Home Energy Management System to Reduce Unconscious Electricity Consumption

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Abstract. The energy consumption in the residential area of Kazakhstan is increasing every year. One of the primary causes of excessive electricity demand is unconscious consumption. Therefore, to reduce the demand in residential area "Home Energy Management System" (HEMS) is introduced. This paper offers low-cost energy management system that will reduce electricity consumption in dormitories, homes, and apartments by notifying residents about excessive and unnecessary loads. The proposed system includes an energy meter to monitor real-time consumption of the house, a microprocessor to read data from energy meter and redirect it to cloud server via Wi-Fi module. The system also includes occupancy sensor that detects when a person leaves the house or arrive at the house. By relating the output of the occupancy sensor and energy meter the system sends electronic notification to the resident when some event occurs. As an example, in case, if person forgets to switch off any of the electronic device (lights, TV or even iron) when leaving the house, the HEMS will send a notification to the phone. The results have shown, that users could save up to 8000tg/year on energy consumption.

This paper aims: the rise of awareness regarding electricity consumption to the end user. State of the art technology – load profiling, demand control, Wi-Fi connection.

Reduction of electricity bills for customers. Reducing risks associated with electricity consumption. The energy management system that collects, process and display load data.

Keywords: Home Energy Management System (HEMS) · IoT · Smart Cities · Energy Savings · Microprocessors · Embedded Systems · Demand Response · Electricity consumption

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1 Introduction

1.1 Related Works

Latest studies on the fields of energy systems are transitioning towards demand side management and optimization. Demand Responses (DRs), Transactive Energy, and HEMS become burning topic in the power and energy systems. The most recent HEMS review in reference [1] has described over 120 articles related to HEMS projects, that includes microprocessor based systems. Recently General Electric presented HEMS that can be controlled via smartphone application [2]. In this work the HEMS is also planned to be controlled via mobile application. Some HEMS projects are integrated with DR that plays essential role in reduction of electricity demand in peak hours [3, 4]. These projects have applied DR model by utilizing load consumption pattern of customers and available distributed energy recourses (DERs). The authors in [5] has presented DR based HEMS for energy management in Hotels. Their system unlike other DR programs do not penalize end-users if they have failed to reduce power consumption. Some HEMS projects reviewed in [6] are designed specifically for smart homes, where household has control over appliances and HEMS optimizes energy consumption. Authors in [7] have presented real-time energy management of residential appliances including air conditioner, electric water heater, and clothes dryer. The authors in [8] have presented similar HEMS architecture for wider variety of appliances including non-schedulable ones. One of the HEMS project uses ZigBee controller to reduce energy consumption in a room via standby power cut-off outlets [9]. The authors in [10] have presented low-cost, user friendly HEMS using microcontroller – server – web interface layout. This work has also presented device recognition theory; however, authors have not implemented it. According to the theory loads have different amplitude (power), and output voltage (resistive, inductive, or capacitive), and due to devices may have different signatures. There are other microprocessor based HEMS that work with wireless communication like Wi-Fi, Bluetooth or ZigBee wireless protocol presented in [11–13]. Only few of related works have demonstrated practical results. This HEMS project will implement state-of-the art methods described in the literature and demonstrate practical results.

The main contributions of the work are to implement an innovative production of home energy management into the residential buildings of Kazakhstan. One of the goals of the project is to reduce risks associated with electricity consumption relate to the human factor, as well as make energy consumption more efficient. More precisely, HEMS product allow customer to track the consumption and reduce his electricity bills. The proposed system sends alert when there is excessive consumption or when user forgets to switch off electronics when leaving house. E.g., if person forgets to turn off the iron while leaving the house, the notification will be sent to his phone. We expect to make a prototype of the system, then test it in Astana IT University dormitory rooms and in case of the success employ system to other residential buildings of Kazakhstan.

2 Methodology

2.1 HEMS Work

Proposed HEMS consists of two parts, that are hardware and software. In the hardware part, the microcontroller with ESP8266 module connects to Wi-Fi network via ssid and pass, then it establishes connection with the remote server by providing "authentication token". The microcontroller continuously read data from energy meter and occupancy sensor, then microcontroller sends API Write Key containing the data to the remote server. User through phone application can monitor consumption and see his load profile. When consumption reaches certain threshold (E^{Max}) set by user, the app sends push notification. In case when occupancy sensor detects that user has left the house and there are some loads greater than E^{Min}, the app sends push notification. In case of two-zone differential electricity tariffs (with peak and off-peak hours) the user can set different energy limits to participate in DR program.

Software: Arduino program (embedded C), iOS/Android application.

Hardware: HEMS hardware, mobile phones with iOS/Android based application.

