Monitoring and Characterization of Miscellaneous Electrical Loads in INDUSTRIES using CPS and IOT

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ABSTRACT: **Energy saving in Industries is often encumbered due to the lack of knowledge about the energy, how much the energy is required and how can be the usage of energy will be automated & how it can be controlled. The problem occurred is especially sensitive for the large number of small devices using this energy. Such type of devices face problem in both residential as well as commercial building. Many of such devices use ac to dc power supply switching to operate the electronic and other supporting devices of components. We explain the communication of energy and controlling information between device and a industrial management entities by the use of Communication power Supply i.e. CPS. We designed a system of Internet connectivity CPSs and implemented both energy reporting and control utilizing the cloud computing based data clearing house. If the CPS technology is used in huge spread in device an integrated human interactive solution and automation would able to save the energy in large quantity. Such types of problems are also faced in irrigation. We can also use the CPS in the irrigation plants for controlling the flow of water. According to the physical parameters such as humidity, temperature of the soil we can sense it with the help of few sensors.**

KEYWORDS: **Internet of Things, Communication Power Supply, Nonintrusive load monitoring.**

I. INTRODUCTION

With limited and lack of knowledge about which uses the energy, it is very difficult task for reducing the waste of energy. The average number of the use of energy by the small devices in industrial as well as residential has been increasing day by day. The use of plug and use devices has also increased. Around 35% of such devices consumes large amount of electricity. With the help of Internet of Things (IoT) we have the opportunity to understand and learn the effective use of such plug and use devices and considerably the energy consumption can be controlled.

The everyday electronic devices are such that they can be connected to Internet. The use of Television with advance media networking features, computers and home appliances are driving much of the increase in building energy use. In the devices until now, there are no in build capability to measure and inform it through the network. In IoT network connectivity is very difficult part for such devices and tasks. If we want to understand the efficiency of the energy consumed to energy wasted then the electricity metering and monitoring is an important task. Till now the metering of the energy is proven costly and complicated.

As introduced the concept of CPS, which includes electricity metering, communicating with electronic devices that can be used with this type of infrastructure. We introduce to add metering by using these properties of the ac to dc switching power supplies that are widely used in day today's electronic devices. This type of power supply has the capability to supply the voltage and current through a transformer at rates between 1 and 100 kHz depending on input voltage and power requirement. Cost required for measuring such type of power supply is very cheap. This electricity measuring and metering can be used for measuring the amount of energy used in small devices such as LEDs and battery chargers. Even for the larger device such as motors and other advanced technology devices needs very less amount of money for metering. Due to such cheap and easy of the existing technology, energy awareness in an application can adopt the concept of IoT over all devices.

In this paper we have introduced the CPS and presented an implementation of a CPS system. In section II, we have discussed the overall concept. Section III contains a survey of the work related on energy awareness devices as well as on communicating energy information on local area network and the Internet. In section IV we discuss about the principals of operations, hardware implementation, architecture and energy saving application. In section V we have provided a view on the widespread deployment of this technology form customer, energy efficiency view of energy policy.
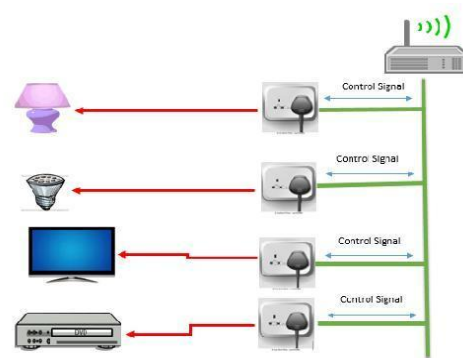

Fig 1.Devices connected to Web Server

II. SECTION

It is very important to reduce the energy required by the plug and use type of loads. As the use of plug and use electronic devices are increasing, the efficiency of the energy used should be also focused. At present there is various energy saving applications available but the user is not totally satisfied with such power saving appliance. The program like EPA i.e. Energy Star Program has the ability to efficiently save the energy. Unfortunately due to advanced technology devices, it has been difficult for such program, to handle this type of advanced technology devices.

