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AHEMS: Android Based Home Energy Management System

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Abstract: The main aims of the proposed system is to save domestic energy usage and reduce carbon footprint through an Android based Home Energy Management System (AHEMS). The system simulates the electrical power consumption by monitoring and controlling the power usage of each load of a typical domestic household in Brunei Darussalam in real time. The consumption of electricity is calculated using the power rating of the appliances connected when appliances are switched on. A threshold is set in which when exceeding this setting will trigger actions such as alerting users and switching off low priority appliances for conserving energy. The proposed project consists of Home Energy Management System (HEMS) unit which was developed using LabVIEW and an Android tablet to PC integration developed using data dashboard which exhibits the ability to display and interact with HEMS remotely. The proposed system adopted the electricity power usage recommendation by the Department of Electrical Services (DES) of Brunei Darussalam for a typical household.

Key words: HEMS, LabVIEW, dashboad, android, carbon footprint, energy conservation

INTRODUCTION

In developed countries electricity is always taken for granted and has become part of the daily lives. A comparison of the electricity consumption of household by Wilson (2015) with data taken from the World Energy Council shows that Canada and US consumed around 11,800 and 11,600 kWh, respectively which approximately 13-20 times more than Nigeria and India household electricity consumption. In terms of the electricity usage per capita, each person in Canada and US uses around 4,700 and 4,500 kWh/year, respectively. This is about 60 times that of a Nigerian that only consumes 74 kWh/year. Household consumption of electricity in Brunei Darussalam is the highest in South East Asia at 2,948 kWh/year which is more than twice to the second highest consumption country (Ahmad *et al*., 2014) in the region.

This variation may be due to some of factors such as wealth, climate condition of the country, different house size and population, cultural habit, electricity prices or tariff and type and amount of appliances. Household electricity use may be different between countries but of similar activities; for example in US people tend not to use air-conditioner too often compared to tropical countries. Too much consumption of electricity could led to increase in the emissions of carbon dioxide from fossil-fuel power generation.

There are many ways to save electricity at home. Understanding and monitoring on how that electricity is used is the starting point to help reduce the usage of electricity by making home owners aware of the behaviour of electricity consumption at home and lead to changing to low energy light bulb or reducing the limit of using air-conditioner. With the presence of modern Information Communication Technology (ICT) we could monitor the usage of electricity and it is proven to be helpful for the user to be aware of their energy usage too. Some energy management systems are intended for gas as well as water consumption but most energy management system now a days tend to focus on the electricity consumption. In our proposed system, we will focus on the electricity consumption of Brunei Darussalam. The findings by Ahmad and Othman (2014) stated that Brunei Drussalam experienced an increase in electricity consumption and it is still lacking in the implemention of energy-efficient technologies. Therefore, the proposed system of Android Home Energy Management System (AHEMS) for Brunei Darussalam is a timely call and approach towards helping Brunei Darusalam in energy conservation and reducing carbon emission.

Generally, the benefit of AHEMS is that it enables a real-time energy monitoring that shows the household electricity usage on a visual display locally or remotely through the internet. AHEMS with a set threshold helps in conserving energy when the value of power usage

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exceeds the threshold value that triggers further actions like alerting users and switching off low priority appliances automatically. The proposed system will simulate the energy usage using the Brunei Department of Electrical Services (DES) recommended household appliances data. The system is developed suing NI LabVIEW for PC and data dashboard for Android tablet Wilson, 2015.

Literature review

Energy saving initiatives: Brunei has started implementing some energy saving strategies especially on the residential and commercial sectors which are the highest consumption of electricity in Brunei. According to the 46th APEC Energy Working Group in 2013, DES has already started looking into potential measures and their first initiative is by using the "smart" tariffs which took place during 1st January 2012. It was said that with this new tariff, people are trying to curb electricity usage while the old tariff system urges to the waste of electricity. In 2010 alone, the use of government subsidies against electricity consumption has already reached as much as B$40 million. Thus, with the renewal of this tariff, subsidy expenses have been reduced by as much as B$20 million and thereby reducing the use of natural gas of the country. This initiative is followed by the use of high energy efficiency appliances within buildings such as 'inverter' air-conditioners, low-energy bulbs and lightning system controls that make use of sensors.

