) approach in which solar assisted air conditioners are promoted.

In USA, DSM programmes are applied at over 70% of commercial buildings and offices in different ways because participating in the programme helps the latter reduce their expenses and the overuse of electricity [1]. It was found that after US citizens participated in a specific DSM programme and achieved good results, the number of participants doubled. It was also found that when the Energy Efficiency Fund programme was applied in the State of Connecticut, every dollar invested in the electricity and gas sector yielded a three-dollar return [2].

According to the data of the EIA Annual Energy Outlook 2008 [3], the budget amount allocated to the DSM programme was not wasted. US $3.72 billion were spent in 2008 to retrieve and provide 86 million MWh of power, which is enough to supply the States of Missouri and Washington with electricity.

The increase of demand for electricity in the residential, commercial and industrial sectors in the USA was set at 1.07% per year between 2008 and 2030. However, using the DSM programme could reduce that rate to 0.83% per year between 2008 and 2030 [3].

There are different assumptions which can be used for analysing the transfer of demand-side management (DSM) strategies between countries by solving the specific problems that may arise in them. The more the similarity between these countries, the higher the level of transferability of DSM programmes between them. There are three levels; namely direct copying, adaptation, and inspiration [17].

There is a major interest in modifying the peak load in Erbil in order to create a more sustainable electricity system. The electricity tariff is too low for customers to opt for solar energy technologies although solar energy is available. The subject of the present research is concerned with the special case of transferring the solar-assisted air-conditioner (AC) technology to Erbil by the help of DSM in order to modify the peak demand. This is because applying the programme can control the peak demand and saving enormous fuel consumptions; otherwise utility will be forced to build new power plants costing hundreds of millions of dollars. Against that the saved fossil fuel can be exported to use for increasing revenue to support the country's economy [16].

Our research focuses on the commercial sector (commercial buildings and offices) because work and electricity consumption continues from morning to evening (i.e., during day time). In addition, air-conditioning and cooling account for the majority of electric power expenses because these offices use split units for cooling and heating.

2. METHODOLOGY

It is important to know the amount of the investment required for installing a solar-assisted AC and to estimate the peak reductions in order to propose any DSM programs.

The method of approach of the present study is shown in Fig. 1. The total cost of DSM depends on the rebate and the number of participants to the program. The peak load reduction is estimated and the feasibility of the program is determined as shown the calculation result from Table 1 & Table 2. Also, the methodology approach is shown in Fig. 1. AC load is estimated from:

$$L_{AC} = \frac{E_{AC}}{\Delta t} \qquad (1)$$

where L_{AC} is the load and E_{AC} is the electricity consumption due to AC usage. Δt is the period of usage. The load reduction for each replacement of standard AC by solar-assisted AC is estimated from:

$$\Delta L_{AC} = L_{Standard\ AC} - L_{Solar-assisted\ AC} \qquad (2)$$

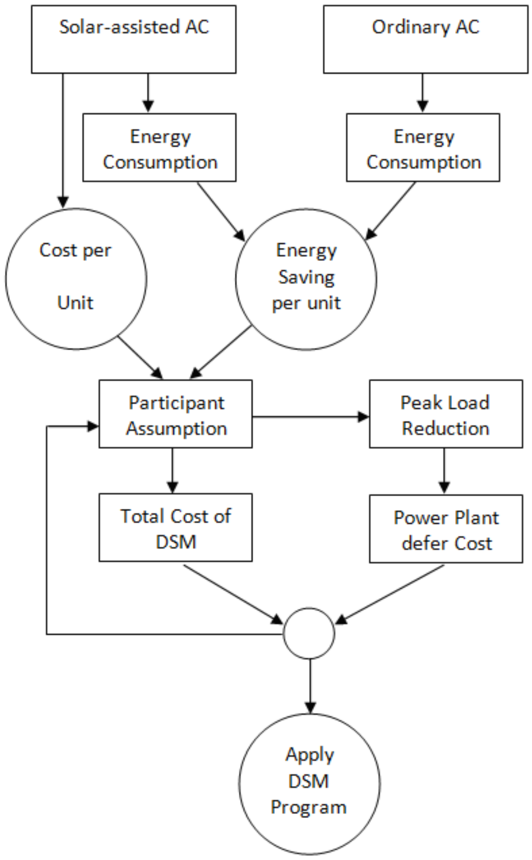

Fig. 1. Methodology approach

3. EXPERIMENTAL SET-UP

The experimental office building consists of nine rooms. Each room has an individual split AC system. We choose two rooms (namely Office_1 and Office_2) that are identical in design on the inside and outside as shown in Fig. 2. One of the rooms (Office_2) is used with an ordinary AC unit and in the other (Office_1) the standard AC is replaced by a solar-assisted air-conditioning unit of 2 ton refrigeration capacity.

Power consumption of both standard and solar-assisted ACs were monitored and recorded simultaneously by a data logger, while the indoor temperatures of the rooms were set to 20^{o}C. We note that both offices' business hours were from 9 AM to 6 PM non-stop daily.

The data was collected in a stick memory using a data logger device consists of multifunction voltage ampere power energy meter model (AC80/260V/100A) communication module with current transformer and temperature sensors.

Fig. 2. Case study office

The data logger was able to collect data (electricity consumption in ordinary and solar-assisted ACs with temperature of indoor and environment) of during a single month. Thereafter, it was possible to estimate the quantity of electric power consumed by both (air-conditioning) units for one year, and as per following real schedule working AC periods:

1) During months of (April, May, October and November) Air conditioner is not working.
2) During Fridays the office is close.
3) The holiday days during the year in the office are eleven days as following:

   (Christmas one day, Nawroz three days, Eid Al-Fitr three days, Eid Al-Adha four days)

In light of the aforementioned data, offices use air-conditioners for about 197 days per year.

Data collection was carried out between 1st and 30th September, 2017. The following data were collected.

5. CASE STUDY IN ERBIL

5.1. Energy Brief

The city of Erbil is the capital of the Kurdistan Region in Iraq (KRI). It has a population of 2.01 million [12] and 525,000 electricity consumers, only the commercial sector is 60,000 [6], by assuming five rooms per commercial building, it will give the total offices are about 300,000.

While the electric power generation capacity is 872 MW, the peak demand for electric power exceeded 2,000 MW and that demand is constantly increasing as shown in Fig. 4. In addition, power transmission capacity is limited. As a result, electric service and supply are intermittent. Last summer, the Ministry of Electricity was only able to provide electricity for 9 hours out of every 24-hour period [5], it means, about 15 hrs electricity shortage. This applied significant pressures on commercial offices and shops, forcing them to use public or private electric generators to be provided with the required and necessary electricity during business hours.

