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THE CASE OF ENERGY RECOVERY SOLUTIONS USING SYNCHRONOUS MONITORING AND ADAPTIVE REAL TIME SYSTEM

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Abstract

Energy recovery both from the economic aspects and also from sustainable the use of energy, is necessitated with an optimal operational of equipment's inside the building. A Synchronous Monitoring and Real Time analysis system using an integrated monitor and control of energy recovery is presented. The test vicinity taken for this approach is based on the analysis of energy usage and the bill pay by the Taylor's University Malaysia. We have scaled down the approach to a test area restricted to a room design and employing the new methodology to optimize the energy usage. The design of this system is based on analysing the energy wastage caused by human factors and the utility usage factor. The system design proposes a real time monitoring of not just load but also the health condition of various equipment and physical environment condition, as they are the other major source for the operational inefficiency. By performing utilities usage control using SMART system, the electricity saving is expected to be 22.13 %.

Keywords: Machine design, Electromagnetic analysis, FEA, CAD.

1. Introduction

Malaysia's industrial sector takes up the largest portion 45%, whereas commercial and residential contributed to 33% and 21% consumption respectively [1]. Taking Commercial building in Malaysia used most electricity for HVAC system (64%) but it is still found to be poorly designed [2]. As a result, the system often performs out of the rated condition which affects the stability of the power grid.

In order to increase the electrical system efficiency, the building electrical system is to be monitored, analyzed and controlled in real time [3].

The proposed system is designed using LABVIEW® Reconfigurable I/O Architecture platform. Figure 1 shows the bird-eye view of TULC which consists of five buildings. Block C, D and E are the test target for this research because these three blocks are mainly comprised of classroom where daily activity is constant. Whereas, Block A and B are administration building and event hall where electricity usage is not constant and much lower than Block C, D and E combined. Figure 2 shows the recordings on the unit consumption economic analysis of TULC for 2013. TULC paid about RM 5500k in year 2013 for electricity usage. This number is expected to increase for the coming years with the growing number of usage. Thus, [5] suggested the operational efficiency can be increased by significantly manage the load with an appropriate electricity usage management system.

Fig.1. Taylor's University lakeside campus (TULC) [4].

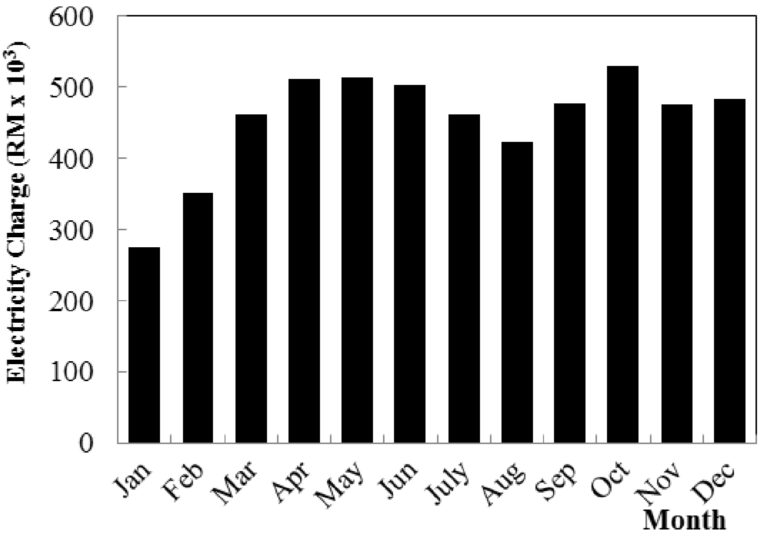


Fig. 2. TULC's economic analysis for year 2013 [6].

