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ENERGY SOLUTIONS FOR THE REDUCTION OF PEAK DEMAND AT TAYLOR'S UNIVERSITY

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Abstract

Peak Demand is a major concern in addressing the commercial or industrial buildings energy saving strategy. Taylor's university lakeside campus (TULC) electricity peak demand consumption is about 30% the total consumption. The charges for the peak demand are about 200 times that of the normal power consumption. On top of this, there is a penalty further if the consumption is over the agreed peak demand usage. An approach to study the peak demand is presented and the results on the photovoltaic standalone implementations to the system is presented and compared for power requirement including the financial implications. It is found implementation of a 3 kW solar unit could reduce the peak demand requirement by 39.68%. With the choice on the optimised position of the solar unit at the appropriate load feeder the savings in cost on the particular feeder is found to be 11.36%.

Keywords: Energy solutions, Peak demand reduction, Ongrid, Photovoltaic.

1. Introduction

Malaysia lying in the equatorial region is exposed to a relatively hot climate with ambient temperature range of 22 °C - 33 °C (72–91 °F). The average daily temperature is 26.5 °C [1]. Figure 1 shows the yearly average solar radiation in Malaysia (kWh/m^2) and is inferred that the peak demand analysis study area receives approximately 1550 kWh/m^2. The location focused on is Taylor's University Lakeside Campus (TULC), Malaysia which is at West of Malaysia laced at coordinated 3.0750° N, 101.5911° E [2]. The most common factor that influences the energy management is the active energy consumption in kWh, the reactive energy consumption in kVARh and the peak demand in kW.

Nomenclatures

A_c	Area of Campus
A_R	Average Peak Demand
k_d	Demand Factor
k_p	Penalty Factor
L_x	Load Compensator to reduce the peak demand
P_A	Actual Power
P_C	Contracted Power
P_D	Peak Demand
P_{Dm}	Actual Demand Power
P_{Dx}	Peak Demand for the Calculation period
$P_{Dx(new)}$	New Peak Demand for the Calculation period
P_E	Excess Power Unused
P_p	Penalty Power Value

Abbreviations

Hz	Frequency
kVA	Kilo Volt Amperes
kVARh	Kilo Volt-Amp Reactive Hour
kW	Kilo-watts
kWh	Kilo Watt-hour
MSB	Main Switch Board
PV	Photo Voltaic
TNB	Tenaga Nasional Berhad
TULC	Taylor's University Lakeside Campus

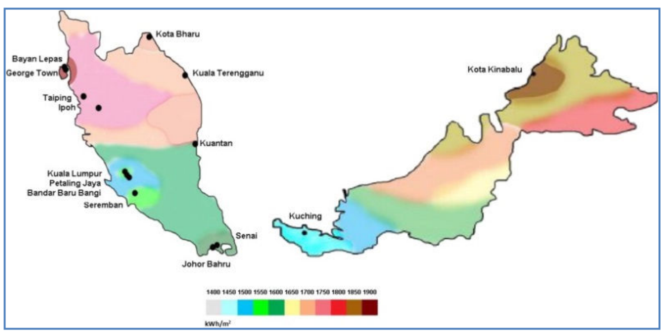


Fig. 1. Average solar radiation in Malaysia (kWh/m^2) [1].

Medium and high voltage consumers prefer kW peak demand management to reduce the use of contracted power, adjusting to the new requirement and avoiding the demand limit penalties [3]. Figure 2 shows the concept in the power management. The power management is interlinked and the possible energy management between the kW and kVARh and thereby the net power consumption can be reduced. In order to find the peak demand requirement, a peak demand analysis for a certain period of time needs to be investigated. Peak demand is the power consumed over a predetermined period of time, typically between 8 min to 30 min. The power is calculated using a power demand meter, which records the highest kW value in the period of measurement, over a month's time. The purpose of demand control is to avoid exceeding the contracted peak demand limit. A number of power demand modelling and analysis, towards optimisation of demand curve [4-6] as well as forecasting [7, 8] are the subjects of interest in recent years. However, accuracy and resolution of the model are important [9, 10]. Once the peak demand is analysed then the loading is classified based on the feeder ratings.

