Visualizing a Control Strategy for Estimating Electricity Consumption

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ABSTRACT
This paper investigates the potential of applying different control measures on low power and high power appliances with the goal of evolving efficiency in electricity consumption. The research involves carrying out simulations on their power consumption readings to set up a control system. The study discovers savings on all appliances under study to be 12.8% Kw, not minding occupancy rate of the building. Air-conditioners have the greatest impact of a 6% Kw contribution on savings. This would lead to a substantial contribution when converted to pricing rates. The results from the study indicate that control measures should be extended to peak periods and power saving measures extended to more appliances.

Keywords
Control measures, efficiency, simulation, occupancy rate, savings.

1. INTRODUCTION
This research proposes a control strategy to estimate electricity consumption which can be used to improve efficiency in electricity usage. Due to the importance of having an efficient electricity consumption system, various studies have addressed the issue of finding a solution to this problem. This varies from the use of sensors, which regulates and control electric usage, to the efficient allocation and scheduling of electric power supply [1]. A previous research derives a speed control strategy to improve operations of renewable source of electricity by promoting manufacture of wind turbines [2]. It is based on the Newton's method, which is a numerical technique.

A paper introducing the use of a smart meter, comprising of an energy consumption controller (ECC) is used to determine whether electricity prices would fluctuate if users shift their energy consumption schedule of high load household appliances to off-peak hours to reduce energy expenses [3]. In the analysis, Heating Ventilation and Air conditioning (HVAC) systems are investigated. These are considered to be high power appliances. Efficiency in electricity consumption was applied to control of Heating Ventilation and Air conditioning systems (HVAC) because of their large energy footprint, [4]. This involves building a mathematical model of the temperature dynamics of the room, and combining this model with statistical methods allows us to compute the heating load due to occupants and equipment using only a single temperature sensor. A paper [5] introducing a load shedding algorithm to maximize efficiency under certain requirements was presented. It employs an algorithm with penalty function method (PFM) and the simplex method (SM) compiled by C++. This algorithm leads to rapid computation speed.

Past research of determining efficiency in electricity consumption is mainly based on control of high power appliances; it does not consider control of low power electrical appliances. The current research seeks to investigate if it is possible to obtain better performance level when controls of low power appliances are considered, together with high power electrical appliances. This research work will implement a control strategy for computing electricity consumption with the goal to minimize electricity wastages in the system and ultimately the costs. This will take into account energy consumption for each electrical appliance, varying time intervals for each appliance, which are used for decision making.

2. METHODOLOGY
The methodology developed in this research involves electricity consumption based on real electricity consumption measurements which are collected from individual appliances through the use of installed power meter connected to electricity grid in the Faculty of Computer Science and Information Technology building, Universiti Malaysia Sarawak where data in this research study is collected from. The study models electricity consumption in order to find out control effects of

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applying power saving measures on low power and high power appliances.

The simulation of time-based electricity consumption visualizations for low power and high power appliances used in this research study is carried out to evaluate the level of efficiency in their electricity consumption. The research is based on real-time electricity consumption data collected for low power appliances; computers, closed-circuit TV (CCTV) and high power appliances; air-conditioners, electricity lightings over a period of time while simulation is carried out for individual appliances.

By applying control measures between the periods October 2013 – December 2013, consumption measurements are obtained for the four appliances under study. For application of control measures to the various appliances, the air-conditioners were switched off at certain periods of the day, i.e. between 6p.m – 12 midnight. The lighting systems in level 1 of FCSIT building were replaced with lighting-emitting diode (LED) lights; CCTV's were connected to power back-ups and power saving measures was applied on computers in level 1 of the building within a period of time. Figure 1 shows a model to determine efficiency in electricity consumption by considering low power and high power appliances.

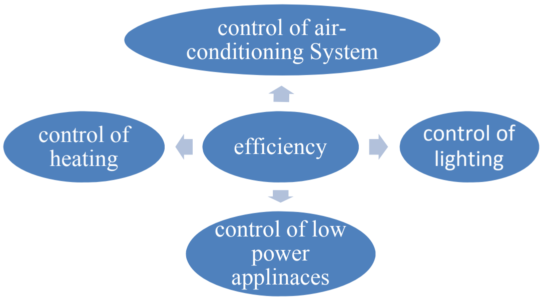

Figure 1. Control strategy to determine efficiency in electricity consumption.