2. Design Methodology

2.1. Design concepts

The main concept of the SMART system is to increases the energy efficient of a building as a whole by synchronously monitoring the equipment condition and managing the energy usage. The system comprises of two networks. Firstly, the power network which controls the operation of the dynamic load mainly air conditional units. In this case, a motor is taken as the representation of dynamic load. The vibration data is acquired into LABVIEW Sound and Vibration Assistant using USB-6009 Data Acquisition hardware for octave and power spectrum analysis. The second network is to control the utility circuit that switch on or off the light and air conditioner. The concept is illustrated in Fig. 3.

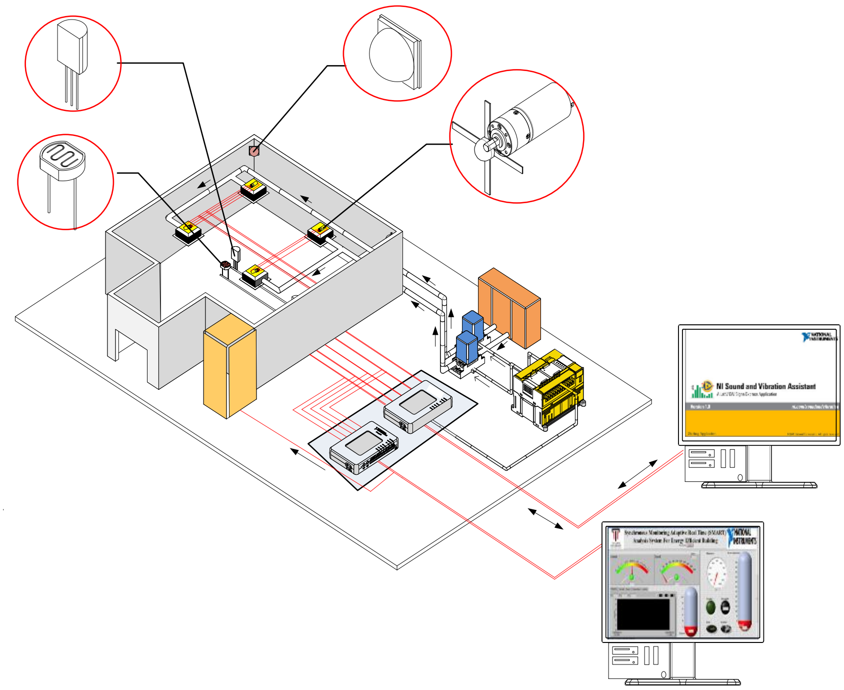


Fig. 3. Design concept.

Figure 4 shows the condition monitoring method for dynamic load. The vibration data is captured and analysed through Sound and Vibration Assistant. This helps operator to identify motor malfunction condition for isolation of the equipment. In order to test utility control operation effectively, a room is taken as test area for light and air conditioner control. LM35, Light Dependent Resistor (LDR) and Passive Infrared (PIR) motion sensors are used for temperature, illuminance and motion detection respectively. The control criteria are based on Ministry of Human Resources Malaysia guidance where the suitable light level is above 400 Lux and temperature is 20^{o}C to 26^{o}C for routine office work. The system switch off the utilities if no motion is detected in 10 minutes as the time interval between classes are usually less than 10 minutes. The control logic used is as shown in Fig. 5.