Currently new types of power saving and controlling appliance are available for the plug and use type of devices. These types of appliances are placed in between the device and the plug. Though this device we have the flexibility of controlling and monitoring the device smartly, one major disadvantage of such device is the loss of controls. Such as switch, remotes, etc. For example, if one device is placed in between the fan and a plug, the actual fan switch must always be "ON", in order for the relay in the output control to function. This type of approach replaces the initial interface, with the controlling device. Sometimes it will not act according to the user. User wants the initial interface which is expected and because of unexpected interface the user gets frustrated and rejects the use of such control technology. The other drawback for plug-through device is that, the specific device is not permanently assigned to the same plug. So the user needs to change the identity of the device which is to be plugged to the plug-through. So changing the identity each time, as we change the position of the device is really hectic job for the user.

The concept used by us related to CPS, measure the energy used for the plug and use type of devices. According to the devices identity is set through the network and we can receive control information of the devices. At the same time we can control the power state directly, interface on the device, so that the existing and basic control of the devices remains unchanged. The concept of CPS can be explained through the Fig.1, in which 4 devices are powered by the CPS. The power supply measures the use of the energy used by the device and also converts ac mains into DC power. The control requests from the user or energy management application is received in the network based control and this request or information is accessed through the web services installed with the CPS system. The CPS passes this information to control the device of interest and the power state of the device can be changed accordingly. The device remains connected to the power supply the entire time and basic controls on the device continues to function. The energy usage information is recorded and reported at regular time period as per the central entity.

Main difference between CPS technology and existing solution are as given below:-

i)   The CPS is a combination of power supply which has information of the devices under control. This makes CPS as a unique device in markets.

ii)   Due to more use of in build features of CPS the cost of monitoring and controlling reduces.

iii)   The CPS make to retain all the basic control

and user interface which do not require the user to adopt different knowledge and types of controls to be used in.

III. RELATED WORK

The use of the device which has the capability to measure and control the energy used has been increased by a large amount in last few years, and there are many activity in academic literature, consumer market and among standard organizations. In this section we will be over viewing the already used solutions for measuring and reporting the use of energy in the device over the network.

A. Consumer Products used for Energy awareness:

Basically there are three types of categories of the existing system for measuring the energy of plug and use level energy monitoring and nonintrusive load monitoring (NILM). There is also many more middleware network communication available for the plug and use energy monitoring with the central unit.

Many of the appliance manufacturers offer a smart line to the home appliance that can be connected to the Wi-Fi and can be monitored and controlled with the help of your mobile or the personal computers. The home appliances are mostly the large appliance such as dryer, dishwashers, and refrigerators. The costing of such appliance is mostly high and has the features that may not be required by the home owners who are only interested in the energy reporting capabilities.

Plug and use energy monitors offer monitoring and control capabilities as an individual power strip at the circuit breaker panel. The more costly plug adapters are used in monitoring each device individually. The communication of the devices takes place through Internet network which provides a User Interface for the user on mobile or computer devices. It costs nearly 70$ per plug and use device and it can also exceed till 1500$ to control and monitor the important devices in a single home by using different gateways and control software. With high initial installation cost it also has certain drawbacks. First, they must be installed and programmed individually. If the device is uninstalled or moved to a different plug, then the control and identification information are lost. Second, many of the devices require correct communication protocols, which lead to incompatibilities and legacy networks.