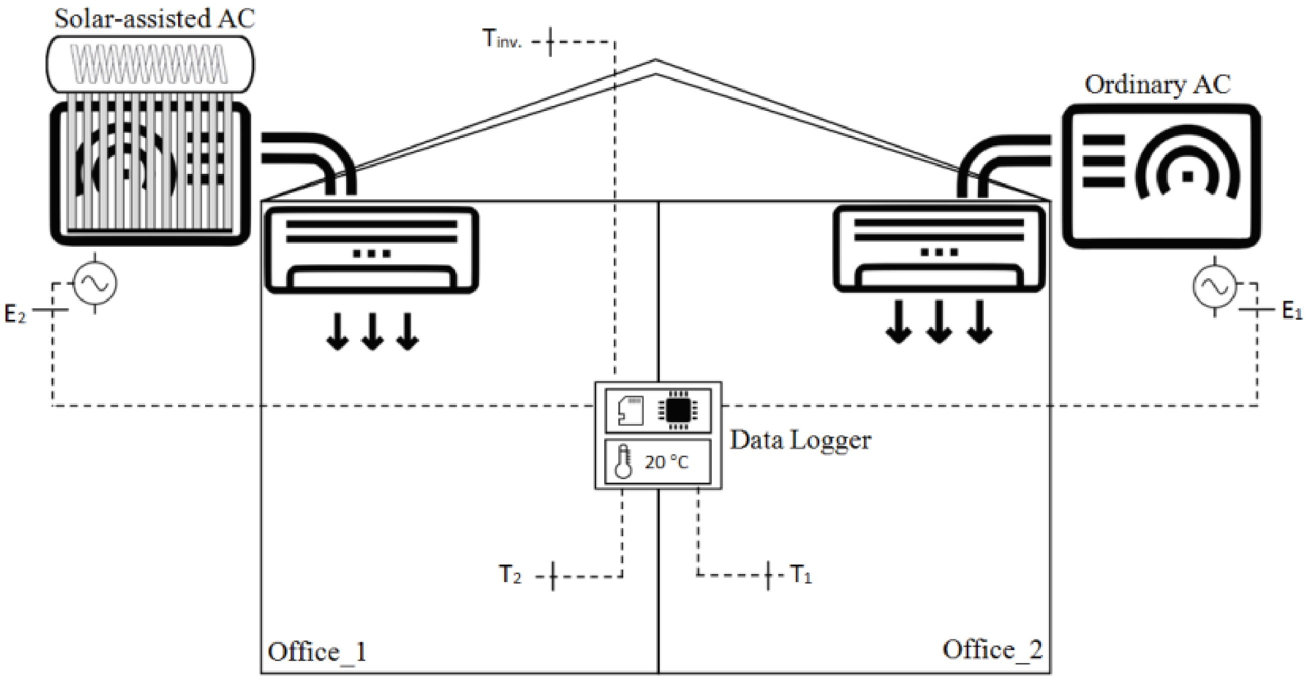

Fig. 3. Experimental layout

With increasing the population of Erbil and controlling illegal electricity line connection by the utility, the demand for electrical power was growing.

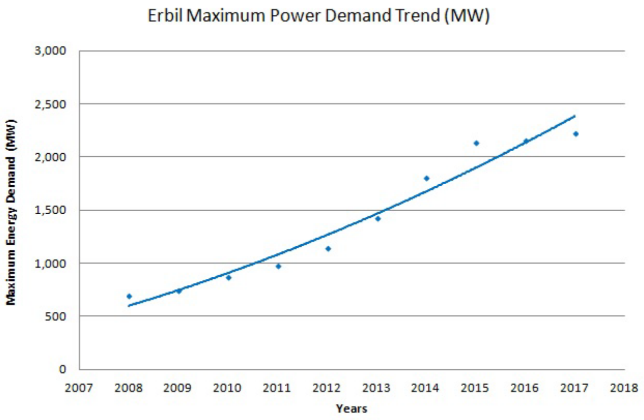

Fig. 4. Trend of maximum demand load in Erbil. Source – Erbil Energy Affairs (EEA) [4]

The utility could not control increasing the electricity demand with all the key developments in the power foundations. With considering the ordinary air conditioning system finds that the systems are using electrically driven based compression technology. The electrical consumption of these devices is high and in the city of Erbil where the climate in summer is hot, these devices bring comfort to human lives but causing a huge electrical demand, paying on huge electrical bills and impact on the environment due to the technology in use.

Since the price of oil is half what it was four years ago, applying the DSM programme will have a significant impact on saving large quantities of lost power.

5.2 Climate Brief:

The climate condition in Erbil varied from four sessions, the difference temperature between summer time with dry, hot air and winter time is around 30 ^{o}C [10].

The climate of Erbil is suitable for applying solar thermal driven technologies because the annual direct normal solar radiation is approximately 2,150 kWh/m^2 as shown the in Fig. 5 [7, 18] and the average percentage of sunny days during the year is about 71% as a statistical data recorded for last eight years as shown the in Fig. 6 [10].