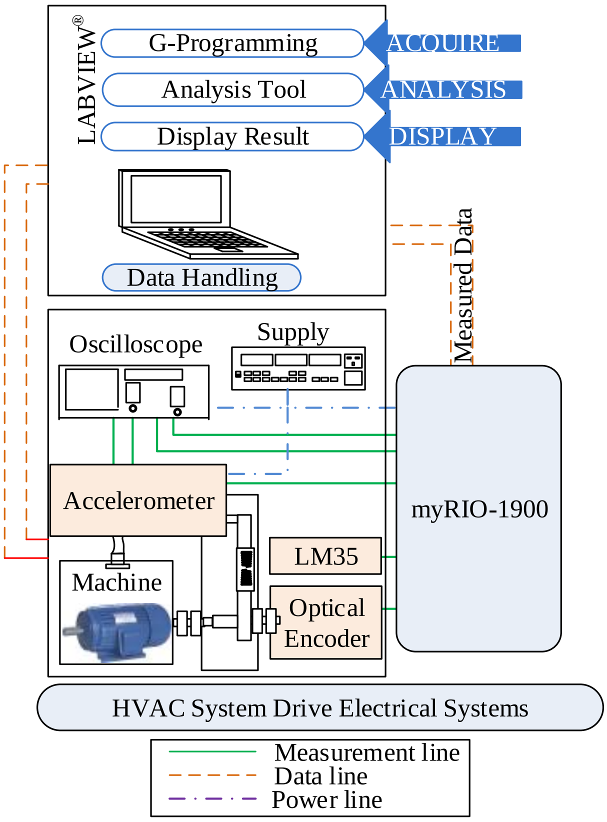


Fig. 4. Condition monitoring system (High voltage AC system).

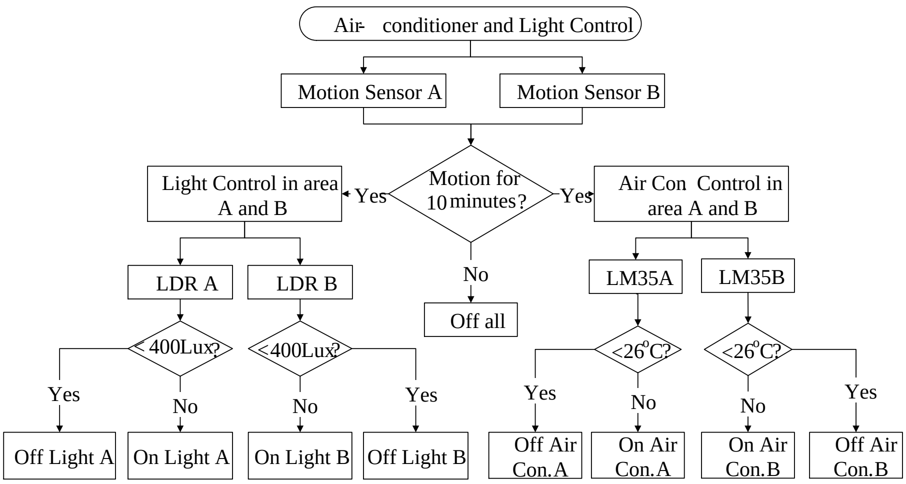


Fig. 5. Overall system concept (shown for two unit control).

2.2. Experimental design

For testing purpose, the system down-scaled mock-up model is mounted on a piece of plywood with proper wiring and electrical grounding as showed in Fig. 6. LED is used to represent the light and motor represented the dynamic load which is mainly air conditioner in this case. The main parts of the system involved laptop, sensors, and myRIO-1900. The sensors used for condition monitoring of dynamic load included accelerometer, temperature transducer LM35 and optical encoder for vibration, temperature and speed measurement respectively; whereas for utility control circuit, temperature transducer LM35, LDR, and PIR motion sensor are employed. The design of the SMART Analysis System front panel Human Machine Interface (HMI) included all the desired parameters which are shown in Fig. 7.

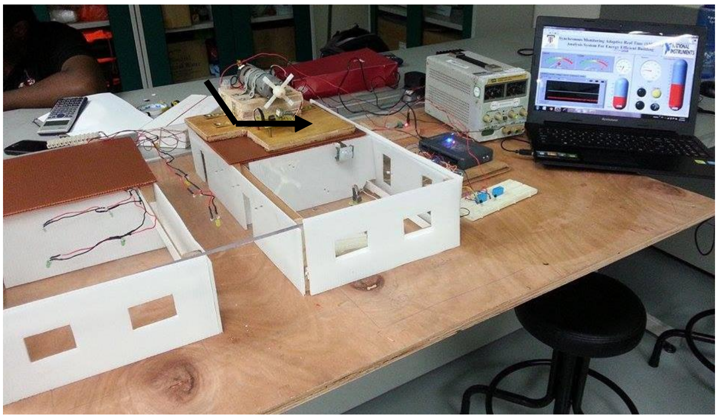


Fig. 6. Experimental Set-up. (video link: http://youtu.be/j2cXrZi7Pa4)