The other option for plug and use monitors are NILM systems. NILM system has an energy meter to measure the whole house energy consumption and use signal processing to separate the end use through methods such as machine learning. There is no commercial product available in today's market. The NILM technique works efficiently for large loads that operates in different levels, but does not work effectively for the low powered loads with large number of changing states, for example microwave oven and electric stove. The energy consumption of an electric stove will not be recognized as any type of load needs to change power consumption within the monitoring time period that is to be identified. Loads also need to change power consumption in different levels. Continuously changing loads such as dimmer switches on light or adjustable speed drives on motor cannot be monitored without implementing expensive
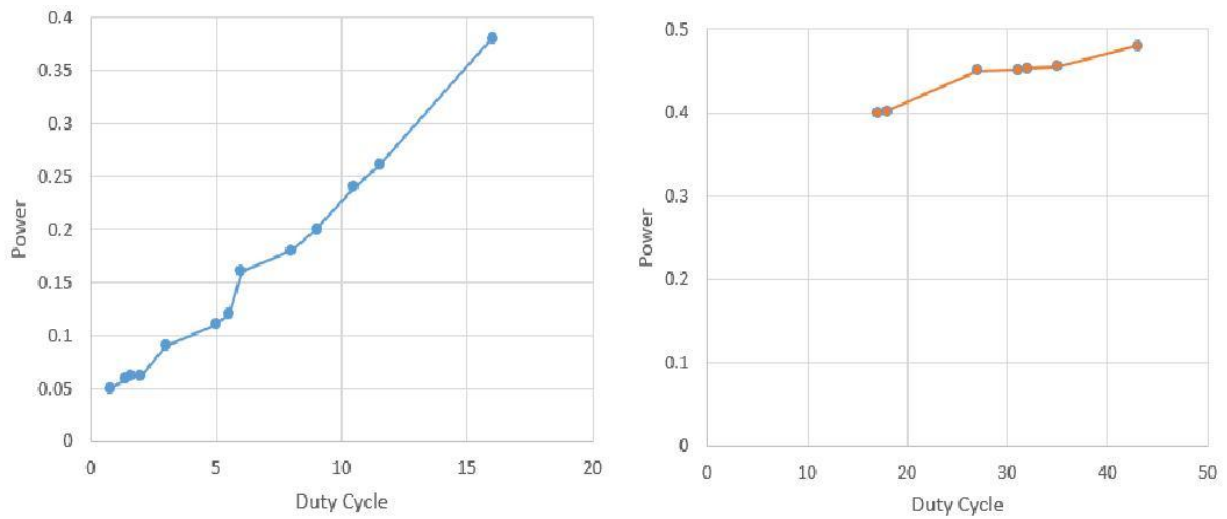
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featured detectors. Low power consumption appliances such as MELs, also has the similar power consumption graphs, by which the recognition task becomes more challenging. NILM has the drawback that it can't meter the energy consumption as such as the actual energy meters. Many efforts are taken for implementing the energy monitoring with the use of open source "Middleware". The software and hardware architecture makes easy communication between the user monitor and central unit. The use of embedded system is done for monitoring the energy and communicates the information over the network layer to the main server with the help of those embedded system. The user interface would load on the users mobile or personal computers, which makes the controlling and monitor the information via data server. By making the use of both middleware as well as CPS, we can implement a complete energy monitoring system.

B. Energy Monitoring and Controlling Protocols:

The number of protocols or formats for energy monitoring and reporting has increased in recent years. Some are implemented using LAN i.e. with the help of Zigbee Smart Energy profile, where as others are implemented by using the Internet protocols. The previously categorised protocols are basically designed to operate with low power wireless devices that support the small size packet and later protocols captured human readability over compactness. The CPS system is concerned with transferring of data through LANs, and it makes sense. We would make use of simple device, low powered network capabilities rather than use of Wi-Fi or Ethernet connections. All the CPS devices use the same network interface and data format for transmission. The CPS has the capability to communicate through both broadband as well as lower speed connections between the network and the device to be monitored. A brief overview of popular and emerging standards for sharing the energy information, the disadvantages and advantages can be seen in this section.

