

# DEVELOPMENT OF A SMART METER TOOLS FOR MEASURING REAL ENERGY USE IN GUEST ROOM TO ANALYSIS ENERGY CONSUMPTION AND REAL DEMANDS FOR BEST SOLUTION TO REDUCE ENERGY IN 4 STARS HOTELS

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## ABSTRACT

*The importance of cost in hotel is electricity cost. The details of energy use are impacts cost of hotel component of Air condition, electricity and all electrical plugs. This research aimed to develop smart meter tools for energy reduction of electrical energy use of hotels guest rooms. The Smart Meter was designed to measure the electricity usage and transmit data via the "Internet of Things" to the cloud network and send real energy usage to mobile application and show the cost of electricity in peak time to creating understand energy consumption for guests. The electricity usage data were collected from the air conditioning systems, lightings and all electrical plugs from the standard hotel room size of 32 m<sup>2</sup> to determine the energy usage and reduce cost of the hotel*

**Keywords:** Development Smart meter, Smart Meter, Energy Management, Energy Saving, Real-Time Energy Use

## INTRODUCTION

Nowadays, the environment sustainability and energy is the goal of energy-saving policy by the government such as the industrial, hotel and household sectors. So, electricity is an essential factor in every business. The government agencies have stipulated the rules to motivate every sector for reduced energy consumption and optimized the efficiency of the existing hotel for the highest energy consumption. Therefore, we can see that energy consumption has been continuously higher in the past several years. It reflects the cost of the electrical hotel is arising. At present, the energy consumption in the country is more and the annual increase rate of energy consumption of hotels. Each hotel has different electricity consumption (Farrou, Kolokotroni & Santamouris, 2016). It depends on the level of the hotel. From the electrical data has discover a four-star hotel are highest energy use. according to the type and size of the room and the electrical appliances in the room, each level of hotel has different power consumption (Shiming & Burnett, 2001). For four-star hotels in Thailand, the proportion of electricity consumed by air conditioning, lighting, elevators, water heating, and fan pumps is 57%, 18%, 9%, 8%, and 8%, respectively (Tangon et al., 2018). Air conditioning systems consume the most energy and are used 24 hours a day to serve hotel guests (Kresteniti, 2007) and staff. Power consumption will also vary depending on usage temperature, size and type of room, such as hotel room, lobby or meeting room (Yao, Zhuang & Gu, 2015). Provide comfortable accommodation (Chen, Bernard & Rahman, 2019), the hotel mainly provides 2

access cards to hotel guests to maintain the air conditioning and temperature (Acosta et al., 2020) of the rooms when the guests are away. Therefore, the state of the room will be similar to the situation when guests check into the room with the air conditioning and lighting system working. Therefore, the energy consumption is 24 hours a day. This is the main reason energy is wasted to provide guests with maximum comfort. (Wang, Lin & Luo, 2008)

Electricity is the most important expense of doing business, especially for the hotel industry ((Lai, 2016)). If electricity bills can be reduced, the direct profits of the entrepreneurs will increase. Therefore, entrepreneurs must develop an energy-saving management plan in the hotel business (Suki & Suki, 2014). Understanding the principles of calculating the cost of electricity is very important for planning the reduction of electrical energy due to electrical load failures. Some parts can be controlled, such as power, maximum load, and power factor load. The uncontrollable parts are Ft, service fee and VAT, which depend on the total electricity bill each month. Therefore, it is important to consider the parts that can be controlled by using them carefully and effectively.

This research focused on the development of a device to collect electricity usage data from the guest room hotels and analyze the real electricity profile. The data of energy use will be data to IoT and the data of the hotel. Analysis to reduce the energy waste from the guest room hotel. Component of Electrical usage of air conditioning, lighting and all electrical plugs are calculate to money , show guest and hotels to understand real energy usage and real energy unit

## METHODOLOGY

The study presents a methodology to assess the energy consumption of hotel rooms. First, the HSM is designed to measure the actual consumption of electrical energy in hotel rooms. The second is to analyze the factors affecting the energy use guidelines of customers. HSM has collected electricity consumption from devices in rooms such as lighting systems, air conditioning systems and electrical outlets. Data from energy users is used to analyze energy use behavior. Network protocol to reduce energy consumption and raise awareness of energy saving has been developed.