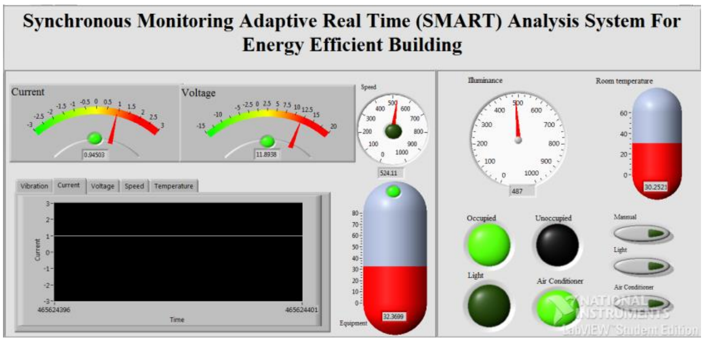


Fig. 7. Human machine interface (HMI).

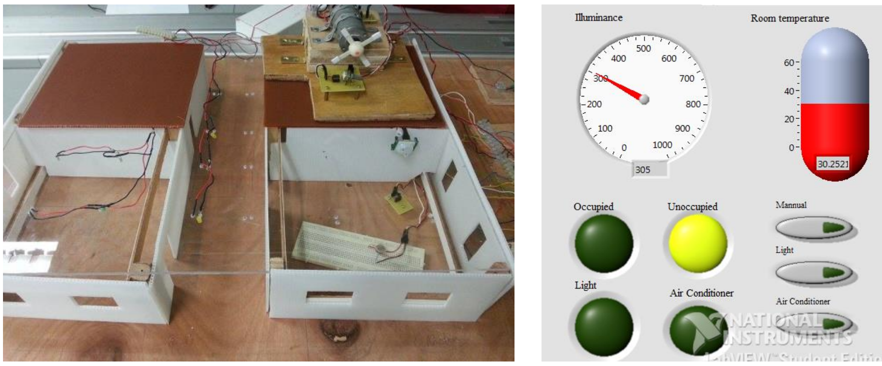
3. Results and Discussion

3.1. Utility operation control

Four possible conditions are considered and tested for utility operation control. The utility being considered here are light and air conditioner where represented with hardware using LED and a motor.

<u>Case 1: No motion for 10 minutes</u>

After the system run for 10 minutes without giving any motion to detect by motion sensor, the system switched off the motor and light which can be seen in the HMI and hardware response in Figs. 8 (a) and (b) even though the illuminance and temperature is above the threshold.

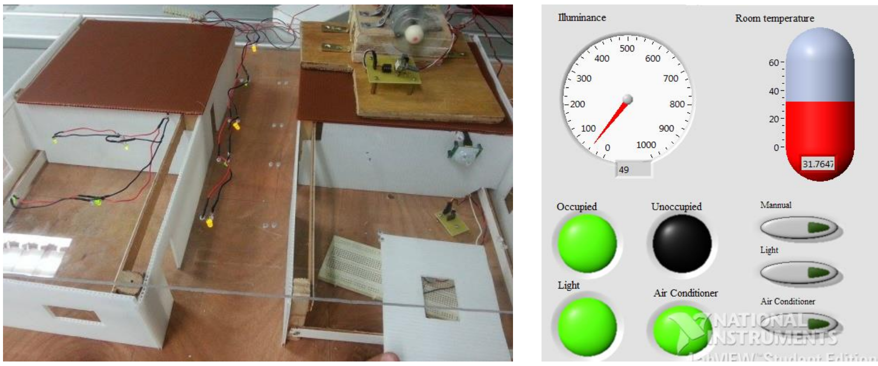


(a) **(b)**

Fig. 8. (a) LED and motor off (b) Light and air conditioner off.