The low powered devices using IEEE 802.15.4 radios with the help of Zigbee SEP version 1.x and 2.0 are used. The SEP version 2.0 can be used over other network link that supports IPv6 in addition to IEEE 802.15.4 links. SEP 1.x was efficiently used for very short packet lengths available in 802.15.4 standard, but there are many interacting problems with 1.x versions. As the SEP 2.0 was designed to operate over IPv6 using the HTTP interface, because of which the challenges likes short packet length, long time delay and complexity increases.

The XML standards such as open ADR 2.0b and GreenButtonConnect are used for communicating and exchanging the energy information between utilities, customer and third party energy provider. The SEP was designed to pass the information over high bandwidth network connections and the file size is measured in terms of tens of kilobytes. Due to high bandwidth network the data passing of lower-power networks become difficult. It is mandatory to use this type of standards with respective application area only.

The development in the framework of energy management of devices is taken by the Working Group known as Internet Engineering Task Force (IETF) . Energy Management Work Group, which is based on Simple Network Management protocol (SNMP). Management Information Base (MIB) is used to interact with the device which we want to monitor and control. The identification and monitoring of the energy state of the object is done by the framework primarily address. A new standard was announced by Electric Power research Institute (EPRI) and Consumer Electronic Association (CEA) that defines a modular communication interface for the appliance which are based on the Universal Smart Network Access Port concept. This standard mentions the details of logical, mechanical and electrical characteristics of socket interface that all the communication of the devices with each other. It is defined as a Universal Communication Modules, "to be separated from end devices" such as the smart communication nodes, smart metering meters and other smart grid devices. This is an upcoming standard, but the interface to the MCI is a simple interface and the networking handled by the MCI. As these types of standards are attractive for low devices, but the use of MCI at present time is relatively expensive as the number of devices connected are more. There is no particular energy monitoring standard or any type of scheme for MCI at present time, but there are also some other protocols that supports the MCIs.

Fig 2. CPS with schematic blocks.

IV PROOF OF DEMONSTRATION OF THE CONCEPT

CPS allows uninterrupted power reporting and controls. To explain the concept of CPS deeply we implemented a network which is connected to CPS and the CPS is connected to the four electronic devices which we explained in previous section. In this part we are explaining the actual operation, implemented software and hardware and examples on energy saving appliances.

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Fig 3. (a)Power Vs. Duty Cycle curve. Calibration for $R^2=0.98$ (b) Power Vs. Duty Cycle curve calibration for $R^2=0.95$

Principles of Operation:

There are various components of CPS. The first component of CPS is the power supply which effectively converts the incoming ac power to dc power. We also added few more components that make us to measure the amount of power converted by the power supply. We have also used the microprocessor to manage those measurements and accordingly control this through network. We have also used a radio frequency transceiver that handles the physical parameters over the network.

The power supply varies the duty cycle of the switch which controls the current in magnetic element, and accordingly the power in the outputs controlled. To maintain the output within the specific set, it is required that the correct duty cycle should be obtained and this can be obtained by taking the feedback of the output voltage or current to the controller. The power supplies which are now available in the markets need to do this task with a very high efficiency with low output powers and they should not consume more power virtually in the no load conditions. To minimize the waste of energy and maximize the performance the power supply needs to modulate both duty cycle as well as the frequency of switching. Fig.2 shows the simplified construction of CPS which is without feedback. The output of the controller which controls the switching action of power supply is digitized by the microcontroller and a low pass filtered. The amount of the input voltage is also measured by the microcontroller. These two values are applied to the lookup table with the interpolation to measure duty cycle and voltage to the power level. Fig.3 shows an example of calibration curve with measured duty cycle on different axis and input power to the supply on the Y-axis for a fixed in input voltages. The curve has a linear characteristics where as there is a clear duty cycles. The frequency reaches the maximum value by only changing the duty cycle. This occurs because of

the output is high. Fig.5 shows the duty cycle output changes over differing input voltage. To determine the system operating voltage it is mandatory to measure the input voltage due to low slope of these curves.