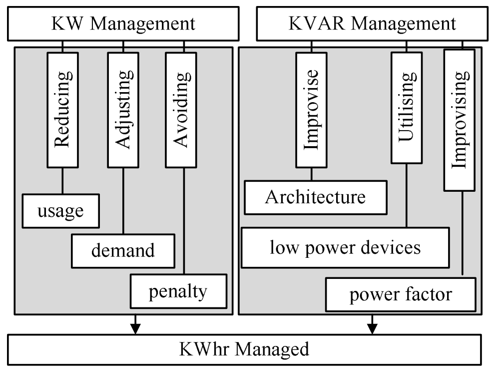


Fig. 2. Peak demand management strategy.

2. TULC Power System Architecture

Taylor's university is supplied with high voltage 11 kV /415 Volt electrical supplies by the Tenaga National Berhad (TNB) with four incoming feeder power supply. Two of the feeders cater for 2500 kVA and the other two numbers of 1600 kVA. The power system architecture consisting of a primary side main vacuum circuit breaker, a switchgear at secondary side, a distribution switch board (essential and non-essential) switch board, a TNB metering panel, a sub switch board, a distribution board, and an auxiliary sub circuit [11, 12]. The facility is supported with some generator sets located at generator set room at Block D with handling capacity 1200 kVA. A Main Switch Board (MSB) for the Block A and B is located at the ground floor the Block B and another MSB of Block C, D and E is located at the Block D roof top. Figure 3 shows the image of the TULC with various load distribution units as the Block A, B, C, D and E. Table 1 shows the peak current capacity of the various MSB. The quantitative approaches are adopted to determine the maximum area for PV implementation as part of energy solution [13]. Based on the schematic diagram of the roof top area of the Block A, B, C and D, the dimension of the rooftop area each block is computed to nearest estimation. This is performed with the aid of Google map of the whole campus area and calculation of the total roof top area (A_C) using Eq. (1).

$$A_C = Area\ of\ Block\ (A + B + C + D + E) \qquad (1)$$

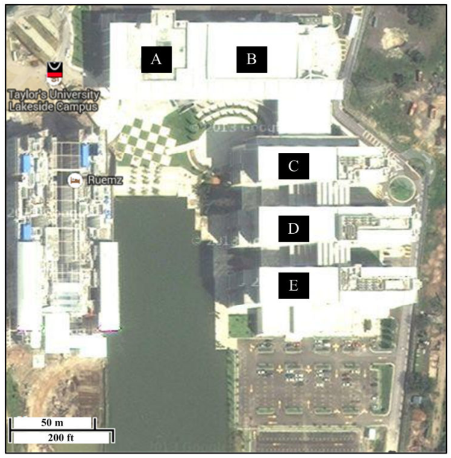


Fig. 3. TULC satellite view (image taken from Google map).

Table 1. MSB current capacity.

Peak Current Capacity	
MSB 1	2500Amps
MSB 2	2500Amps
MSB 3	4000 Amps
MSB 4	4000 Amps

3. Methodology

A power system architecture is shown in Fig. 4. The computation procedure for the demand analysis and the net kW demand computation is stated below. Let the contracted power be (P_C), the peak demand is (P_D), the power used in excess be (P_E), is the actual peak demand value from the peak demand meter be (P_{Dm}), Therefore, the actual kW value (P_A) computed is given by Eq. (2).