<u>Case 2: Motion detected; Illuminance < 400 Lux; Temperature >26°C</u>

When the system detected motion and with temperature above and illuminance below threshold, both air conditioner (motor) and light (LED) are switched on as shown in Fig. 9 (a) and Fig. 9 (b).



(a) **(b)**

Fig. 9. (a) LED and motor on (b) Light and air conditioner on.

<u>Case 3: Motion detected; Illuminance > 400 Lux; Temperature > 26°C</u>

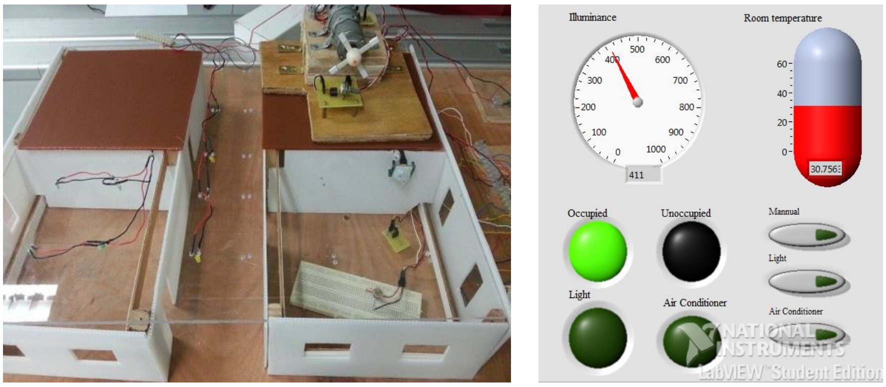
In a condition that illuminance is above 400 Lux and temperature is more than 26°C, the light level is acceptable whereas the temperature is not in the comfort zone of 20°C to 26°C. Thus, the light is switch off and air conditioner (motor) switched on as illustrated in Fig. 10 with human occupancy detected.

(a) **(b)**

Fig. 10. (a) LED off and motor on (b) Light off and air conditioner on.

Case 4: Motion detected; Illuminance > 400 Lux; Temperature < 35°C (Adjusted for test)

The threshold of air-conditioner to switch off is 26°C which is difficult achieve under laboratory condition, thus, the threshold is adjusted in the program to 35°C to for testing purpose. As a result, the system switched off the air conditioner (motor) as the measured temperature is 30°C even though occupancy is detected. Apart from that, the light is switched off since the illuminance is 439 Lux. This control action is greatly reducing the energy usage without compromise the comfort level of user. Besides, the alteration of threshold demonstrated adaptability and flexibility of the system to meet user specific requirement.



(a) **(b)**

Fig. 11. (a) LED and motor off (b) Light and air conditioner off.

3.2. Dynamic load vibration analysis

The dynamic load where in this case is the motor that represented the air conditioner is analyzed using LABVIEW Sound and Vibration Analysis Assistant. Order analysis on the motor vibration is performed with octave spectrum and power spectrum. The result from octave spectrum in Fig. 12(a) showed that harmonic exhibits vibration at 20 Hz as 1st order, 80 Hz (4 x 20 Hz) as 4th order and 140 (7 x 20 Hz) Hz as 7th order. The vibration caused at 20 Hz and 80 Hz (Low order) are due to imbalance, miss alignment or loose coupling. Whereas 140 Hz 7th order (High order) harmonic is due to blade defects. Others harmonics are caused by the fault of loose mount. On the other hand, Fig. 12(b) shows the power spectrum/loss data from the vibration level. Isolation on the peak sustained vibration conditions helps to operational benefit of the consumer and reduce the pressure on the source supply.