To formulate models for electricity consumption systems, firstly, the different types of appliances that would be considered are identified. In order to effectively model the electricity consumption problem, this research measures and controls electricity consumption for the selected appliances, the frequency of consumption for each appliance and at what time of the day electricity is consumed by these appliances.

In this research, the standard deviation (SD), which is the square root of the variance, is used to compute variations between measurements obtained from appliances while applying power saving measures (controlled) and measurements obtained from appliances without power saving measures (uncontrolled). The study applies SD in order to calculate the percentage difference between the respective measurements for controlled data and uncontrolled data, whereby investigating the degree of effectiveness of the application of power saving measures to individual appliances.

This research utilizes a similar technique applied in a study on genome biology, [6]. It uses SD to measure level of variability between experiments conducted for perfect match (PM)-only model and experiments conducted for PM/mismatch (MM) difference model in the model-based expression indexes (MBEI) study. In the study, variability between the two experiments is reduced for lower SD estimates and provides a natural method of investigating variations and reliability between two techniques in model analysis.

SD can be expressed as:

$$SD = \sqrt{\frac{S_1{}^2+S_2{}^2}{n-1}} \quad (1)$$

where,

$$S^2{}_1 = \sqrt{\sum_{i=1}^{n} \frac{(x_i-\mu)}{n-1}} \quad (2)$$

For $x_1, x_2, \ldots, x_n$ independent variables denoting meter readings without power saving measures.

$$S^2{}_2 = \sqrt{\sum_{i=1}^{n} \frac{(y_i-\mu)}{n-1}} \quad (3)$$

for $y_1, y_2, \ldots, y_n$ independent variables denoting meter readings while applying power saving measures.

μ = population mean and n = sample size.

3. SIMULATION RESULTS

Electricity consumption data simulations were made using the Matlab and the SPSS software in order to compute daily meter readings for each appliance, over the duration of the given period. The software utilizes daily electricity consumption data readings and takes into account power consumption for each appliance.

Figure 2 present the trend of daily electricity consumption for selected low power and high power appliances under study in 2013.

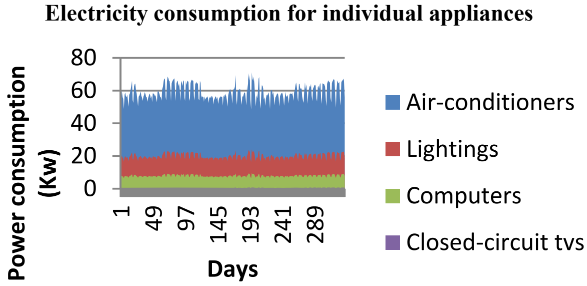

Figure 2. Electricity consumption for Appliances (Source: Jan 1-Dec 31, 2013).

It shows clearly that consumption for the high power appliances, i.e. air-conditioners and lighting systems are very much higher than those for low power appliances, i.e. computers and CCTV's. The consumption for low power appliances fall below a daily value of 35 Kw, while that of high power appliances are of higher consumption values.

Power saves or control measures were applied to appliances by making comparison with actual meter readings for appliances without the application of power saving measures in order to find out power savings for each appliance.

In the analysis carried out, computations of variations in the application of power saving measures to individual appliances yielded the following SD values:

Table 1: SD values obtained for applying control measures to individual appliances

Appliances	SD
Air-conditioners	6
Lighting	2
Computers	1
CCTV's	0.1

Figure 3-6 shows comparisons for the selected appliances between simulated data for daily electricity consumption and their respective control measurements.