### Hotel Smart Meter Concept

The role of electrical management is a critical factor to maintain the energy consumption of the electrical power system. It means management and control of electrical equipment efficiently and reduces the amount of electrical energy usage. The HSM was implemented to measure actual electrical energy usage data (Beccali, 2018) in the hotel room related to the air conditioning, lighting, and outlet system (MB et al., 2018). The data of the energy in real-time was transmitted via IoT and stored in the Cloud data system. Especially, the energy usage data could automatically be shown in real-time as kWh and electricity expenses in the guest room's TV and HSM mobile application. The guest will be aware and understand the actual amount of electricity used and the load profiles from each apparatus in the room during the 24 hours stay. The amount of electricity usage was calculated into the actual electricity cost of the guest as follows.

$$P_{R,i}(t) = V_i(t) \times I_j(t) \times \cos \theta_i(t) \quad (1)$$

$$kWh_{R,i} = \sum_{t=1}^{24} \times \text{average} (P_{R,i}(t)) \quad (2)$$

$$AEC_{R,i} = kWh_{R,i} \times \text{Energy Charge Rate} \quad (3)$$

Where  $V$  and  $I$  are voltage of rooms and current of room.  $P_R$  is real or active power of the room number  $i.i$  is rooms number of the hotel.  $kWh_R$  is total energy consumption of rooms.  $i.ACE_R$  Is the actual electricity cost of the guest of room's number per day? Meanwhile, the energy charge rate is defined

The yield of the HSM was installed in the guest room need to manage and reduce electricity usage. During the period with the highest electricity consumption demand, the guest of real-time electricity usage for the critical load is air conditioning and lighting. The results could be used to reduce the wasteful energy consumption from the guest who came from turning on the air conditioner during the day. Moreover, the hotel can be managed electricity usage during low peak periods and low demand times, such as turning on the water pumping system and laundry at night time for energy balance control. (Mey, Akbar & Fie, 2006). Therefore, the guest rooms' behavior was represented using electrical energy conservation. The real-time monitoring data are essential to analyze and create strategies to reduce energy saving related to operating costs and conserve the environment.

### Hotel Smart Meter Design

The HSM consists of the central part of the control box hardware and connection. The control box hardware is divided into five-part. The HSM consisted of a Microcontroller (Node MCU), sensor for measuring electrical energy PZEM-004Tv3, system data communication for internet (Protocol), AWG 26 mm cable, and Power supply 12 VDC. The HSM was measured by installing to measurement at the main breakers of the guest rooms. There is an operating system procedure by measuring energy and comparing between 2 types of energy meters. The Node MCU was integrated using protocol config RS485 and PZEM-004T for the power measurement module. Meanwhile, the platform to display energy values in most industries is no standardized up to the developer. Therefore, the measurement data needed to communicate and relate from the specifications of the company. The easy way in applying data was selected by creating a dashboard platform. This paper was designed and built an intelligent energy meter in conjunction with the energy config Protocol RS4875 to measure energy usage and display the data measurement as described in figure 1.

The HMS measurement is developed by microcontrollers, measurement sensors and electrical equipment. Therefore, the HMS is necessary in order not to affect the electrical system and to comply with the safety condition. The wiring diagram for the test can be shown in the following Table 1.

### The Guidelines to Reduce Energy Consumption

A strategy for implementing HSM was created by hardware, software of the HSM, but needed to prepare for increasing the efficiency from the purpose of the HSM development.