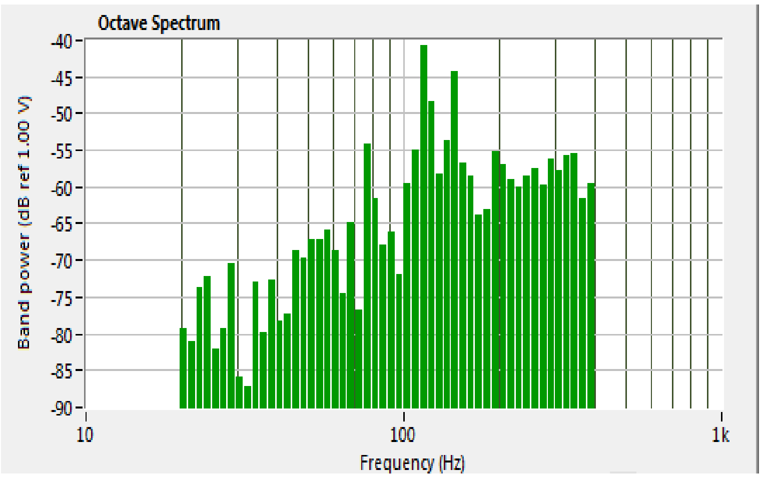


Fig. 12(a). Octave spectrum of the Vibration Data.

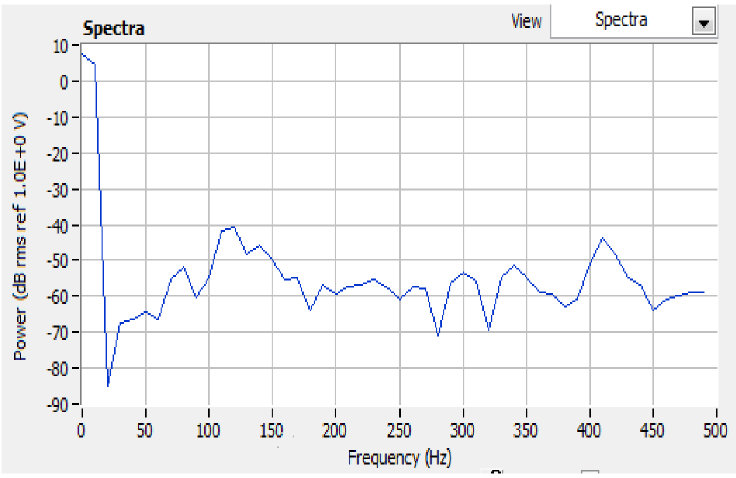


Fig. 12(b). Power spectrum of the Vibration Data.

3.3. Energy recovery analysis

The SMART system is focused on Blocks C, D and E as their energy usage are similar in nature where daily operation took place such as classroom, divisionary office and library; whereas Block A and B are made up of administration office and event hall. Electricity usage in Block C, D and E (RM 3493789 in 2013) are much higher compared to Block A and B (RM 1977593 in 2013). The electricity capacity of TULC is mainly ventilation, air-conditioner, lighting and general equipment (power outlet). Air-conditioner and lighting load are found to be 80 % of the total capacity. Contribution of air-conditioner and lighting load in Block C, D and E for year 2013:

80%×RM349789 = RM2795031

Thus, by controlling usage on these two utilities, the electricity efficiency can be increased significantly. Since Block C, D and E mostly consist of classroom, the operation start at 8am to 6pm. However, the utilities (air-conditioner and light) are left in switched-on condition after users left. It is only being switched off by facility management staff at around 8pm. Thus, the utilities usage duration is 12 hours even though the actual demand is only 10 hours. Besides, some of the classrooms are not fully utilized from 8am to 6pm duration. Therefore, the actual demand for the utilities is estimated to be only eight hours. By performing utilities operation control using SMART system, the extra four hours of electrical energy wastage can be vastly reduced. Taking year 2013 electricity usage as example, energy or kWh charge is 80% of the total electricity charge. The energy saving can be calculated as below and the new monthly kWh charge with SMART system is presented in Fig. 13. In the process, maximum demand or kW charge is also expected which made up the remains 20 % of the bill is expected to decrease by 5 % with the SMART system implementation. A graph that illustrated the new saving for each month in 2013 is presented in Fig. 14. Overall, the forecast saving is RM 773292 per year or 22.13% for Block C, D and E electricity expenses. In the process, the user comfort level is maintained at an acceptable standard specified by Ministry of Human Resources Malaysia.