In another move DES of Brunei has replaced the use of post-meter to pre-paid meter that help users to monitor their actual consumption. This is another initiative to encourage people to save energy. By the year 2035, Brunei is aiming to reduce the energy usage by 45%.

Related works in Home Energy Magaement System (HEMS): The importance in HEMS has grown significantly especially with the growth and emergence of modern ICTs and related technologies. A number of HEMS products have increased ranging from simple electricity feedback displays into fully integrated energy management system. It tends to help in improving energy efficiency and upgrade electricity infrastructure. The earliest HEMS technology was only providing feedback on electricity consumption via displays. Research by Ehrhardt-Martinez *et al.* (2010) has shown that this method was effective in making the electricity information visible to users and results in home energy savings. The most common type of information is providing the energy feedback like total electricity power used in a day and the resulting electricity bills. Others types of information such as demand response prompts to users (Rahman, 2013) or provide comparison of user's energy use with other users (Han *et al.*, 2011). The information on the electricity use is collected from existing hardware in several ways such as either from meter, utility, sensors implemented on the appliances or smart devices.

In the research, there are two factors that might impact user's engagement on using HEMS which are presentation medium and the design of the electricity feedback devices. Various projects on HEMS having various type of GUI have been proposed. In the study, Kuzlu *et al.* (2012), the GUI displayed power consumption in sensor node in a form of graph. Some research by Karlin *et al.* (2015) proposed GUI that enabled the homeowner to find out their status of appliances such as the power consumed for each appliance, the total power consumption in a day and sometimes even allow the changing of setting like the load priority and so forth.

In the research, Niyato *et al.* (2011) the operation of the home appliances can be controlled and viewed by the user from a remote location in the home via a user interface. The control request is transmitted to the appliances via various networks. There is a research by Niyato *et al.* (2011) that proposed different communication protocols like Zigbee, that are used to control a room. The research by Asare-Bediako *et al.* (2012) proposed a network architecture that uses machine-to machine communication for the HEMS to be able to collect energy consumption demand and status from the household appliances.

In a more advanced intelligent system, rule-based control is used in scheduling where users set some sort of a plan on how to manage household appliances ahead of time (LaMarche *et al.*, 2011; Zhao *et al.*, 2013). Optimization of all the previous usage data by analyzing and using an algorithm to develop for demand respond is also highlighted by Niyato *et al.* (2011) and Abo-Zahhad *et al.* (2015). Researchers proposed an optimal power scheduling method for Demand Respond (DR) in their HEMS in an attempt to help reducing electricity expense and Peak-to-Average Ratio (PAR). Web-based HEMS for demand responds by Rahman (2013) have developed an algorithm that can control appliances operation based on user preferences.

HEMSs mentioned above use different components to fulfill their specific purposes such as HEMS with user interfaces and displays, HEMS with different monitoring and control devices (example smart appliances) and HEMS that enable communication network (such as Zigbee). Android based monitoring using the maximum load or the rating of appliances can offer an innovative