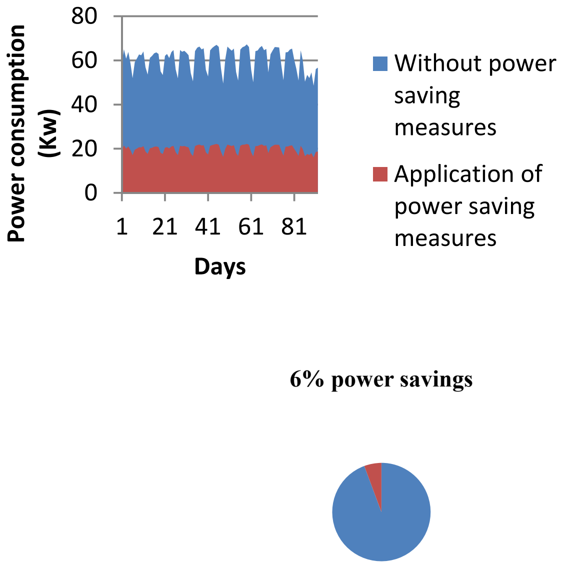

Figure 3. Controlled vs uncontrolled power consumption for Air-conditioners (Source: Oct 1- Dec 31, 2013).

For Figure 3, an inefficient situation without switching off the air-conditioners would lead to an over-consumption of 6% Kw by comparison with the controlled case.

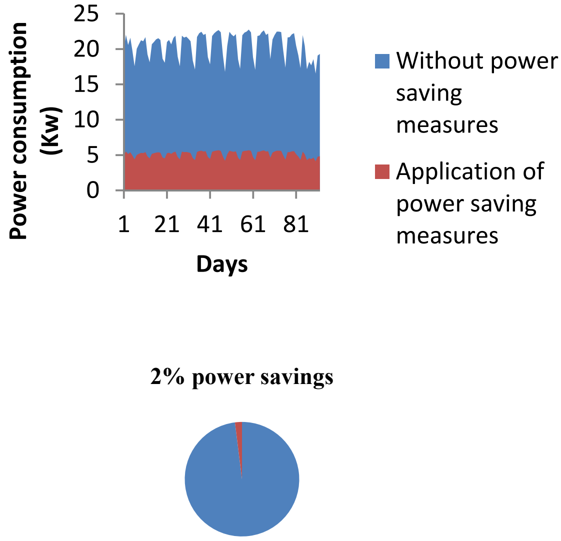

Figure 4. Controlled vs uncontrolled power consumption for Lighting (Source: Oct 1- Dec 31, 2013).

From Figure 4, an inefficient situation without using LED lightings would lead to an over-consumption of 2% Kw by comparing with the controlled case.

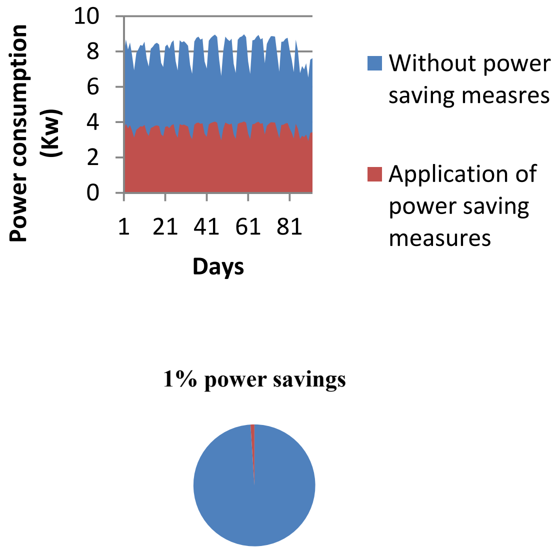

Figure 5. Controlled vs uncontrolled power consumption for Computers (Source: Oct 1- Dec 31, 2013).

From Figure 5, an inefficient situation without applying power saving measures to computers would lead to an over-consumption of 1% Kw by comparison with the controlled case.

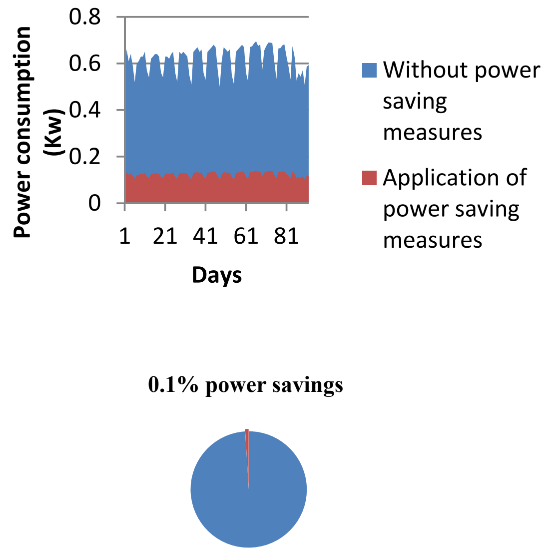

Figure 6. Controlled vs uncontrolled power consumption for CCTV's (Source: Oct 1- Dec 31, 2013).