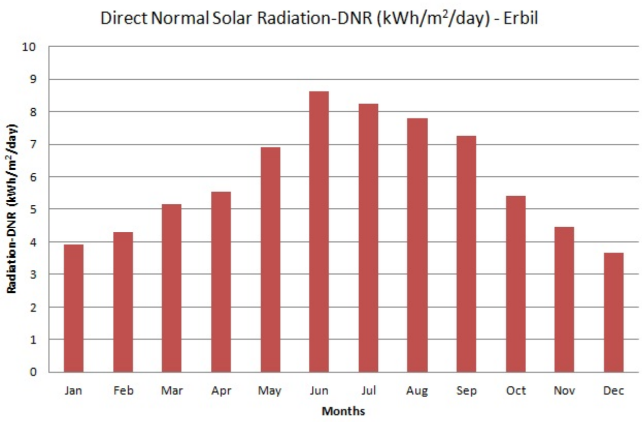

Fig. 5. Direct normal solar radiation DNR for Erbil, Source – NASA database [7]

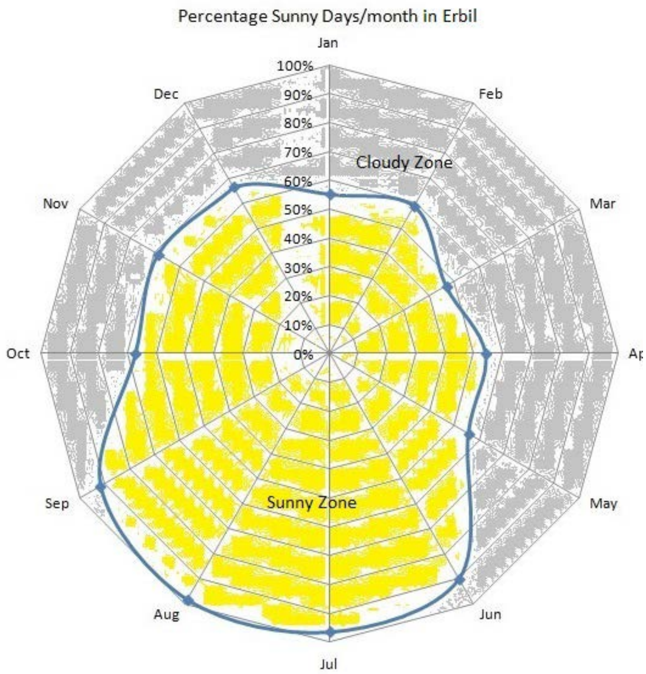

Fig. 6. Sun and cloud days/year in Erbil, Source – world weather online [10]

6. CALCULATION

The market price of an ordinary air-conditioner unit is about US $450, and the annual running cost in the commercial sector is about US $546. In contrast, the market price of a solar-assisted air-conditioner unit is about US $700, and the annual running cost of power in the commercial sector is about US $376.

According to the power consumption above, replacing a ordinary air-conditioner unit with a solar-assisted air-conditioner unit would generate annual savings of up to 1,548 kWh, which corresponds to a capacity of 873 watts from 09:00 AM to 06:00 PM and reducing energy consumption by 37% which cover the peak demand time during the summer season [4] and the consumers will save yearly about US $170.

Applying the DSM programme at over 100,000 offices and shops would reduce the demand load of 87 MW of electricity, which would be a significant step towards for deferring the construction of a power plant of that size for ten years. It would also be a safe and highly effective way of helping the government overcome the current impasse and financial crisis.

In light of the foregoing, the utility could spend US $80 million but generally and continuously save 87 MW of electricity, and a Gas Turbine (GT) power plant of that size would cost US $138 million. In other words, the utility builds an 87-MW capacity power plant for US $80 million, and offices just change their [air-conditioning] units, they would save about US $170 in electricity annually per unit.

7. EXPERIMENTAL RESULTS

The experimental results showed that the average electricity consumption from the ordinary air conditioner and solar-assisted air conditioner are 25.2 kWh and 15.9 kWh, respectively. As shown in Fig. 7. Also, the power demand in (kW) and current load in (ampere) for both air conditioner types are shown in Fig. 8 and Fig. 9, respectively.