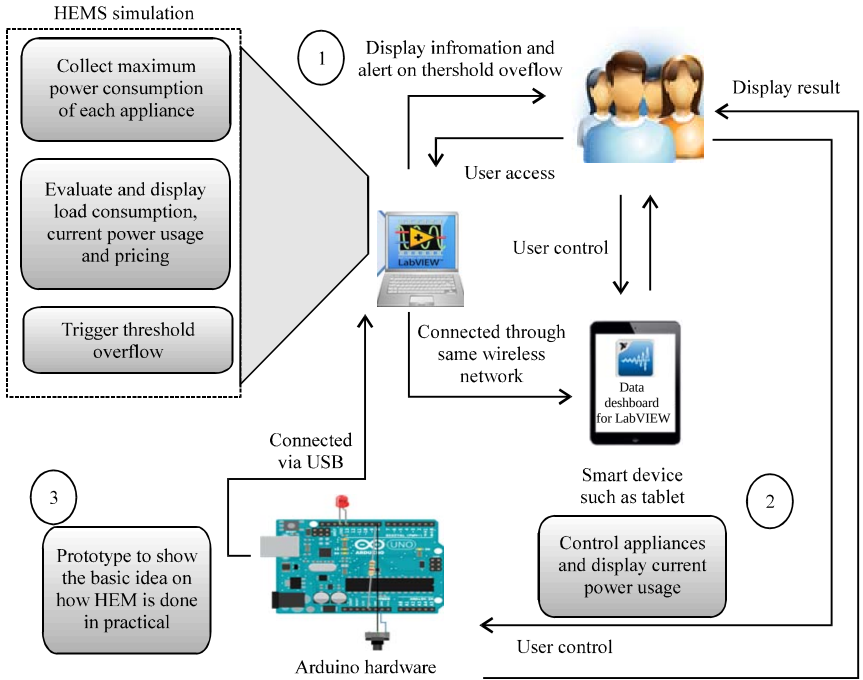

Fig. 1: Proposed AHEMS system architecture

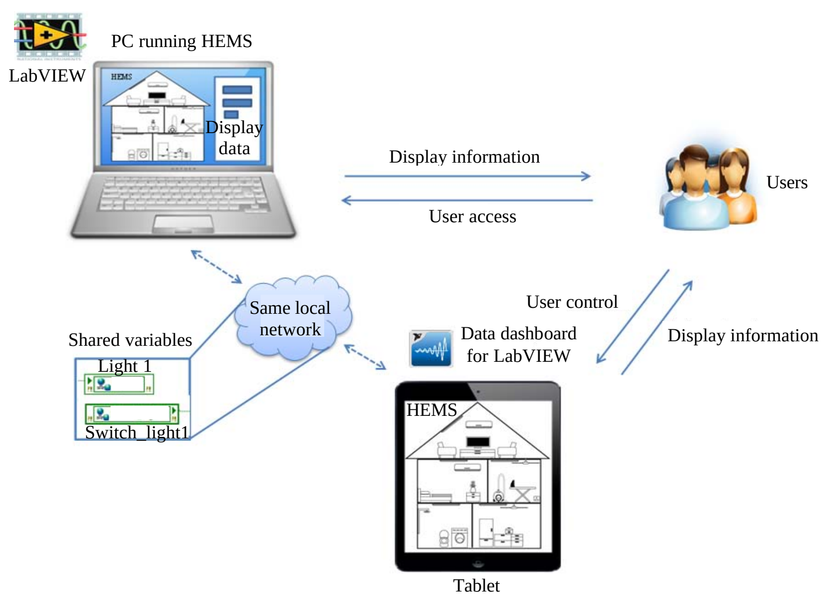

Fig. 2: Android to PC integration architecture

and quick solution for users to easily monitor the energy usage and by setting an energy threshold value could help to conserve energy in a house through alerting users or sending alert signals. We developed a portotype and used typical household appliances based on DES recommendation (Table 1) to simulate the proposed system.

AHEMS system architecture: The proposed AHEMS system architecture is shown in Fig. 1 and 2, it consist of three parts:

- Home Energy Management System (HEMS) unit: it is where the graphical user interface for monitoring and control of appliances can be seen

Table 1: Electricity bill rate at home

Electrical equipment	Watt	Amp	Estimated cost of use
Air condition	840	3.50	20 sen per jam
Fan	84	0.35	0.2 sen per jam
Fluorescent light	40	0.17	288 sen per hari
Teleision 29	100	0.41	3 sen per jam
Refrigerator	550	2.30	80 sen per hari
Refrigerator ais	330	1.38	45 sen per hari
Washing machine	1080	4.50	0.4 sen per min
Vacuum cleaner	550	2.30	0.25 sen per min
Air cleaner	550	2.30	0.25 sen per min
Computer	400	4.10	12 sen per jam
Water pump	150	0.63	4.5 sen per jam
Water heater	2000	8.33	43.6 sen per jam
Iron	1000	4.16	21.8 sen per jam
Microwave	1300	5.42	28.3 sen per jam
Rice cooker	1000	4.17	21.8 sen per jam
Cloth dryer	3000	12.50	65.4 sen per jam
Dish washer	2700	11.25	58.9 sen per jam

- Android tablet PC integration: connecting an Android tablet with the HEMS allows the display of the monitored data to be remotely controlled as long as there is an inernet connction
- HEMS prototype with Arduino hardware: an Arduino was used for demonstartion and proof of concept to connect the controlling mechanism to the household device such as lights, fans, etc.