For Figure 6, an inefficient situation without using power-backups would lead to an over-consumption of 0.1% Kw by comparison with the controlled case.

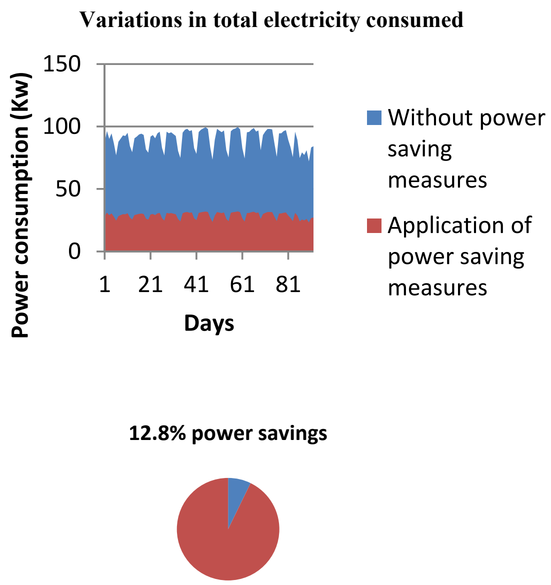

Figure 7. Controlled vs uncontrolled power consumption for total electricity consumed (Source: Oct 1- Dec 31, 2013).

The research investigates the gains obtained with the application of power saving measures on low power and high power appliances. Considering all appliances under study, SD = 12.8, which gives an over-consumption of 12.8% Kw by comparison with the controlled case (Figure 7). Comparing the application of control measures on the different appliances, most savings is obtained from controlling for efficiency in air-conditioners; an estimate of 6% is saved in Kw, which makes it the most high power consuming appliance in this study.

It is observed that the respective area charts for individual appliances presented in Fig. 3 to Fig. 6 indicate substantial higher consumption compared to power savings represented by their respective pie charts. The results from the study show that while there is over-consumption without the application of power saving measures, the resulting power savings for individual appliance differs depending on whether it is low power or high power appliance, and the power consumption show fractional savings, which albeit will have an effect on total electricity costs.

4. CONCLUSION

This paper tried to analyse the performance of applying power saving measures on low power and high power appliances to enhance efficiency.

The first part investigates power meter measurement of different appliances, including readings from applying control systems on the appliances. Electricity consumed was measured by the power meter, with and without application of power saving measures. In the research, it is discovered the control on air- conditioner has a saving of 6% Kw and the control on CCTV's has a savings of 0.1% Kw. This would infer some multiples of costs would be saved when converted to pricing rates. More over the overall contribution to savings when a combination of low power and high power appliances are considered in this study is 12.8% Kw. Evaluating these values, it can be inferred that the control system can have more savings in the system when control measures are applied to all appliances consuming electricity.

The controls on appliances are applied according to specifications in the research study and could be extended to cover more time schedules. The study shows that electric savings are more when applied to off-peak periods when most appliances are not much in need and could be more when control measures are applied during peak periods. When adjusting air-conditioner use, energy savings are still higher even during off-peak periods, as this research focusses on data collection during off-peak periods. As against what is in use now, a decentralized air-conditioner system is preferable for each office or meeting rooms and air-conditioners are switched off when not in used so as to be able to further reduce electricity wastages.

The research show that electric lighting savings are more when LED bulbs are used, not minding daylight availability of users. Electricity wastages would further be reduced if occupancy sensors are introduced into the building. This is because lighting in many meeting rooms and toilets would be turned off when not in use and wastages would be reduced as occupation rate decreases.

Further study would investigate control measures been applied to appliance during peak periods, when occupancy rate is higher, to determine the amount of electricity consumption that would be saved. Also more appliances would be considered to increase further energy savings in the system.

5. REFERENCES

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