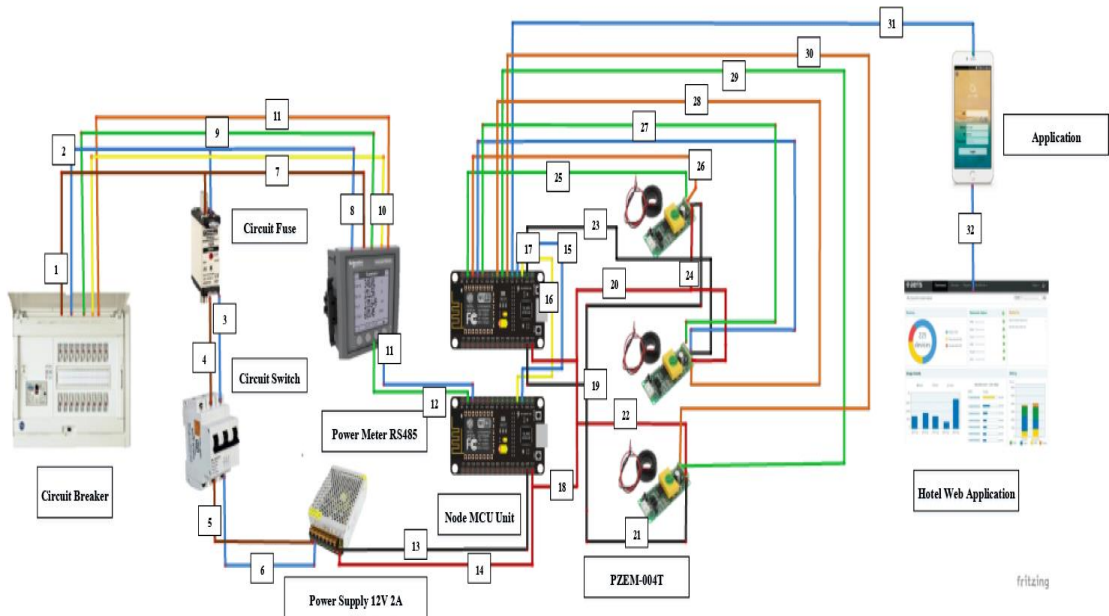
- 1) The development of hotel's smart meters record the vitality of use by analyzing the air conditioning, lighting frame and control output in the remains of the guests.
- 2) Hotel Smart Meter and mobile application and decision data of electricity.

<b>Table 1 MICROCONTROLLER (NODE MCU) CONFIGURATION OF THE HMS MEASUREMENT</b>			
<b>Line</b>	<b>Table 1(INPUT, COLOR, OUTPUT)</b>		
No.	Input	Color	Output
1.	Circuit Breaker	Brown (line)	Circuit Fuse