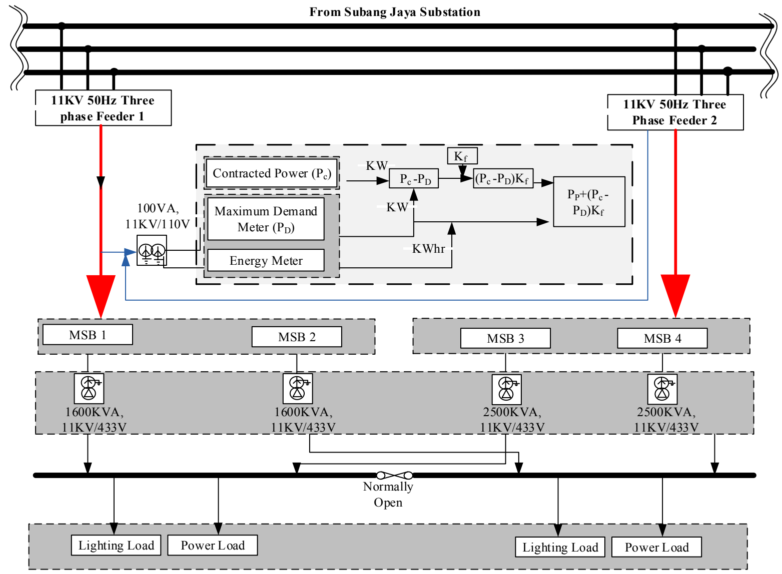
$$P_A = [(P_C - P_D) X K_P] + [P_{Dm} X K_d] \quad (2)$$

The demand analysis is made based the grid-PV capable to suffice the selected load throughout demand period. The, average ratio of selected load to average peak demand (A_R) of connected MSB for the year 2013, is as in Eq. (3).

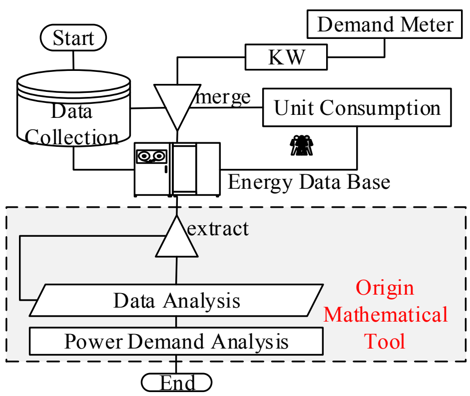
$$A_R = \frac{Load\ Size\ (kVA)}{Average\ MD\ of\ connected\ MSB(kVA)} \quad (3)$$

Based on the ratio obtained, monthly impact of the selected load is tapped with grid-PV on the peak demand of its MSB, L_x is computed using the following Eq. (4) for 12 months in the year 2013.

$$L_x = A_R \times average\ load\ of\ the\ month(kVA) \quad (4)$$



(a) Peak demand compensation logic.



(b) Data Handling and Extraction Method

Fig. 4. Power system architecture for the peak demand computations [12].

Therefore, based on L_x, the new load of the connected MSB which has the grid-PV tapped to its load is computed using Eq. (4). Assuming, the selected load tapped with grid-PV is completely powered using solar power and no power consumed from the grid. Thus, new monthly load of the MSB for the year 2013 is tabulated. Based on tabulation, percentage difference and graphical analysis between new MSB load with grid-PV and MSB load is done. Based on the new monthly MSB loading, the new monthly peak demand for the selected MSB, P_{Dx} is computed using Eq. (5), by assuming power factor of the selected MSB is 0.9.

$$P_{Dx} = L_x \times power\ factor \quad (5)$$

The new monthly peak demand of the selected MSB, P_{Dx} is used to calculate the new monthly peak demand of TULC for the year 2013, $P_{Dx(new)}$ is computed. The results obtained is tabulated and plotted in comparison with the original peak demand of the campus. The percentage difference in the peak demand is also computed to determine impact of the grid-PV in reducing the peak demand.