HEMS: This unit is responsible for the estimation and conversion of power usage into readable display view. It involves the follwing steps:

- Step 1: collect the maximum power usage of each appliance in Watt per Hour (W/h)
- Step 2: convert the maximum power usage taken in hour (W/h) to second (W/sec) in order to be able to trigger threshold and alert the overflow on time
- Step 3: total up the maximum power usage (W/sec) of appliances that are switched ON
- Step 4: convert total maximum power usage from Watt (W/sec) to kW (kW/sec) in order to get the load consumption that is used for calculating electricity based on kW
- Step 5: generate the electricity bill based on the total load consumption used with the DES electricity tariff structure
- Step 6: total up the maximum power (W/sec) of appliances and use this value to set the percentage threshold value
- Step 7: visualize all the gathered information such as the total power consumption (W/sec), load consumption (kW/sec), the electricity bill (B$) and the threshold value
- Step 8: compare the total power consumption with the threshold value. If it is more than the threshold value, then
- Step 9: alert the threshold overflow by turning on the overflow indicator alarm
- Step 10: switch off appliances based on load priority's decision

Android tablet PC integration: Dashboards offer monitoring and controlling from LabVIEW application. It is also able to update information through network published shared variables. The reason of using Android tablet is that it provides easy interface, allows fast startup and the size is convenient to be used for this simulation purpose. The tablet and the PC with LabVIEW must be connected to the same wireless network.

Data dashboard allows pages to be produced with real-time data updates that is sent from the PC running the HEMS through the NI shared variables that are being program in the LabVIEW. So, whenever, a user makes changes on the PC running the HEMS GUI, example switching on the light, LED indicator of the light turns on both the PC and the tablet and vice versa, both devices will sync with each other.

Arduino connection setup: In order for the Arduino to be able to communicate with the LabVIEW, the toolkit called LINX is needed to be installed. Hardware setup are required depending on how many devices are connected to the ahrdwre. For proof of concept and simulation purpose two appliances are used which are a light and a fan that represent low-priority household appliances. The controlling mechanism in this simulation meant that controlling the ON/OFF of the appliances can be either from the GUI LabVIEW on the PC, GUI on the Android tablet or the physical control on the appliancs.

AHEMS Dashboard on Android and PC: The Android tablet device AHEMS can be connected to the HEMS on PC with the use of Data Dashboard application that result in saving time and effort. Dashboard page was set up with an interface that matches the HEMS LabVIEW interface but for proof of concept we limited to contain only the light indicators that indicate the on/off of appliances for the purpose of monitoring and controlling appliances. Figure 3 and 4 show the screenshots of HEMS LabVIEW and AHEMS Adroid data dashboards. Both the dashboards will be sync once the system is running.

In Fig. 3, when appliances are switched on for example the aircon, light, etc., the aircon and light

