

Suitability of Demand Response Program Equipped with Solar Energy in UTHM

N. A. Jefry, N. A. Zambri*

Department of Electrical Power Engineering, Faculty Of Electrical and Electronic Engineering, Universiti Tun Hussein Onn Malaysia (UTHM), 86400 Batu Pahat, Johor, Malaysia

*Corresponding author, e-mail: aira@uthm.edu.my

Abstract

Demand Response Program (DRP) is a program developed in western country to cater high load demand. This system enhances the quality of the current smart grid system. This program encourage two-ways interaction between the consumer and the utility provider. The consumers are required to reduce their load consumption upon request by the utility provider, thus avoiding them from paying for the high load demand. However, the current design of DRP is seem to put the user at disadvantages. Thus, deployment of the new practice equipped with renewable energy sources will make the system more user-friendly. As DRP prove to be beneficial in many terms, this project is conducted to find DRP relevancy to be implemented in Universiti Tun Hussein Onn Malaysia (UTHM). According to the electrical consumption data disclosed by Facility Management Division, the power consumed by UTHM is remarkably high especially during 11.00am to 12.00 pm. Thus, DRP is being proposed to be put into practise during this period. Nonetheless, it is not economically wise to implement the program to the whole campus. Therefore, three buildings with the most power consumption had been chosen for this study. They are the library, Faculty of Civil and Environmental Engineering (FKAAS) building and Faculty of Technology and Vocational Education (FPTV) building. The building power consumption and economic evaluation had been analysed using HOMER simulation. From the analysis, the combination of FPTV and FKAAS had been chosen for DRP implementation. The reason are, these buildings have superiority over the library in term of reliability and effectiveness. In terms of economy, it is almost equivalent to each other.

Keywords: demand response program, UTHM, photovoltaic, HOMER

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1. Introduction

The growing number of population each year has led to the desire to obtain a more reliable and high performance electricity transmission and distribution system. Based on the growing pattern, the current conventional system will be less effective for future generation. Thus, studies had been actively conducted in order to counteract this issue.

One effort to prevent the issue from getting out of hand is by improving the efficiency of the current smart grid system. A smart grid is an improvised version of electrical grid that uses information and communication technology (ICT) in an automated fashion [1]. ICT influenced has indirectly increased the performance of the electricity grid in term of its economic factor, sustainability, reliability and efficiency in producing and transmitting electricity.

Another technology that intensify the productivity of smart grid is the demand response program (DRP). DRP paramount function is to address the increasing energy consumption during high peak time or when system reliability imperils [2]. DRP can be further subdivided into incentive based program and time-based rate program. Both programs have different approaches in evaluating the energy consumption matter.

One main environmental problem occurs in Malaysia is the carbon footprints where carbon dioxide (CO₂) emissions happen when the CO₂ gas is released into the atmosphere over specified area and period of time through either natural processes or human activities [3]. As an effort to mitigate the carbon footprints, the deployment of renewable energy sources in the smart grid had been proposed. Besides the ability to reduce carbon footprints, this effort can also act as an alternative for those who are reluctant to participate in DRP.

Not everyone can cope with the revenue loss from curtailing energy consumption. For some large manufacturing firms, they need to sign a contract as an agreement to curtail energy

consumption upon request. As a return, the utility provider will compensate their loss [4]. This may look like a 'win-win' situation in the beginning, but if the matter persists, it will put the firm at disadvantages.

Thus the integration of renewable energy source in DRP is a brilliant step taken in order to create a better performance electricity transmission and distribution system. The system, considering all the benefits that it may serve, will be adequate to cater our need in the future.

2. Research Method

This proposed study exploit the hybrid of a small distributed generation (DG) and the grid system. The DG are made up from photovoltaic (PV) cell since solar energy is the one of the most promising as it is clean and easily available source [5] and it is expected to cater 5% of total consumption of the chosen building during peak-hours period.

2.1. DRP Definition and History

DRP define as a tariff or a program to motivate changes in electricity consumption by the customers in response to change in the price of electricity over time [1]. DRP also define as the electricity usage pattern change via consumer to follow spot electricity price or receiving predesigned incentive to reduce electricity in high price time or when system reliability imperils [2].