Also, total energy consumption during the month of September 2017 of ordinary air conditioner and solar-assisted air conditioner are 755.3kWh/month and 477.2kWh/month, respectively.

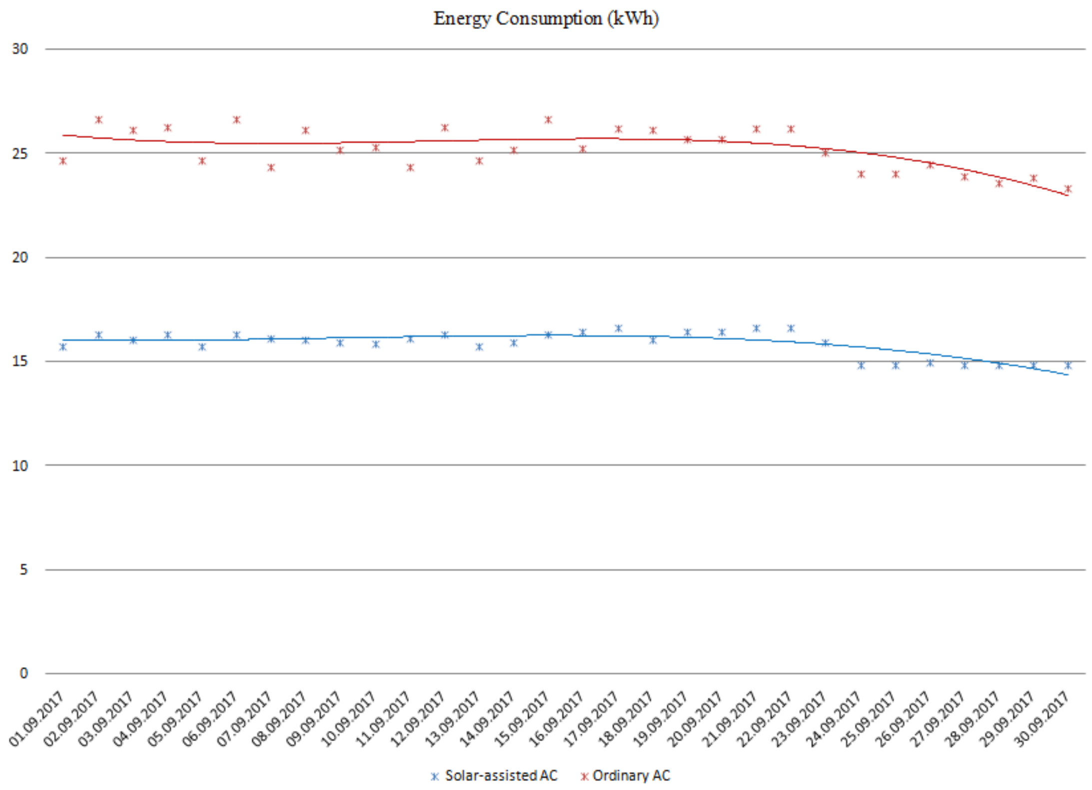