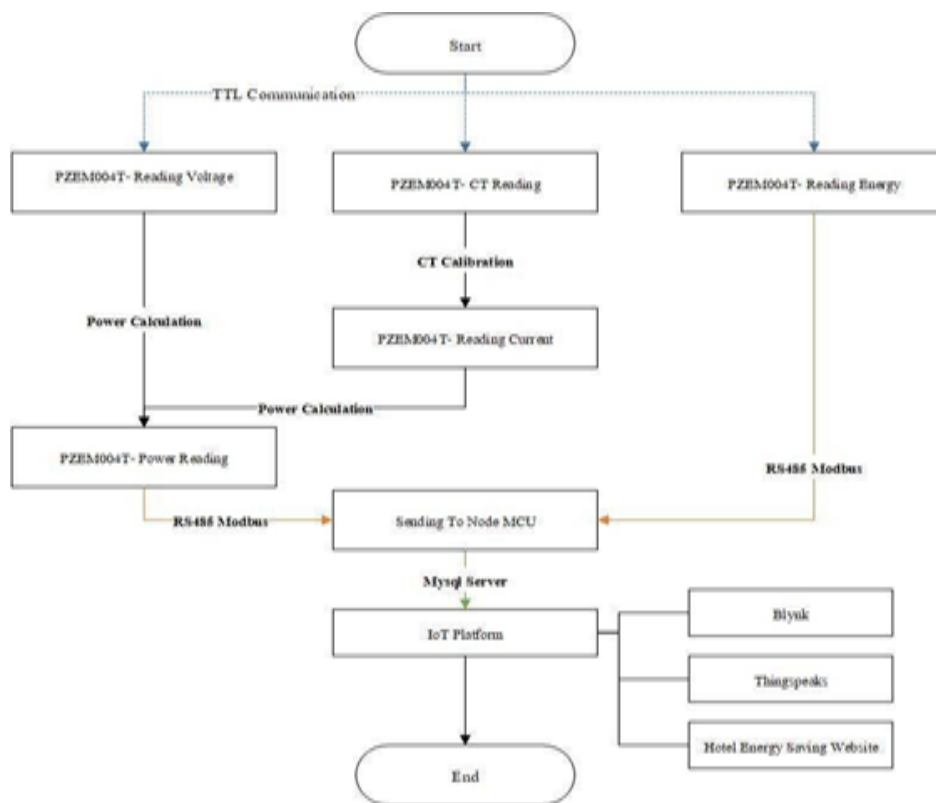
2.	Circuit Breaker	Blue (Neutron)	Circuit Fuse
3.	Circuit Fuse	Brown(Line)	Circuit Switch
4.	Circuit Fuse	Blue (Neutron)	Circuit Switch
5.	Circuit Switch	Brown(Line)	Power Supply
6.	Circuit Switch	Blue(Neutron)	Power Supply
7.	Circuit Breaker	Brown(Line)	Power Meter RS485
8.	Circuit Breaker	Blue(Neutron)	Power Meter RS485
9.	Circuit Breaker	Brown(Line)	Power Meter RS485
10.	Circuit Breaker	Blue(Neutron)	Power Meter RS485
11.	Circuit Breaker Air	Yellow	Power Meter RS485
12.	Circuit Breaker Light	Orange	Power Meter RS485
13.	Power Supply	Red(+)	Node MCU No.1
14.	Power Supply	Black (-)	Node MCU No.1
15.	Node MCU No.1 RX	Blue	Node MCU No.2 TX
16.	Node MCU No.1 TX	Yellow	Node MCU No.2 RX
17.	Node MCU No.1 TX	Yellow	Node MCU No.2 D9 Pin
18.	Node MCU No.2 Vin	Red(+)	PZEM-004T No.1 Vin
19.	Node MCU No.2 Vout	Black (-)	PZEM-004T No.1 Vout
20.	Node MCU No.2 Vin	Red(+)	PZEM-004T No.2 Vin
21.	Node MCU No.2 Vout	Black (-)	PZEM-004T No.2 Vout
22.	Node MCU No.2 Vin	Red(+)	PZEM-004T No.3 Vin
23.	Node MCU No.2 Vout	Black (-)	PZEM-004T No.3 Vout
24.	Node MCU No.2 Vin	Red(+)	PZEM-004T No.3 Vin
25.	Node MCU No.2 RX	Yellow	PZEM-004T No.1 TX
26.	Node MCU No.2 TX	Green	PZEM-004T No.1 RX
27.	Node MCU No.2 RX	Yellow	PZEM-004T No.2 TX
28.	Node MCU No.2 TX	Green	PZEM-004T No.2 RX
29.	Node MCU No.2 RX	Yellow	PZEM-004T No.3 TX
30.	Node MCU No.2 TX	Green	PZEM-004T No.3 RX
31.	Node MCU No.2 TX	Blue	Mobile Application
32.	Node MCU No.2 TX	Blue	Hotel Web Application

### Hotel Smart Meter Data Collection Protocol and Display

The HSM algorithm is developed using the advantages of measurement units and microcontrollers (node MCUs) with integrated equipment in the room. Data correction and RS485 serial communication are used to analyze and display the monitoring of the entire Blynk platform on the IoT platform, as shown in Figure 2. Figure 2 shows the HSM algorithm. The HSM system is corrected after receiving the power consumption from the smart meter. The RS485 protocol setting is used to read and send data with the PZEM004T energy detector sensor and analyze the error together. HMS will calculate tolerance and measurement error-index correction values. Therefore, the data to be used is accurate. The data transmission process will be used via TTL communication channel through RX and TX ports as shown in Figure 1. After that, metering indicators will be calculated and presented to motivate guests and the hotel. The unit of measure data correction will be stored by cloud servers using the Blynk server cloud and the Thingspeak cloud.