Originally, DRP was introduced primarily to manage load consumption when in emergencies state or during peak demand. Back then, there was not much we can do to effectively manage the energy consumption. Forcing the generation plant to work overtime in order to suffice the peak load demand will just increase the operational cost. Thus, to counteract this problem, DRP had been introduced as a method that can economically manage the peak demand issue. In this program, the energy consumed by the participants will be curtailed during high energy consumption. United State was the pioneer participant as they had been practicing the DRP in their load management back in 70s [6]. The technology had evolved over years and today, this method had been acknowledged worldwide.

2.2. DRP in Malaysia

For this pass few years, Malaysia has undergo a rapid economy development. Though it is not as booming as China, the gradual increase has affected the energy market. New generation plants had been introduced to suffice this growing need. The industrial players are the main consumers of the electricity [7]. The electricity market in Malaysia depends on various factor, for example the rate for every units of energy consumption is fluctuating [8]. Plus, taxes and GST had significantly increased the price of electricity. As a result, consumers suffers the burden of high price electricity.

Furthermore, the approach being used by utility provider to cater high demand issue is burdening the consumers. The management is based on surcharge, where the consumer mandatorily being charged for the override. Besides, the reliability of the electrical grid is also questionable. Power shortage still happen despite the increasing number of generation plant. In 2005, a major blackout had occurred in Kapar generation plan that put almost the entire peninsula Malaysia in hours of darkness. Moreover, the impact of renewable energy participation is undeniable which could help to alleviate the energy required by load demand but refined approach still needed to avoid uncertainty over the period of operation [9].

Thus, considering the positive impacts of DRP, Malaysia utilities should revise the possibility of practicing DRP in Malaysia. Findings and data analysis based on the verified data will be presented in this paper.

2.3. UTHM Overview

UTHM is located in Parit Raja, Johor, precisely at coordinate 1.8586 °N 103.0856°E as mapped in the GPS [10]. The weather in UTHM is hot and humid throughout the year. Sun availability will not be a big deal. As compared to other university, UTHM is not gigantic in size. UTHM academic year can be divided into two semester. The first semester is between September and January where as the second semester is between February and July. Normally, the student population is concentrated only during this period.

In terms of the campus size, UTHM is not remarkably huge. The student population is less than 20,000 in year 2016 and expected to grow in the future. UTHM offers various field of studies, including postgraduates and diploma studies. UTHM campus comprises of nine faculties, two grand halls, a library, a mosque and six residential colleges and several management offices. Majority of the lecture halls, offices, tutorial classes are confined room, with air conditioning system as the only option for ventilation.

Due to high dependency on air conditioning system, the power consumption for this campus is expected to be high. Apart from that, UTHM is relying 100% on the power from the grid. Introduction of DRP coordinated with photovoltaic technology hopefully can reduce the dependency on the grid as well as saving more for utility bills.

2.4. Power Consumption in UTHM

Figure 1 illustrated the power consumption in UTHM for the year 2015. The average consumption for one academic year (September to January and February to July) is around 3000 MWh.

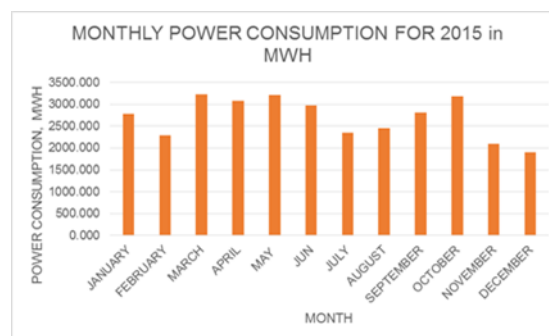


Figure 1. Monthly consumption for year 2015

2.5. Load Analysis

In this project, three buildings had been chosen for the DRP deployment. The chosen buildings are Faculty of Civil and Environmental Engineering (FKAAS), Faculty of Technical and Vocational (FPTV) and Tunku Tun Aminah Library (TTAL). These buildings are chosen based on their floor size and the high monthly power consumption. Table 1 shows the power consumption of top eight buildings in UTHM and their floor size respectively.