4. Analysis and Discussion

4.1. Peak demand

Figure 5 shows the monthly recorded peak demand of the campus [1, 11-12]. It can be seen that the campus has a monthly average peak demand of 2974 kW. The highest peak demand recorded is 3257 kW in the month of October. The average peak demand is about 21% and the kWh utility, which is about 79% for the three year period. If the average peak demand is catered through an optimised energy management system the power system network ideally becomes sustainable.

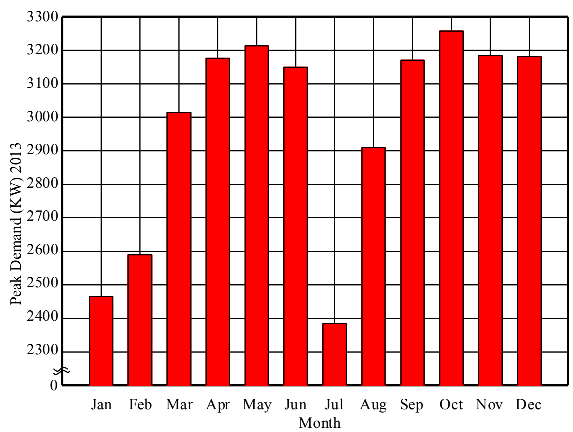


Fig. 5. Monthly peak demand, 2013 [2].

4.2. Analysis on daily peak demand

Figure 6(a) shows the power consumed by running connected loads of MSB1 at different timings on weekday basis. The result shows that the connected loads of MSB1 have average total power consumption of 668 kW. The peak power consumption of MSB1 is on Thursday at 12 pm which is 733 kW. Based on pattern of the plotted figure, it can be seen that the highest power consumption is high from 12pm to 3pm in most days. Figure 6(b) shows the power consumed by running connected loads of a MSB2 at different timings on weekday basis. The results show that the connected loads of the MSB2 have an average total power consumption of 294.1 kW. The peak power consumption of the MSB2 is on Tuesday at 3 pm which is 328 kW. Based on pattern of the plotted figure, it can be seen that the power consumption is higher between 12pm to 4pm in most days. Figure 6(c) shows the power consumed by running connected loads of a MSB3 at different timings on weekday basis. The results shows that the running connected loads of the MSB3 have average total power consumption of 1066.4 kW. The peak power consumption of the MSB3 is on Thursday at 2 pm which is 1239 kW. Based on pattern of the plotted figure, it can be seen that the power consumption is high from 2pm to 4pm in most days. Figure 6(d) shows the power consumed by running connected loads of a MSB4 at different timings on weekday basis. The results shows that the running connected loads of the MSB4 have average total power consumption of 668.1 kW. The peak power consumption of the MSB4 is on Thursday at 3 pm which is 729 kW. Based on pattern of the plotted figure, it can be seen that the power consumption is high from 1pm to 4pm in most days. The percentage contribution of each MSB on the total power consumed by all MSBs is shown in Table 2. As an overall summary, MSB3 and MSB 4 are the highest load contributors of the campus. The demand period of the campus based on average occurrence of daily high power consumption duration is between 12pm to 4 pm. Implementing PV can reduce peak demand during sunshine.