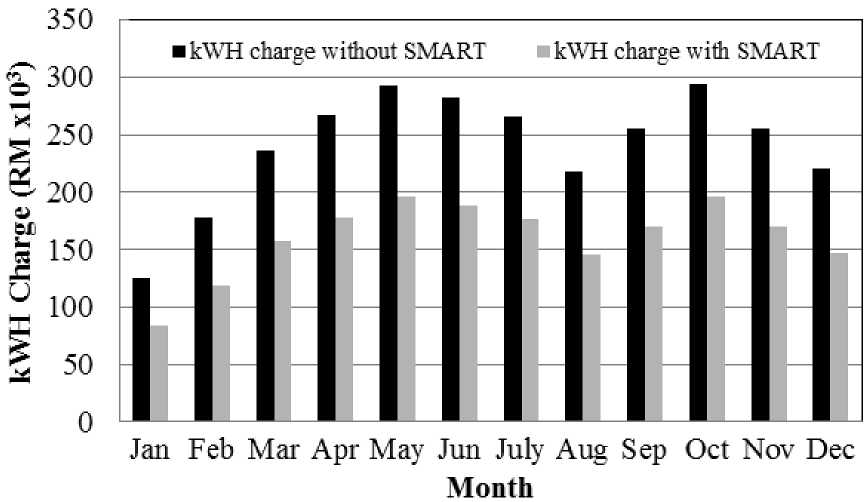


Fig. 13. Unit charges with and without SMART system.

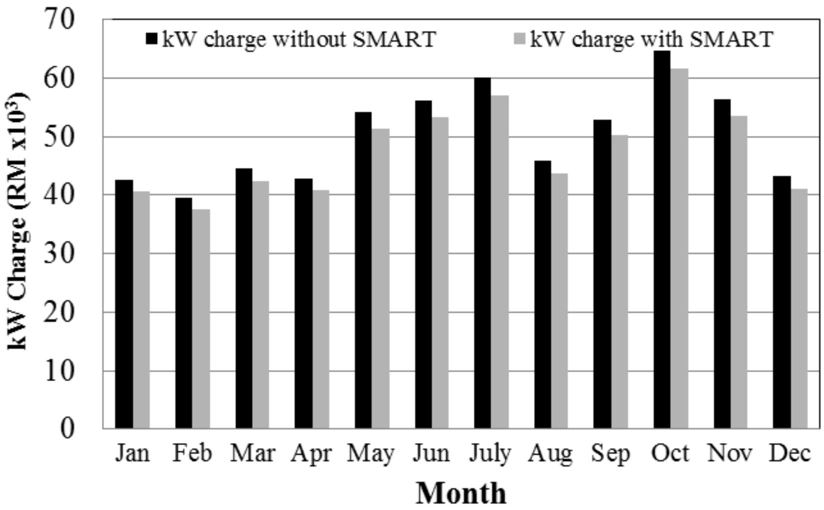


Fig. 14. Power charges with and without SMART System.

4. Conclusions

In this paper, the energy recovery through the Synchronous Monitoring and Real Time (SMART) Analysis System is presented. We have scaled down the approach to a test area restricted to a room design and employing the methodology proposed in this paper to optimize the energy usage. The design system has two circuits control. The dynamic load control where it isolates the faulty machine by performs regular condition monitoring of the load. Through USB data acquisition, the sensors data are analysed and the machine condition alerts the operator for isolation and maintenance. The other control is for lighting circuit which controls the operation of the lighting when not in usage. An algorithm is programmed into the FPGA chip of the myRIO unit for this operation. SMART system can enhance the operational control which leads to higher energy efficiency usage and the sustainability to a larger extent.

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