From Table 1, the TTAL has the largest power consumption contributing 34% to the total consumption of the eight buildings. As compared to its total floor area, the power consumption is rational but it still remarkably high. As the library is a confined building with operational hours from 8.00 am to 10.00 pm on weekdays, the usage of air conditioning system is expected to be high. Apart from that, the library is the only building that has a dense student's population. Thus, to ensure the occupants are comfortable, air-conditionings are working at its optimum. Followed by the Tunku Tun Aminah library is the Faculty of Civil and Environment Engineering (FKAAS) with 18% of the total consumption in par with Faculty of Technical and Vocational Education (FPTV) with 17%. Among all faculties in UTHM, FKAAS made up the highest population of student. Most classes for FKAAS students are being thought at the faculty as well as FPTV. Hence, this can be the reason for the high power consumption.

The main contributor for high power consumption is the air conditioning system. Air conditioning system contributes up to 60% of the utility bill followed by lighting system which gives out 10%-15% contribution. The remaining is from the audio-visual and other electrical miscellaneous.

Figure 2 shows the power consumption in terms of time block. The time blocks shown are between 8.00 am and 10.00 pm for 21st February 2016. The official operation hours for UTHM is from 8.00 am to 5.00 pm, however, there are lectures being conducted after office hours until 11.00 pm.

As shown in Figure 2, the peak hours are at 12.00 pm and 4.00 pm. These are the time when the day starts to heat up. Due to this uncomfortable condition, the air conditioning system is being operated at its maximum capability. Thus, it leads to the highest power consumption during this hour.

Table 1. Power consumption and floor area

Building	Floor Area (M ²)	Monthly Power Consumption (Kwh)
TTAL	56,189	292,400
FKAAS	42,057	152,390
FPTV	26,426	141,900
FSKTM	10,712	49,470
Block Q	14,198	80,120
DSI	7,666	25,899
Masjid	8,600	33,188
FPTP	14,488	73,391

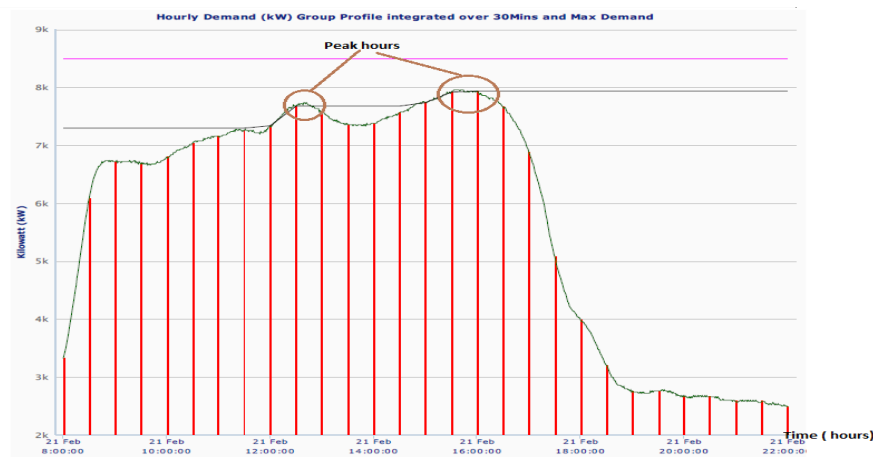


Figure 2. The power consumption according to time block

Therefore, if DRP being put into practised to the power consumption during 11.00 am to 12.00 pm and 4.00 pm, it mitigate the power consumption by switching the power supply to the alternative renewable energy; precisely the energy produced by the photovoltaic cell. Plus, during this time, the sun irradiation is the highest. There will be no problem for the PV to operate at its maximum capabilities.