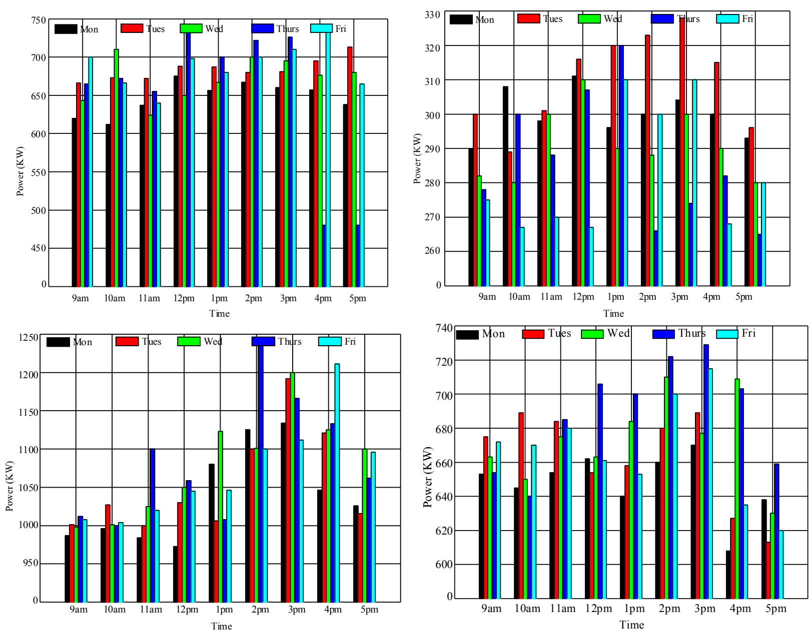


Fig. 6. Daily power consumption of MSB1 with respect to time.

Table 2. Percentage contribution by each MSB with respect to time.

Main Switchboard	Percentage of Contribution (%)
MSB1	24.55
MSB2	10.86
MSB3	39.84
MSB4	24.74

4.3. Energy solution for peak demand reduction

An on-grid PV solution is modelled for the energy solution at the test facility design [13]. In order to optimise the position on placement, a simulation on the various loading condition with a sized PV is tested and tabulated in Table 3. It can be seen that there are significant changes in reactive power flow in Feeder 1, Feeder 2 and Transformer 4. The power consumption of the Feeder 1 and Feeder 2 from the grid has reduced by 9.36%. The power consumption from the grid of the load 4 and load 5 has reduced by 34.2%. The PV sized to tap with Load 5 is sized, by taking into consideration the peak sun hours. Thus, it is assumed that PV sized large enough to suffice the demand of Load 5 throughout the demand period and to power the Load 5 from 9 am to 5 pm. Table 4 shows the impact on the chosen Load 5 with the designed PV in place. Therefore, based on L_x the new load of the MSB4 is computed. Whereby, the assumption made is that the Load 5 is completely powered by PV thus no power is consumed from the grid. Thus, new load for the MSB4, a new MSB4 is computed and shown in Table 5.

Figure 7 shows the graphical analysis of load of the MSB4 (kVA) and new load of the MSB4 (kVA) for the year 2013. Based on the figure, it is seen there is a significant variation on the load of the new and existing MSB4. The percentage difference between the new and existingMSB4, $Percent_{diff}$ is given in Eq. (6).

$$Percent_{diff} = \frac{(554.425 - 334.4292)}{554.425} \times 100\% = 39.68\% \quad (6)$$

Table 3. Comparison with and without grid-PV.

Element	Existing System	With Proposed System
Feeder 1	1367	1239
Feeder 2	1367	1239
Transformer 1	747	747
Transformer 2	349	349
Transformer 3	888	888
Transformer 4	749	493
Load 1	744	744
Load 2	349	349
Load 3	886	886
Load 4	528	529
Load 5	219	220
PVA1 (grid-PV)	Not Available	256

Table 4. Impact of Load 5 on the MSB4.

Month	With Existing MSB4	With Existing MSB4 on L_x
January	469.5	186.2976
February	457.1	181.37728
March	511.3	202.88384
April	571	226.5728
May	619.6	245.85728
June	590.5	234.3104
July	498	197.6064
August	493.5	206.4
September	495.1	186
October	541.4	297.1
November	579.6	213.5
December	450.3	207.4

Table 5. Comparison between original and proposed load on the MSB4.