Fig. 7. Energy consumption during SEP2017

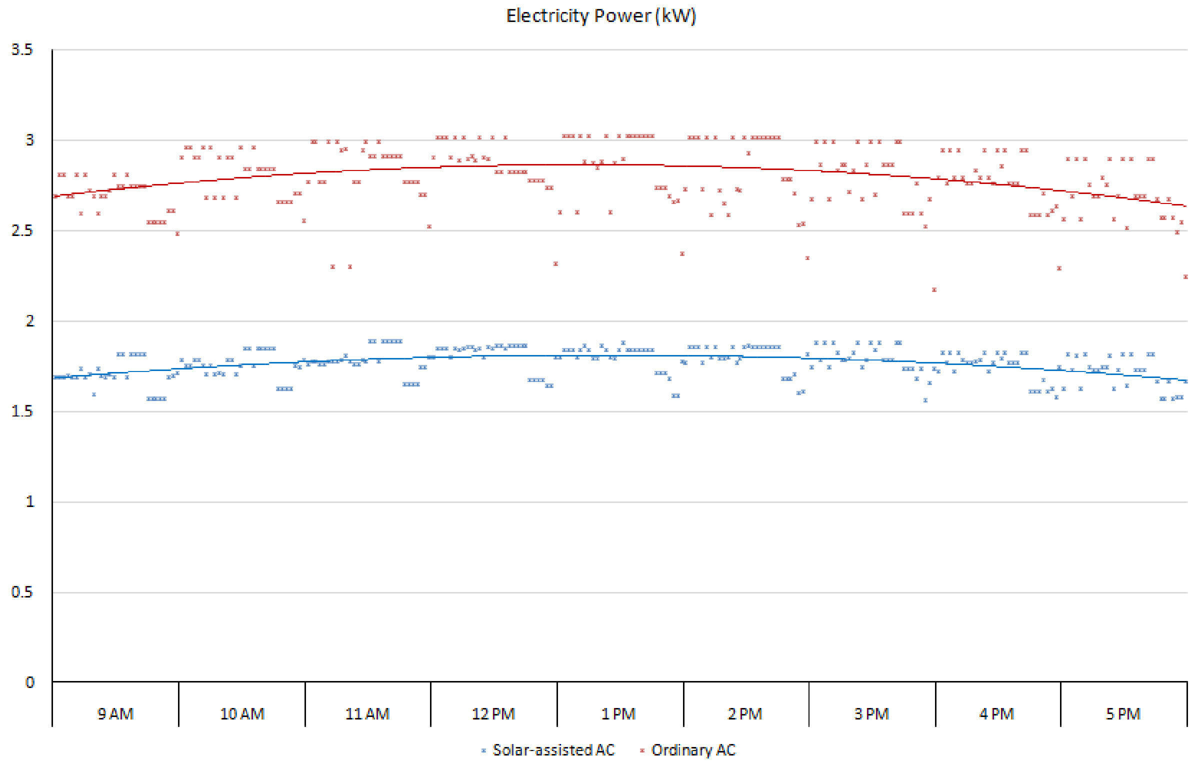

Fig. 8. Both type of AC's power consumption

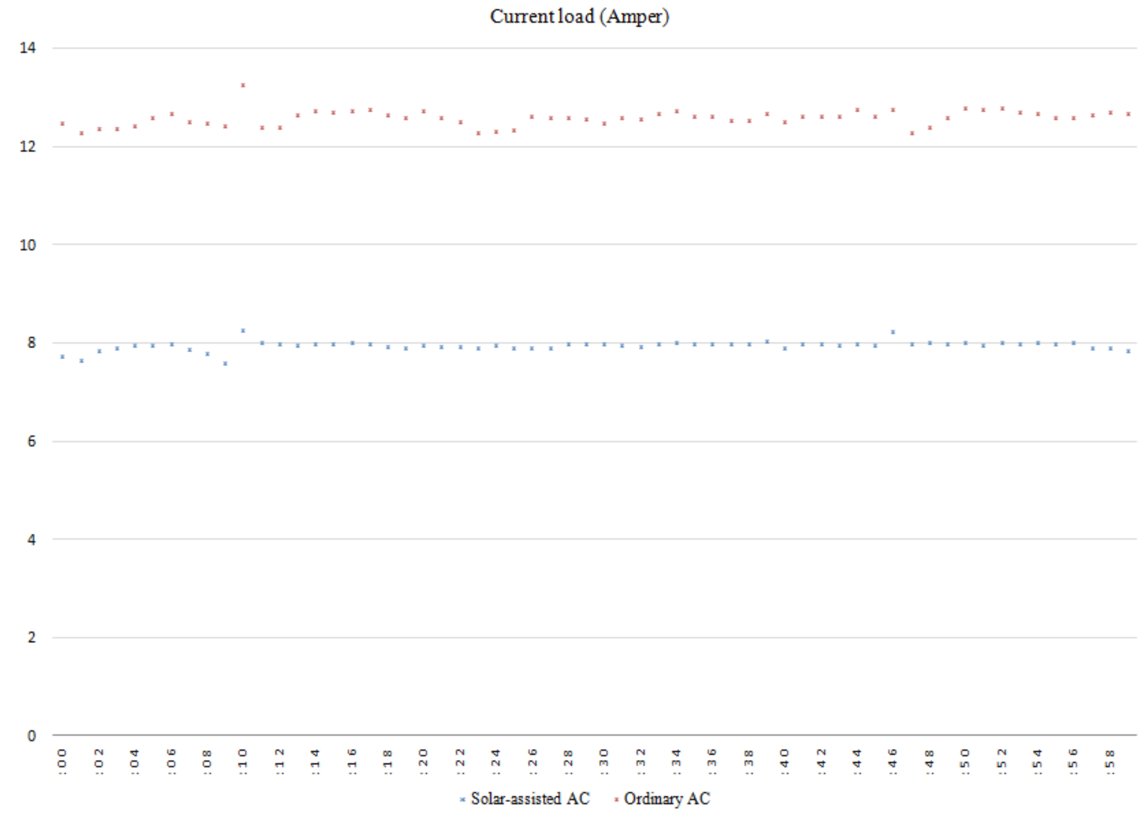

Fig. 9. Current load, Amp.