Undeniably, the price that needs to be paid for installing PV is quite high. However, this system can be paid back in 7-10 years period by calculation. When the PV is not supplying to the load, the power generated by PV cells can be sold to the grid with certain amount of Feed-in-Tariff. The effectiveness of this transaction span for 21 years. Taking 10 years as the maximum payback period, UTHM can fully enjoy the saving for the next 11 years. In addition, new technology such as building integrated photovoltaic (BIPV) become an attractive alternative for both end users and for national policy makers in which photovoltaic technology into buildings is straight forward as no additional space is required and building materials are simply replaced by PV modules [11]. The optimum setting for this system is shown by simulation conducted using HOMER software.

2.6. Homer Analysis

HOMER simulation is software that enables the consumer to do simulation to assist the consumer in designing the micropower systems and to facilitate in the comparison of power generation technologies [12]. This software is developed by the US National Renewable

Energy. This software provides a free trial with a set of complete standard module for the consumers. It can be downloaded from www.homerenergy.com.

In order to put DRP into practise, it is irrational to cater the whole power consumption in UTHM as it seems unprofitable. Undeniably, the capital cost for PV cell is quite high and in order to implement solar energy, large space is needed. Thus, the practice is being applied for certain buildings that have high power consumption and concentration of occupants. Some buildings had been chosen as the subject for the analysis. They are Tunku Tun Aminah Library, Faculty of Civil and Environmental Engineering (FKAAS) and Faculty of Technical and Vocational Education (FPTV). After the simulation has been conducted and analysed, decision will be made based on the most profitable investment as well as the suitability of the implementation.

Before executing the simulation, some limitation had been set to ensure the precision of the simulation output. The first constraint is related to the PV panel. The lifetime of the project is set to 21 years. This figure is according to the value set by Sustainable Environment Development Authority (SEDA) Malaysia [13]. SEDA also responsible in determining the project nominal discount, which is for solar power, 8.0% and also the Feed-in-Tariff (FIT). The value varies, depending on the size of PV array. For this project, the chosen FIT rate is RM0.593. The derating factor of the PV panel is 80% with operating reserve of renewable output is 25%. As the lifespan of the PV panel is set to 25 years, consumers may enjoy the salvage value of the PV panel. PV is assumed to be capable of producing 1,250 kWh for 1 kWp annually.

Next constraint is the whole project is engaged with manual capacity shortage of 5%. Plus, the operating reserve in term of load in current step is 10%. The annual peak load is set to nil as the annual peak for this project is inconsistent. As UTHM is categorized in Large Power Consumer (LPS), the TNB tariff for every 1 kWh is RM 0.365.

In this project, the photovoltaic is being used to supply 5% of the total consumption of the studied building; FKAAS, FPTV and library while the rest of the total consumption will be supplied by the grid. The percentage had been chosen in order to reduce the capital cost of the project. The reliance on PV cell is only from 11.00 am to 12.00 pm. The balance of the PV production will be sold to the grid.

The rate is not fixed and it is reduced as the size of the project growth. This will lengthen the payback period making the investment is unwise. Thus, in order to make this proposed study a wise investment, only small portion of the energy will be taken off from the grid. The capital cost for installing PV to cater up to 30 % of total power consumption is at least 5 million with payback period increase to more than 10 years. The large figure will be the constraint for start-up project. Equation (1) shows the equation to calculate payback period.

$$\text{Payback period (yrs)} = \frac{\text{Capital Cost (RM)}}{\text{Total Revenue per annum}} \quad (1)$$

3. Results and Analysis

3.1. Economic Analysis

1) Tunku Tun Aminah Library

The average total consumption for Tunku Tun Aminah Library for one academic year is 4,562,736 kWh with total budget allocation of RM 1,665,298.64. The capital cost for this project is around RM 1,392,000.00. If 5 % of the total consumption being supplied from PV cell during peak hour, 11.00 am to 12.00pm daily, profit of RM 138,013.03 will be gained every year. Thus, the payback period for this project is 10.1 years. However the result from HOMER simulation will be deviated from the one that manually calculated. From HOMER, the total revenue is RM 1,869,935.00; thus reducing the payback period to only 7.1 years.