Under the circumstances of our demonstration the wireless networking we performed is a simply rough system. We also overviewed to the wireless networks which are available now a day and found out that it was not easy with such networks for our demo prototype and we had many spectral objections faced while implementing the system. When the communication become uncertain, the network communicate with central hub, an accordingly changes the carrier frequency. If the communication gets disconnected then the nodes search issues the carrier frequency for reconnection.
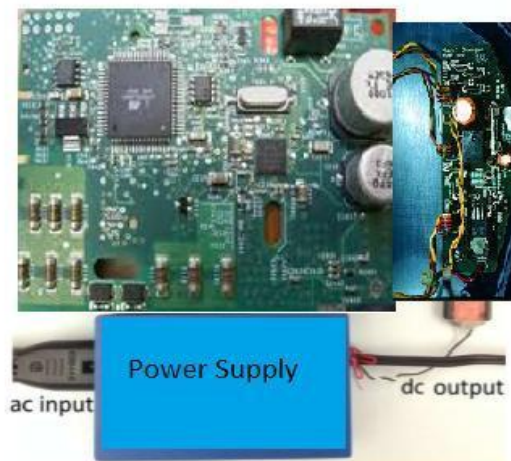

Fig 4. Circuit having Power Supply, RF Module

B. **Implementation of Hardware**:-

The purpose of our demonstration has two reasons to explain the working of the CPS as it is related to the IoT. We selected the hardware components whose software libraries was available on internet as an open source. The only power supply was the device which was used for interfacing the components. The changes which we brought in our power supply which cost almost nothing for us. We used ARM for developing and used LPC1768 Microcontroller. The processor which we used for developing the system is more than capable and the network complexity is also low and the 8 bit device can also be implemented efficiently. ARM also has the software flexibility with the help of which we can easily switch to other microcontroller which reduces the production cost. The basic network which we used was with the help of Nordic Nrf21FL01 transreciever. We also design a PCB on which we mounted the microcontroller with which we interfaced the components which we required for reading the values from power supply. A photograph of a CPS which includes power supply, processor and RF module which is mounted on PCB is as shown in Fig 4.

Before controlling any device the basic of product should be understood. Turning the device ON or OFF is controlled by a simple press button. The CPS switch is done with the help MOSFET transistor which is connected in parallel to the user switch.

We used DAC converter where it was needed to control analogy signal and with the help of OP-amp the required signal was used to drive the microcontroller. Interfacing the things with devices with already available interface, it is easy to accomplish as a part of designing process.