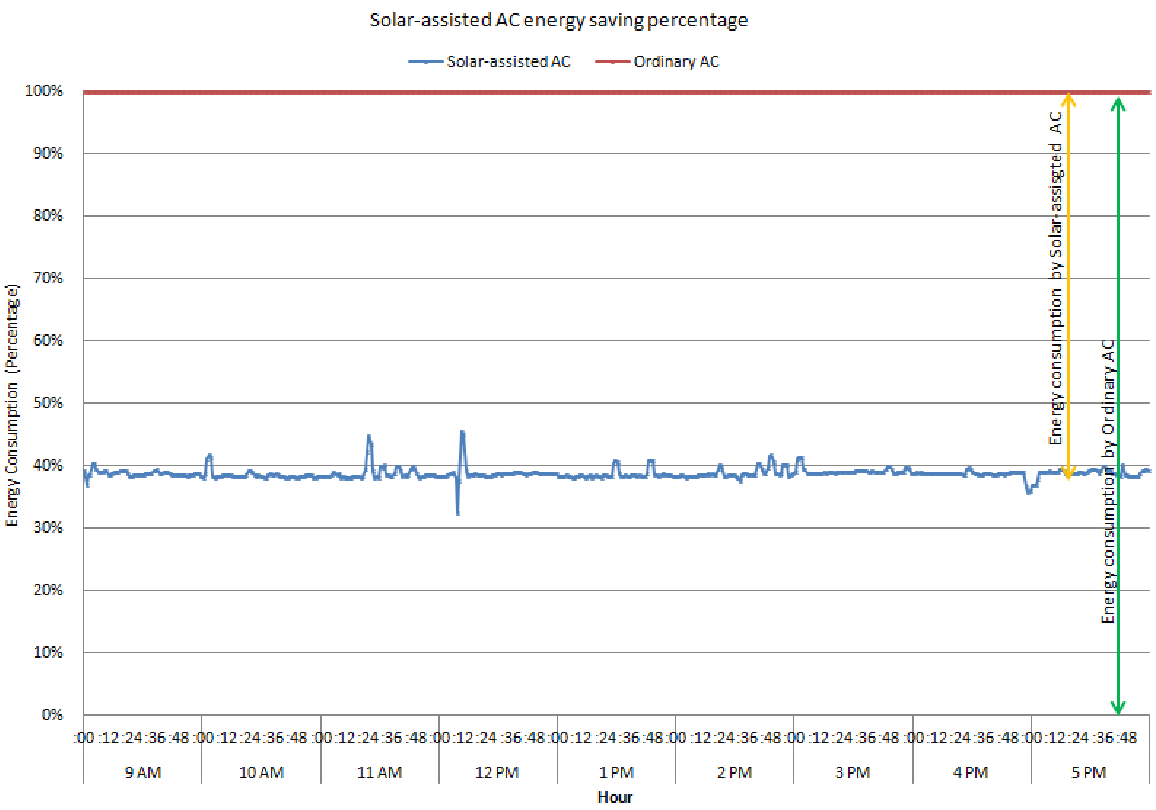

Fig. 10. Solar-assisted AC energy saving percentage compared to ordinary AC

As the result, solar-assisted air conditioners can save energy about 37% as shown in Fig.10 and it is matched with manufacturer specification references [8] and [13]. This load reduction result is a significant value for applying DSM by utilizing solar thermal technologies in many petrol export countries that abundant availability of solar energy.

Table 1. Power Plant Cost. [11]

Suitable Power Plant Type	**Plant Capacity (MW)**	**Capital Cost (US $M)**	**Fixed and Variable O&M Cost for 10-yrs (US $M)**	**Total Cost (US $M)**
Gas Turbine (CT)	87	96	42	138

Table 2. Analysis of Proposed DSM for Erbil

DSM Programme	**Cost/ AC-unit plus rebate (US $)**	**Total Gov. cost (US $M)**	**Peak load redu-ction (MW)**	**Opp. cost (US $/MW saving)**
Replace Ordinary Air Conditioner with Solar-assisted Air Conditioner for 100,000 units	800	80	87	0.9

8. DISCUSSION OF DEMAND SIDE MANAGEMENT

Since the power generation plants in Erbil are unable to supply and meet the demand load for electricity, the utility should have plans and programmes to establish and build a new power plants. Applying the DSM programme could defer the need to construct new power plants for years and the cost of the programme is US $916,380 per MW, this is less than the capital cost per MW of installing new power plant this is excluded the O&M running cost and fuel consumption during that period [11]. In addition, it is known that the government is facing an economic crisis due to the drop in oil prices and other reasons. Indeed, according to the Ministry of Electricity's official annual report, the demand for electricity was increased during last 10 years at a rate of 12.3% per year [5]. The future peak demand L_f can be estimated using the following formula [9]:

$$L_f = (1+X)^Y \times L_c \tag{1}$$

L_c = current peak load (MW)

Y = number of years

X = peak annual rate