**FIGURE 1**  
**SCHEMATIC OF IOT SMART METER CONTROL BOX HARDWARE AND CONNECTION**



**FIGURE 2**  
**ALGORITHM OF THE HOTEL SMART METER TOOLS OPERATION FOR MEASURING POWER IN 4-STAR HOTEL**

A Website designed the research for hotel energy monitoring to show guests rooms by individual energy consumption and conservation. The real-time system can present the monitoring of electrical appliances of guests rooms via iPad. The incentive for the guest rooms was used by the saving energy that also saw the saving rate. The hotel would return to the guests when checking out.

Moreover, the guest login would be used to monitor guests' electricity costs with different habits and create a discount on the next stay. The energy consumed by the guest's rooms relates to the many data of the users' information. The key of the users' information is nationality, duration of stay, and objective for stay. Therefore, the energy usage profile could be collectively analyzed to motivate the guests to stay by offering promotions or discounts rate for guests of different nationalities.

More detailed analyses are required to determine the foreign tourist behavior, including calculating refunds. The incentives for guests needed to create awareness of energy conservation and implementing energy-saving activities. Therefore, the hotel can benefit from guest access to manage energy usage and reduce total energy costs.

## EXPERIMENTAL RESULTS

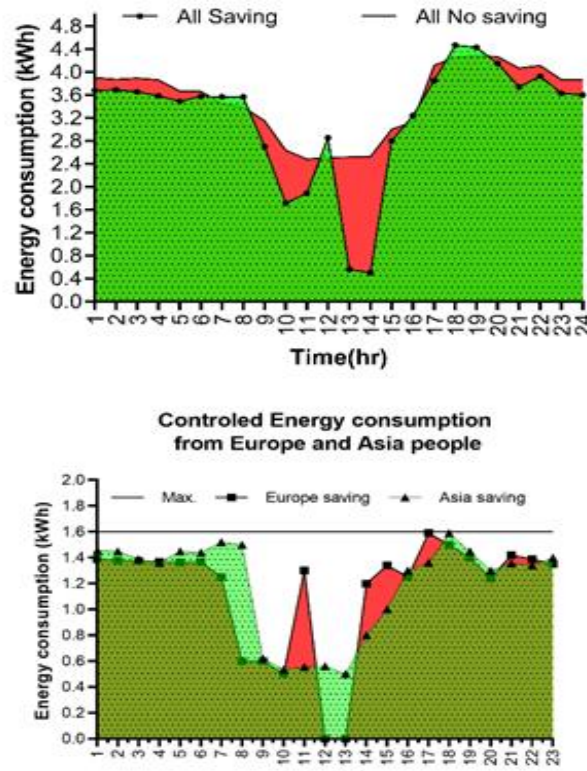
### Energy Profile

At the room hotel, the general vitality utilization profile was measured by hotel smart meter and show to smart applications. The energy utilization behavior within the lodgings between 10:20 and 11:50 is the high power consumption of guest rooms. The period sometime recently 11:50 and amid 12:00 – 14:00 will be for utilizing electrical machines such as vacuum. Meanwhile, the apparatus load of the guest's room are discussing conditioner, lighting and other frameworks counting water pump to do exercises for both the workers and client services. After 14:00, the energy utilization was higher than the recently 11:50 sense of the energy utilization from clients after the check- the period of 14:30 – 18:00 appeared that the overall energy utilization is 20 – 24 kW. Therefore, the energy usage reached the peak point, which causes the electric power price in the hotel to hit the peak point, and the electricity bill would be higher. The conduct of guests utilizing the discuss conditioner simultaneously makes the power fetched rise to the peak point. In this manner, the HSM information of energy utilization profile would permit the hotel to create expectations of almost the utilization of electrical equipment inside the hotel. When utilizing inn Smart-Meter for the real-time estimation in a hotel room of 32 sq.m, the information for two days for discussing conditioning, lighting and outlet framework control utilization. The power consumption is mainly used in the afternoon and at night time. The discuss conditioner begun to function and devoured energy until it comes to a consistent setting of 25 °C and after that the discuss conditioner would work less. The air conditioners of 1,800 BTU have a maximum operating condition of 1,500 W. The HSM might measure the real-time control utilization for the unit of seconds. Average Air-condition measurement the data from hotel smart meter in the guest room during the operating air conditioner. 229-230 V. displays the rooms voltage from the estimation and the real-time control utilization of the discuss condition control unit, other apparatus units from the outlet, and lighting unit. the start of the air condition. The blower and fan coil unit was consumed approximately 0.052-0.062 kW at about 4.5- 5.5 minutes.