Month	MSB4 (kVA) for 2013	N_{MSB4} (kVA) for 2013
January	469.5	283.2024
February	457.1	275.72272
March	511.3	308.41616
April	571	344.4272
May	619.6	373.74272
June	590.5	356.1896
July	498	300.3936
August	493.5	330.01072
September	495.1	300.63488
October	541.4	505.90384
November	579.6	328.08048
December	450.3	306.4256

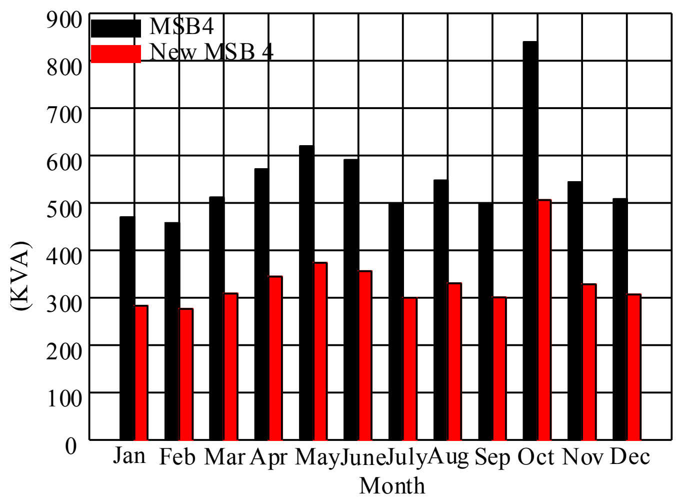


Fig. 7. Comparison of new MSB4 and MSB4 on L_x.

4.4. Economic analysis on the peak demand reduction

Based on the new peak demand MSB4, $P_{Dx(new)}$.The new peak demand of TULC for the year 2013, $P_{Dx(new)}$ is shown in Fig. 8 in comparison with peak demand of TULC for year 2013, P_D. The percentage difference between $P_{Dx(new)}$ and P_D is 11.36%. The percentage difference is as shown in Eq. (7).

$$Percent_{diff} = \frac{(1937.191667-1717.195827)}{1937.191667} \times 100\% = 11.36\% \tag{7}$$

The cost comparison between original cost of peak demand, MDC $_{(month)}$ and new peak demand of TULC $N_{MDC\ (month)}$ is shown in Fig. 9. The percentage difference of P_D and $P_{Dx(new))}$ is 11.36%. This means, the new peak demand after grid-PV is 11.36% cheaper as compared to cost of peak demand prior installation of grid-PV.

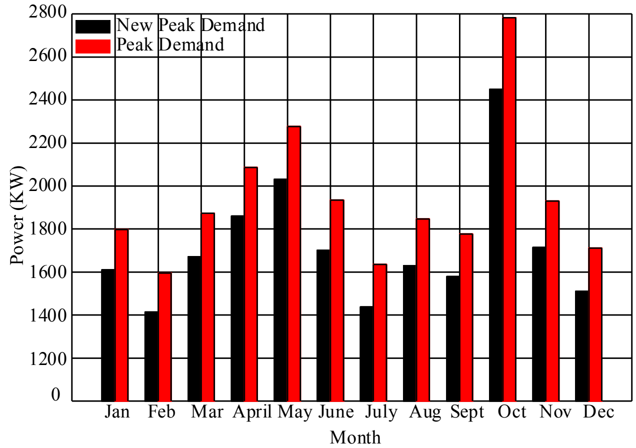


Fig. 8. Comparison between new peak demand and peak demand.

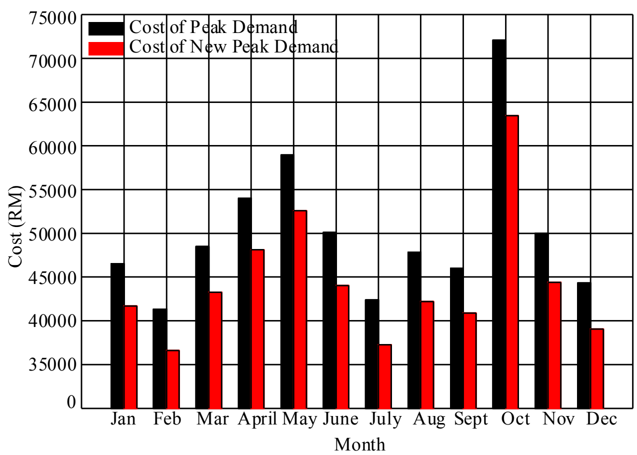


Fig. 9. Economic savings with peak demand reduction.