For testing the components we implemented them on the bread board and observed the actual functionality. We also designed and implemented the circuit board that has no of connections fabricated on it.
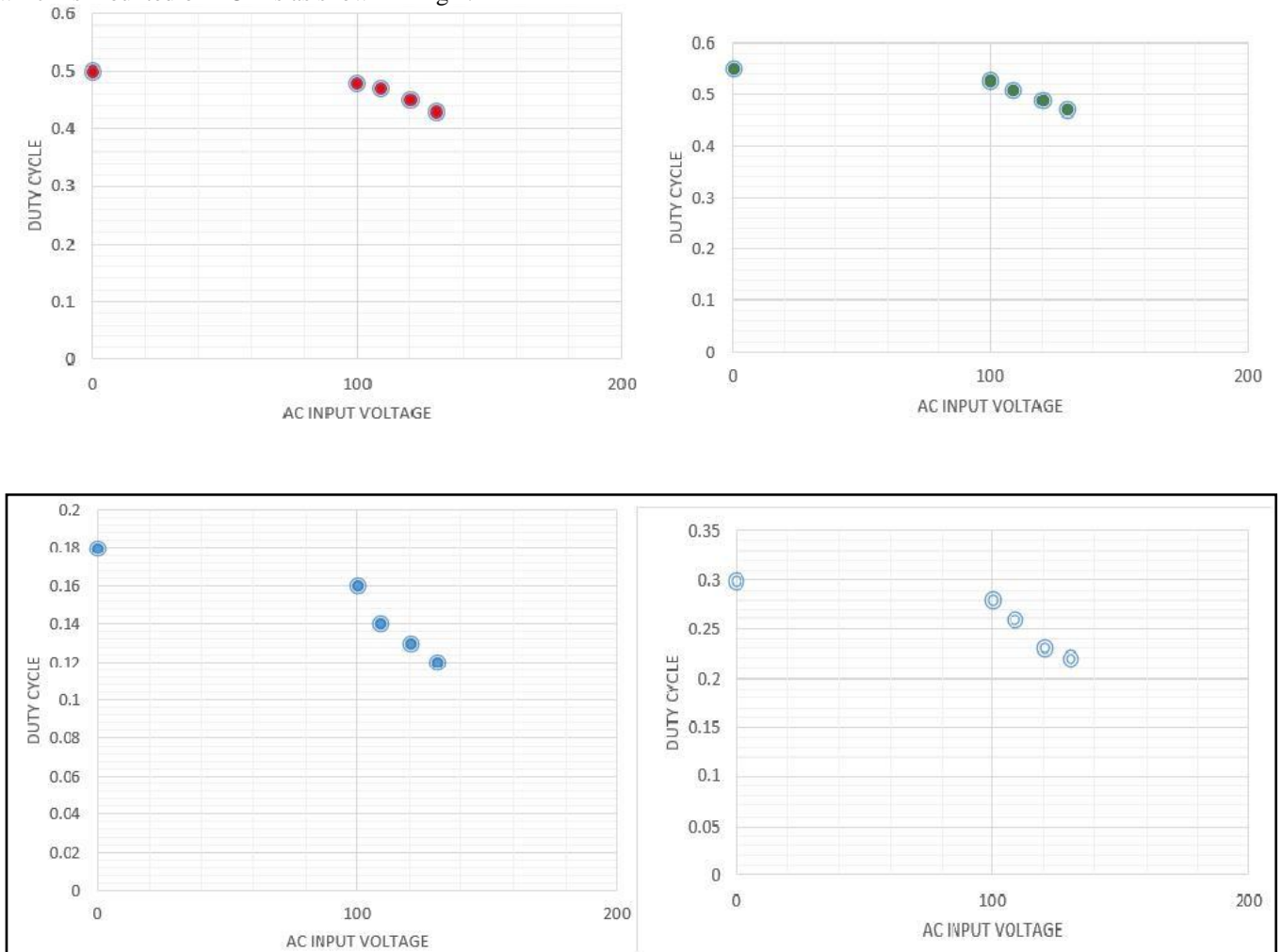
Fig 5. Duty Cycle Variation by Input Voltage (a) Curve for 6W (b) Curve for 11W (c) Curve for 20W (d) Curve for 44W

C. System demonstration Architecture:

With the help of CPS technology we interface the LED, lamp, TV and DVD player. The energy used by the four devices was monitored in real time and resulting data was displayed on monitor with the help of internet. The monitor provides or displays the energy usage information and one can also control the devices which are connected to CPS. Fig 6 shows an example of overall system. The device connected to the CPS and the central hub provides as a brain to them. The hub is connected to the local server with ARM based Linux computer, which interacts with the web services running in the cloud. In this section the detailed functions and interaction of the system is mentioned.

DVD player, TV, LED and lamp are integrated with the embedded nodes with the power supply. Fig 6 shows the functioning description of all blocks used in CPS. The control and measuring of the energy consumption is done by this embedded nodes. These nodes also receive the control signal and accordingly control the devices. There is a wireless communication between the nodes and the devices. The hub receives the energy usage information from those nodes and gives this information to the CPS which is connected with the devices. We used the tablet/mobile to interact with the internet server and to display the energy information to the user. Fig.7 shows the example of mobile display with the information such as temperature, power and controlling buttons like ON and OFF. It was approximately three weeks needed for building our prototype with few employees, low cost and few hardware.