The smart meter can display the power consumption and can control the devices installed in the smart meter. The smart meter can monitor the electricity consumption of the hotel at a specified time. If the access control card is not inserted, the system will cut off the power. The system will automatically power off between 11:59 and 14:00, but if the access card is inserted, the system will continue to run. So that guests can use the room as usual. Figure 3 shows a comparison of energy savings when implementing measures to turn off the air conditioning when guests leave the room. Therefore, using smart meters can help guests understand energy usage. It can be seen that the

energy-saving rate of air-conditioning reduces the room cost by about 250 baht per room per day. A lot of energy can be saved just by changing the energy consumption behavior of some guests.

**Energy Conservation Comparison** The use of electricity data is understood through the development of hotel smart meters, and energy-saving measures are taken to turn off the air conditioning in hotel rooms within 24 hours of leaving the hotel.



**FIGURE 3**  
**COMPARISON OF ENERGY SAVING BY IMPLEMENTING ENERGY CONSERVATION MEASURES OF TURNING OFF THE AIR CONDITIONER WHILE THE GUEST VACATES THE HOTEL ROOM**

### Energy Consumption Behavior and Decision Strategy

Information of Energy use to show in application and websites in real-time for the owner and guest to see the electrical consumption and understand how to reduce energy from each electric in the guest room from the graph in mobile and smartphone. By analyzing the power consumption situation, it shows that customers use the electricity of air conditioners at a high rate and let the air conditioner run all the time, which leads the motor to work too hard and consume power. electricity. Compared to different nationalities, the energy consumption behavior of the first day was essentially the same, leaving the air conditioning on while the guest was not in the room, wasting energy. Each hotel has a different policy. Hotels that provide 2 key cards tend to be higher for guests who leave one of the key cards in the slot to keep room availability at their convenience. The variation in humidity in the room depends on the physical condition of the individual. Research has found that men set their air conditioners lower than women and have more options to keep the air conditioning on during their periods. Age is not a factor that affects the temperature setting of an air condition, but rather depends on individual thermal comfort. The trend of opening air conditioners in Thailand at low temperatures will force the air conditioners to work hard at first, resulting in high electricity consumption.

The results from development hotel smart meter finding a measuring load profile of electricity data can make a decision strategy and more understand a behavior. leading to reduce cost

from manage electrical use by time and period of energy use. The cost of electrical in day to manage electrical load.