5. Conclusions

An appropriate implementation of a photovoltaic system could support the sustainability of the commercial and industrial unit. Taylor's university lakeside campus electricity peak demand consumption is about 30% the total consumption. An approach on reduction of the peak demand requirement through the numerical design is presented. It is found implementation of a 3kW solar unit could reduce the peak demand requirement by 39.68%. With the choice on the optimised position of the solar unit at the appropriate load feeder the savings in cost on the particular feeder is found to be 11.36%.

References

1. Wong, J.; Lim, Y.S.; Tang, J.H.; and Morris, E. (2014). Grid-connected photovoltaic system in Malaysia: A review on voltage issues. *Renewable Sustainaible Energy Reviews*, 29, 535–545.
2. Taylor's University (2014). Retrieved February 19, 2014, from http://www.taylors.edu.my.
3. Zedan, F.M.; Al-Shehri, A.M.; Zakhary, S.Z.; Al-Anazi, M.H.; Al-Mozan, AS.; and Al-Zaid, Z.R. (2010). A nonzero sum approach to interactive electricity consumption. *IEEE Transactions on Power Delivery*, 25(1), 66-71.
4. Pallotti, E.; Mangiatordi, F.; Fasano, M.; and Del Vecchio, P. (2013). GA strategies for optimal planning of daily energy consumptions and user satisfaction in buildings. *International Conference on Environment and Electrical Engineering* (*EEEIC*), 440-444.
5. Koutitas, G.; and Tassiulas, L. (2013). Periodic flexible demand: optimization and phase management in the smart grid. *IEEE Transactions on Smart Grid,* 4(3), 1305-1313.
6. Miorandi, D.; and De Pellegrini, F. (2012). Demand-side management in smart grids: An evolutionary games perspective. *International Conference on Performance Evaluation Methodologies and Tool*, 178-187.
7. Hernandez, L.; Baladron, C.; Aguiar, J.; Carro, B.; Sanchez-Esguevillas, A; Lloret, J.; and Massana, J. (2012). A survey on electric power demand forecasting: future trends in smart grids, microgrids and smart buildings. *IEEE Communications Surveys & Tutorials,* 16(3), 1460-1495.
8. Hoffman, A.J. (1998). Peak demand control in commercial buildings with target peak adjustment based on load forecasting. *IEEE International Conference on Control Applications*, 2, 1292-1296.
9. Lin, Y.; and Gang, Q. (2005). Analysis of energy reduction on dynamic voltage scaling-enabled systems. *IEEE Transactions on Computer-Aided Design of Integrated Circuits and Systems,* 24(12), 1827-1837.
10. Rethinagiri, S.K.; Palomar, O.; Unsal, O.; Cristal, A.; Ben A.R.; and Niar, S. (2014). PETS: Power and energy estimation tool at system-level. *International Symposium on Quality Electronic Design,* 535-542.
11. Aravind, C.V.; Mushtak, Al-Atabi.; Arasan, B.; and Ramesh, G.P. (2014). The case of the energy solution to the eco-tourism model for sustainable development using PV/T technology. *International Journal of Scientific & Engineering Research*, 5(4), 174-177.
12. Nadarajan, S.; and Aravind C.V. (2013). Peak demand analysis for the look-ahead energy management system at Taylor's University Engineering. *Engineering Undergraduate Research Catalyst Conference*, Kuala Lumpur.
13. Aravind, C.V.; Al-Atabi, M.; Jayashri, R.; Anam, M.; Arkar.; Eliathambi, A. (2013). Eco-tourism sustainability through PV Technology: A comprehensive review. *Journal of Engineering Science and Technology*, 8(6), 654-668.