D. Behaviours and Applications of Energy Saving:

For demonstrating the uninterrupted load and controlling the CPS we used very less software development and used the hardware which was already available. We just made the changes in term of intelligent behavior of the devices and implemented the setup. If suppose the TV is OFF, then our server detects that and accordingly turns OFF the Blu-ray player, and when the Blu-ray was turned ON the server makes the TV also turned ON. These type of controlling presented the energy saving smartly without facing any type of obstacles. The network of the CPS can be also with the number of such type of controlling action and hence for the energy is also saved.
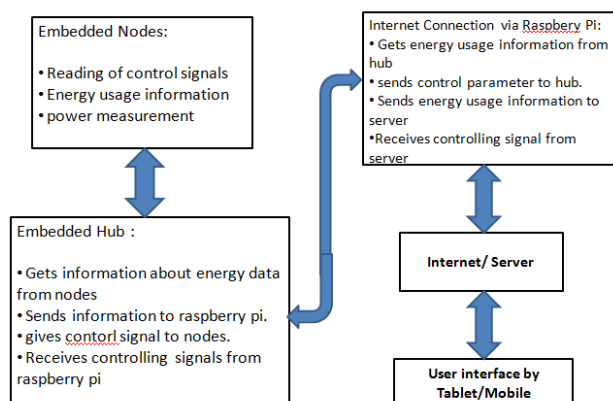

Fig 6.Fuctioning Description of Blocks

.Fig 7. Example of Mobile controlled and measuring

E. Comparison to Related Work:

Advantages of CPS with the related work are that the CPS is sold as a part of the product. This results in market scalability, low cost and ability to expand widely. The main feature of the CPS is the ability to use to use the basic controls of the dashboard interface. The hardware only represents the extra functionality instead of replacement for the control with which the user is comfortable. When the devices are plugged in accordance to the user then they need not to do any additional setting to configure the functionality of the device. The hardware instantly starts functioning. The users also have the option of not using the control and monitoring option through the web.

As the CPS is a part of the product, so identity the product in the factory itself. Even though the product is moved from one application to the other application the identity will always with it. By making the control and monitoring of the device into a single hardware device the consumers face very less burden in learning the device monitoring and controlling. For adding power measurement capability a microprocessor as mentioned before can be used and it will cost around USD 0.10 of the total price. For networking purpose a low cost IEEE 802.15.4 radio can be used which will cost about $1 which also includes radio chip, there are also some other networking topologies but they cost somewhat high comparatively. Implementation of hardware is an important step of this technology, because we are implementing it from a low advanced technology to a relatively high and advanced technology and it also need to adopt this technology by an average consumers.

Raspberry Pi Hardware

The Raspberry Pi is a credit-card sized computer that plugs into your TV and a keyboard. It is a capable little computer which can be used in electronics projects, and for many of the things that your desktop PC does, like spreadsheets, word-processing and games. It also plays high-definition video. We want to see it being used by kids all over the world to learn how computers work, how to manipulate the electronic world around them, and how to program.
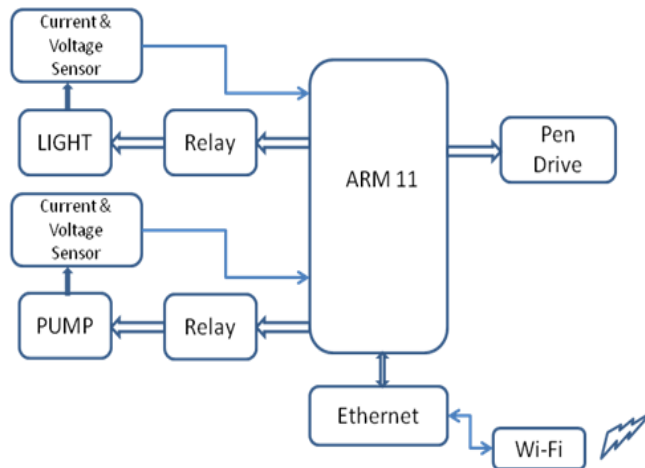
BLOCK DIAGRAM OF COMMUNICATING POWER SUPPLY