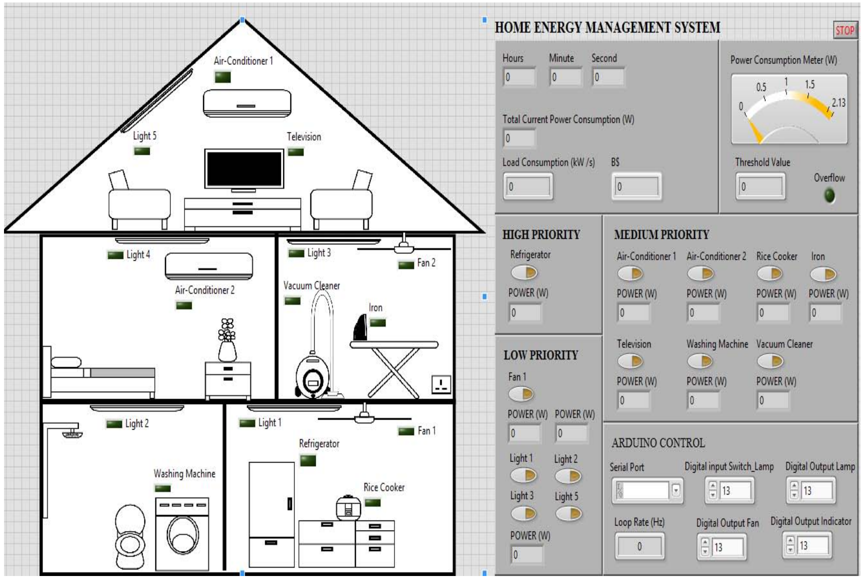

Fig. 3: HEMS GUI using LabVIEW on PC

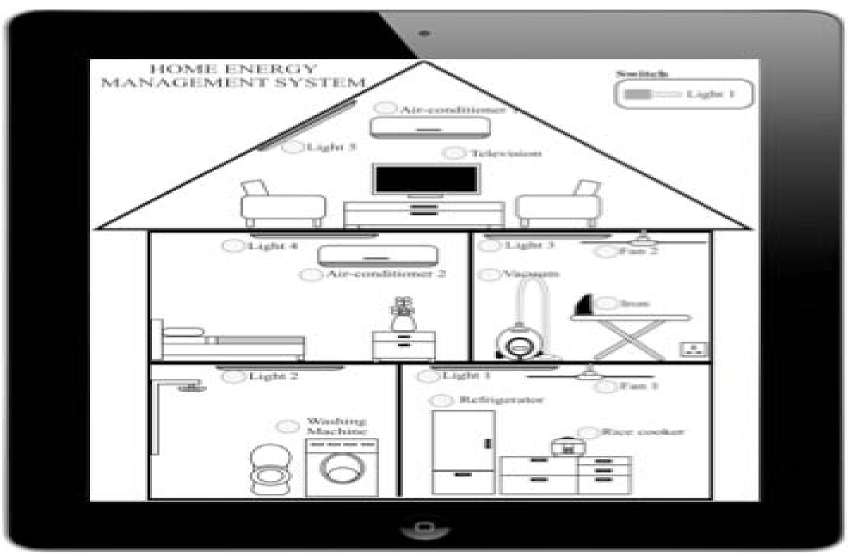

Fig. 4: Screen of AHEMS dashoboard panel showing the status of applicances in a home

indicators will be on too as highlighted in Fig. 5. Like wise for the other appliances. The total maximum power consumption for the household will also be calcualted and will be shown real time on the dashboards. The bill of electricity will also be estimated and displayed. As for the threshold setting, it consists of a light, indicator and the value can be set by the user. The threshold value can also be set to be automatic so that whenever there are new appliance installed and switched on, it will be updated to the new threshold value. Table 2 shows the running of the AHEMS with the threshold value set to 40% of the total power of a household appliances to see if the system be have as expected. It can be seen that the alarm is triggered once the total current power consumption exceeds the threshold value set. What the system do next is to switch off low priority appliance and to make user aware on the overflow. In this simulation, light 5 is switched off when the threhold is reached. However when, the current power consumption is still exceeding the threshold, there is no further action carried out but the overflow indicator still ON to alert the user in this simulation.

Table 2: Responds of devices when threshold is reached

Device	Maximum power usage (W)	Overflow indicator condition	Threshold 40% (0.852) Consumption (W)	Action
Fridge	550	0.153	OFF	NIL
Light 4	40	0.164	OFF	NIL
Light 5	40	0.175	OFF	NIL
Fan 1	75	0.196	OFF	NIL
Fan 2	52	0.211	OFF	NIL
Light 2	40	0.221	OFF	NIL
Light 3	40	0.233	OFF	NIL
Light 1	40	0.244	OFF	NIL
Air-Con1	920	0.499	OFF	NIL
Air-Con2	1850	1.013	ON	Light 5 off