## DISCUSSION

Energy saving by developing a Hotel Smart Meter (HSM) which can understand energy data by displaying electricity consumption. It can control the device installed on the smart meter. Smart meters can monitor the amount of electricity consumed during the hotel's specified period. If the key card is not inserted, the system turns off the power. The system will automatically cut off the power from the guest don't stay in the room but the system will continue to operate if the key card is inserted. So guests can use as usual. Therefore, the use of smart meters helps customers understand the amount of electricity consumed and recognize the amount of electricity consumed. As can be seen, the energy saving rate of the air conditioner is greatly reduced to 95% and consumes reduce cost of electrical use 250 baht per day per rooms

The power usage data received from the smart meter can be calculated as the power consumption to reduce the peak load of guests staying at the same time. Hotels can reduce their electricity bills at peak times. From taking data on frequency, ethnicity and purpose of stay to analyze how to reduce electricity costs in hotels, which are considered high costs in the operation of 4 star hotels. The air conditioning can be integrated into a smart hotel switch to reduce the energy consumption of air conditioning by having a display to know the energy used versus the common energy and to remind the maintenance time. This can reduce the power consumption of the air conditioner and lower the costs and expenses caused by the improper operation of the air conditioner.

Research on hotel energy use found that air conditioning energy use accounts for the highest proportion of the hotel's total energy consumption. If the energy waste of air conditioners can be reduced without guests, energy costs can be reduced by 10% and energy consumption can be reduced by 5% by increasing awareness of energy conservation. By testing Hotel Smart Meter PZEM and developing the Hotel Smart Meter mobile application to study energy usage and electrical units in the hotel, you can create a way to reduce energy consumption and save more electricity bills. The investment is 75,000 baht, and the return on investment is 1.25 years from reduce electricity cost by energy saving and new strategy marketing.

## CONCLUSION

Real-Time Energy use from Hotel smart meters to collect energy usage of customer to stay in room and measuring the energy behavior and send the electricity usage data into mobile application and transmit the data to be processed and calculate electric cost to show cost of electrical in Real-time from Air –Condition lighting and all plugs that electrical usage data received from the smart meter. To show the real electric consumption of one day use to operation of hotel to reduce peak loads and show electrical usage to mobile application to guests at the same time to understand real energy unit usage of Air-condition , lighting and all plugs to show real power and cost per minute and cost per hour and cost per day . The Owner to understand customer use and have a data to decision could reduce cost and manage electrical use in the higher cost electrical in day that higher than cost of electrical in night to manage electrical load. Information of Energy use to show in Application and websites in real time for the owner and guest to see the electrical consumption and understand how to reduce energy from each electric in guest room from graph in mobile and smart phone.

In addition, energy consumption data can be used to inform the decision of the electrical technician and the hotel owner. To study the efficiency of air conditioning form power consumption that abnormality are higher power consumption to remind maintenance time or the data to decision



to change electrical such as air condition that are effective in reducing electricity from reading the real data usage from the smart meter to compare the energy consumption during the average occupancy energy use. To compare usage averages and then create a discount in case guests realize the value of their electric power. building understanding and Realizing the Reduction of Unnecessary Power Consumption By cooperating to turn off the electrical appliances by pulling the keycard before leaving the room. This could create the awareness of energy use to the guests. And operation cost from analyzing electricity usage profile and reduce cost of hotel,

The Marketing Strategy the hotel can create a new CSR to promote the energy saving and find a new group customer that concern in environmental. These strategy of energy saving also help reduce the electricity waste and cost. This results a development hotel smart meter can create a new way to creating participation in energy saving by a hotel smart meter.

## RECOMMENDATION

The research of Development of Smart Meter can be create the understand of energy use to show the data via IoT and Real time cost of each Electrical in the room hotel such as Air condition, lighting , and all plugs. Hotel Smart Meter to collect data and measure the energy consumption on real time and send the data to the owner to know the cost. To Management the cost of energy and can use reducing cost and A new way to create new strategy to promote in green hotel by creating awareness in energy saving. Customer to understand Energy use in Real-time and can understand unit use to saving when they come back home to creating participation in energy saving in the long time because the understand energy unit from graph of energy use in mobile or smart phone. The hotel and customer more understand energy saving. In the next time Mobile application can be used to show the energy saving to friend and family to understand energy saving, energy lost, and measure the amount of electricity used in home or hotel or shop by understanding and touching HSM. Creating sustainable strategy in energy saving.

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