2) FPTV

Meanwhile, for FPTV, the average total consumption for one academic year is 1,933,224 kWh with total budget allocation of RM 705,626.76 The capital cost for this project is around RM 700,000.00. If 5 % of the total consumption being supplied from PV cell during peak hour, 11.00 am to 12.00pm daily, profit of RM 72,556.00 will be gained every year. Thus, the payback period for this project is 9.6 years. However the result from HOMER simulation will be deviated from the one that manually calculated. From HOMER, the total revenue is RM 983,707.00; thus reducing the payback period to only 7 years.

3) FKAAS

As for FKAAS, the average total consumption for one academic year is 1,917,480 kWh. Total money spent on this building is approximately RM 671,118.00 annually. The capital cost for this project is around RM 700,000,. If 5 % of the total consumption being supplied from PV cell during peak hour, 11.00 am to 12.00pm daily, profit of RM 71,808 will be gained every year. Thus, the payback period for this project is 9.8 years. However the result from HOMER simulation will be deviated from the one that was manually calculated. From HOMER, the total revenue is RM 972,540; thus reducing the payback period to only 7 years.

3.2. Summary

From the analysis, both manual calculation and HOMER simulation; prove the relevancy of using DRP in UTHM. Instead of curtailing the load during peak hours, user is given the alternative route of power generation. In this case, the alternative route is PV cells. The capital cost for the implementation is quite high, however, with steady sun shine; factoring few months where the weather is rainy, the consistency of solar energy and the various study in PV development such as the effect of temperature to the PV output performances [14] would not be a big problem.

Nonetheless, it is not wise to use DRP for the whole campus as it may double the cost. Thus, the approach that will be taken is by deciding the building with the highest power consumption. From the analysis, implementing DRP to FPTV combined with FKAAS is more favourable than implementing it in library alone. The total power consumption and the Net Production Cost (NPC) of these two buildings is almost the same as the library alone.

Hence, the factors affecting the consideration are the reliability and the effectiveness of the project. The reliability can be explained in term of device failure. Having two separate project will reduce the possibility of malfunction in time of lightning strike or power quality problem. The possibility of lightning to strikes two different location simultaneously is lower as compared to one project alone. Next is in term of effectiveness. Although the two buildings are located in UTHM, both buildings are located in different exact coordinate. This coordinate also will affect the amount of sun ray reaching the PV. Apart from that, both building will never have an identical cloud density. Thus, making the sun irradiation varied depending on the exact location of the object studied.

The result produced by the analysis was indeed virtual and not precise. All the data is based on approximation and algorithm method. However, this result can be a benchmark for the project implementation in the future.

4. Conclusion

The electrical consumption in UTHM is explicitly high as compared to the population density and its floor area. This leads to the high utility bill every year. Even with the implementation of OPTR meter that was supposed to reduce the bill amounts, the figure shows no degradation. Thus, the relevancy of DRP practise in UTHM is being put into this study. However, the DRP being used in this study is not simply using the curtailing method approach. In this case, consumer is given a choice to be 'off-grid' during the peak hours which is 11.00 am to 12.00 pm. The energy being supplied to the system will be from the PV cell. Then, the energy being produced outside the peak hour, will be sold to the grid.

The use of DRP would not cater the whole campus as it seem to be economically unwise for the time being. Yet, buildings with the most power consumption are being targeted. By doing so, hopefully the high energy demand can be limited or reduced. Thus, resulting in lower utility bill. Initially, the chosen buildings that is suitable to implement the study are Tunku Tun Aminah Library, FKAAS and FPTV. In order to make a fair and unbiased choice, analysis and economic simulation had been done to all building. All three buildings prove to be a profitable investment.

Nonetheless, a combination of FPTV and FKAAS had been chose. This decision is being made based on the reliability and effectiveness of the system. The capital cost for the combination of FPTV and FKAAS are almost similar with the library alone. The payback period to recover the capital cost also almost the same. Frankly, implementing DRP in two different places will reduce the possibility of simultaneous failure as compared to implementing it in a

building alone. This point puts the library at disadvantage. Hence, this will be the project saviour in long term.

Acknowledgement

The authors would like to thank the Office for Research, Innovation, Commercialization and Consultancy Management (ORICC) and registrar office of Universiti Tun Hussein Onn Malaysia (UTHM) for the opportunity and sponsoring for this conference.

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