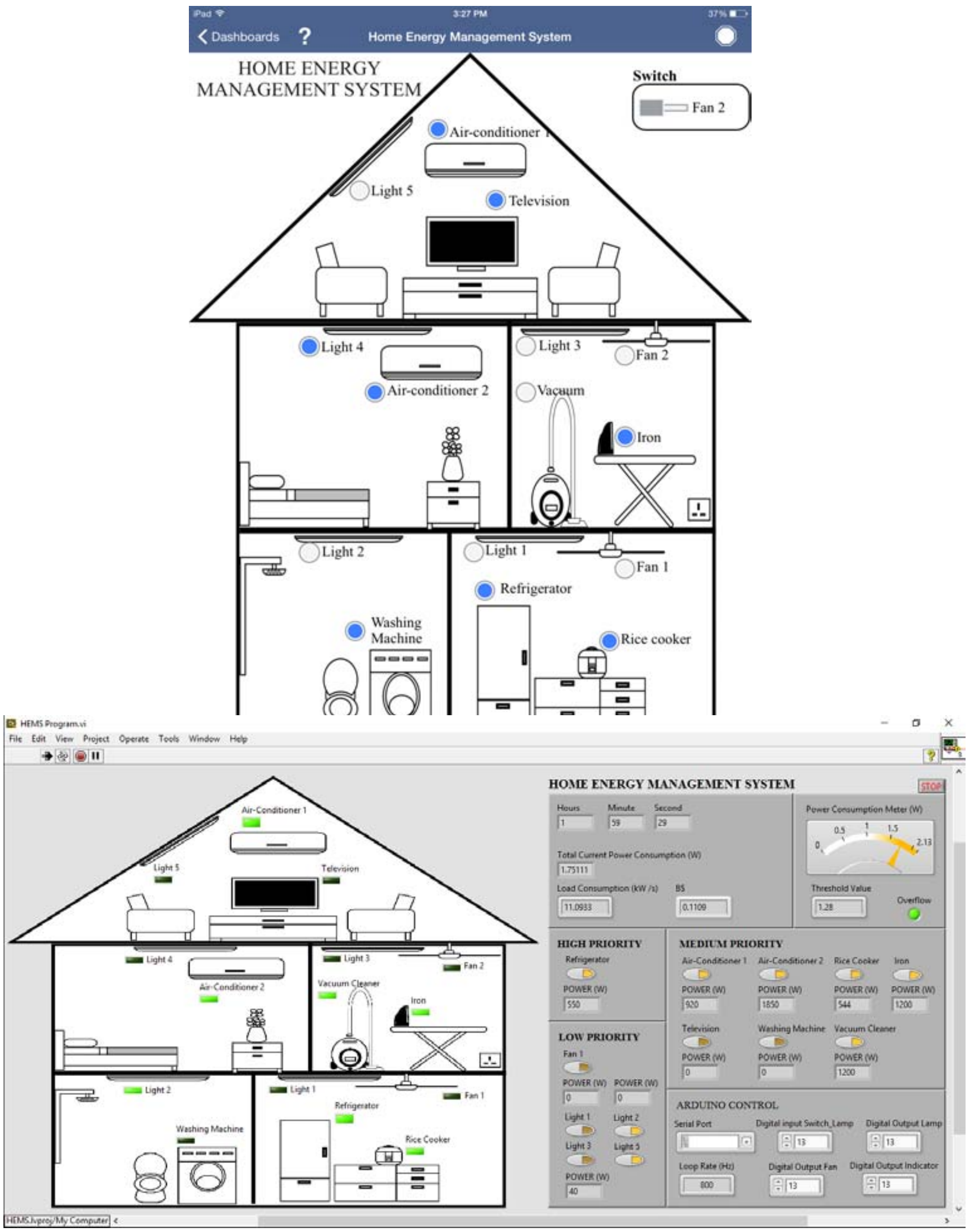

Fig. 5: a) Light and aircon indicators on and b) Total power consumption comparing to threshold

CONCLUSION

The AHEMS provides a good starting points of an annovative and cost effective way of providing awareness to energy conservation through setting the threshold value by the user, switching off low priority appliances and alerting user when the threshold value is exceeded. The simulation however is using Brunei DES recommended values based on a typical Bruneian household without taking into consideration the household size, the nuumber of people living in the household, peak demand period, climate change and individual behavior towards usage in electricity. These factors will have impact to the development of the AHEMS. Therefore, further work can be extended to better understand user's energy usage, usage behavior, house structures and climate change to be included in the intelligent part of the system. Research concerning consumers adoption and their willingness to use AHEMS should also be considered.

The proposed system used only real-time power usage based on ratings of appliances instead of actual power used by the appliances. Therefore, the AHEMS only shows and used the maximum power when apliances are switched on. The system can be made more sophisticated by inclduing means of measuring the actual power consumed by using power measuring equipment such as a power meter but this will add up to the cost of the total design of the system.

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