The peak demand load in 2017 was 2,218MW and by estimating the same increasing rate of demand 12.3%, in the next 10 years, the peak demand load will be close to 7,000MW. Accordingly, the DSM programme is an encouraging solution to increase the energy efficiency among electricity customers and should be applied now or in the near future in order to stop the increase in demand, which has a significant impact on the country's economy and infrastructure [15]. Since the utility is unable to provide the necessary power at this time, how will it be able to satisfy the increase in demand for electric power in the future?

9. CONCLUSION

In this study, the utility DSM programme with solar thermal technologies is proposed as a new solution transferred to the petrol export countries that abundant availability of solar energy and the stored fossil fuel can be exported to use for increasing revenue to support the country's economy. An offered plan embodies the provision of solar-assisted air conditioners to commercial offices free of charge.

The result can be used applying for DSM programme and to evaluate in the future, the opportunities of deferring the installation of a new power plant.

In the case study of Erbil, it can be concluded that through applying DSM as a new solution for strategic conservation plan with solar-assisted air conditioners, the construction of a US $138 million worth new power plant can be deferred for at least ten years, this is excluded the running cost and fuel consumption during that period, by spending a capital cost of US $80 million for applying DSM plan, and consumers will save energy consumption and bill yearly about 37% and US $170 per unit, respectively.

Acknowledgements

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Nomenclature

DSM Demand-side management

O & M Operation and Maintenance

MW Megawatt, Power

kW Kilowatt, Power

kWh Kilowatt hour, Energy

AC Air conditioner split unit (tons of refrigerant)

L_f Future peak demand load (MW)

Lc Current peak demand load (MW)

DNR Direct normal solar radiation (kW/day/m^2)

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