The Raspberry Pi is a low cost, credit-card sized computer that plugs into a computer monitor or TV, and uses a standard keyboard and mouse. It is a capable little device that enables people of all ages to explore computing, and to learn how to program in languages like Scratch and Python. It's capable of doing everything you'd expect a desktop computer to do, from browsing the internet and playing high-definition video, to making spreadsheets, word-processing, and playing games.

What's more, the Raspberry Pi has the ability to interact with the outside world, and has been used in a wide array of digital maker projects, from music machines and parent detectors to weather stations and tweeting birdhouses with infra-red cameras. We want to see the Raspberry Pi being used by kids all over the world to learn to program and understand how computers work.

Basic Setup

Typical Hardware Raspberry Pi will need while the RsPi can be used without any additional hardware (except a power supply of some kind), it won't be much use as a general computer. As with any normal PC, it is likely need some additional hardware. The following are more or less essential,

1. Raspberry Pi board

2. Prepared Operating System SD Card

3. USB keyboard

4. Display (with HDMI, DVI, Composite or SCART input)

5. Power Supply

6. Cables

Highly suggested extras include:

a. USB mouse

b. Internet connectivity - a USB Wi-Fi adaptor (Model A/B) or a LAN cable (Model B)

c. Powered USB Hub

d. Case

The diagram is to connect everything together, by using the following instructions:

- Plug the preloaded SD Card into the Pi.
- Plug the USB keyboard and mouse into the Pi, via a USB Hub. Connect the Hub to power, if necessary.
- Plug the video cable into the screen (TV) and into the Pi.
- Plug some extras devices into the Pi (USB Wi-Fi, Ethernet cable, hard drive etc.) This is where may really need a USB Hub.
- Ensure that USB Hub (if any) and screen are working.
- Plug the power source into the main socket.
- With my screen on, plug the other end of the power source into the Pi.
- The Pi should boot up and display messages on the screen.

It is always recommended to connect the MicroUSB Power to the unit last (while most connections can be made live, it is best practice to connect items such as displays/h/w pin connections with the power turned off).The RsPi may take a long time to boot when powered-on for the first time.

V. POLICY AND ENERGY IMPLICATIONS

The CPS has the capabilities of both saving energy as well as using energy effectively. The CPS also has the capability to report the power state, energy and unique identity to the central entity. So that the user has a proper acknowledgement of the energy use. Allowing the people to inform the usage of energy helps, but the informational action makes the user to take effective steps for saving energy. The devices which are now available in markets have very low sleep power. So the 50% of energy used by the devices is wasted [17]. The CPS has an ability to reduce the wastage of energy. Plug load research which are used in the industries suggests that simple timer controlled non-networked plug loads would save about 7% of commercial building energy use [20]. And many advanced control option can be made available in CPS technology so as the energy saving capability is increased by 5% to 10% in the buildings.

VI. CONCLUSIONS

We presented on Internet based system CPS that has the capability of energy saving and also energy awareness of devices and users. The CPS technology would be playing a vital role in the future energy monitoring of the plug and use type of loads and would be able to share the energy usage information over the network. The demonstration of the CPS is valid at a reasonable price and even a common man could purchase the CPS. Differing from other available technology, CPS devices has the ability to provide the basic controls of device to remain unchanged so that the user would not get confused. The CPS is low cost device with amazing concept of IoT. Hence above use of CPS can be also useful for irrigation in implementation of sensing humidity, temperature, etc of soil and accordingly control the physical parameters of the soil.

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