System Flow Chart

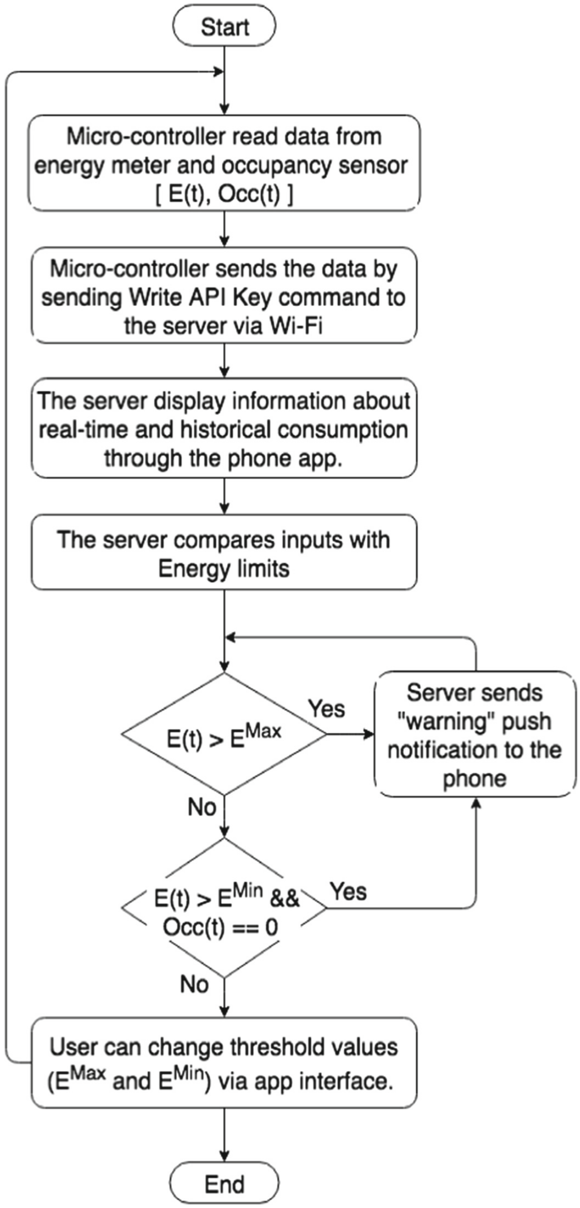


Fig. 1. Flow chart of HEMS

Components. Arduino Uno is used as a hardware that monitors data from the sensors. ESP8266 Wi-Fi module is used for transmitting and receiving data via Internet. Remote server is used to establish communication between hardware (Arduino + ESP) and mobile application.

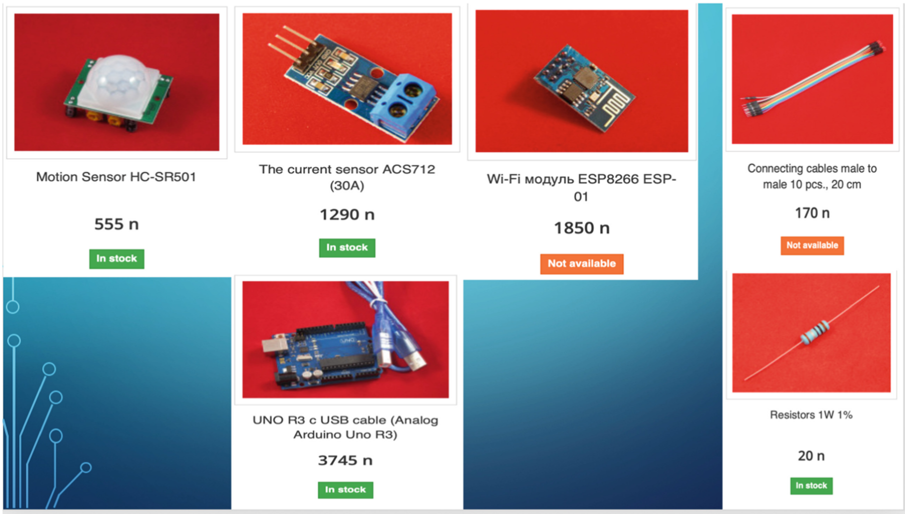


Fig. 2. Hardware components

HEMS project has the iOS/Android app. Unique authorization token was generated for the project. The project was built by utilizing several application widgets. The widgets include chart for power monitoring, several labels and gauges for current, power, occupancy and energy.

The interface has 2 menus: General and Settings. In general menu, all necessary information is displayed. In settings menu, user can choose recommended settings: 221V, pf = 0.85, tariff = 13.5(tg/kWh), $E^{max} = 75$ and $E^{min} = 15$. User can also customize sliders in custom settings.

Application for iOS/Android

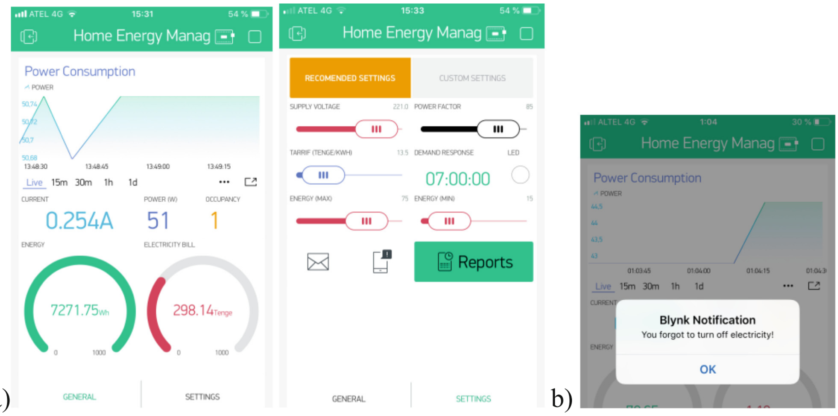
a) 

Fig. 3. a) Interface for mobile application. b) Notification system in case of extensive energy consumption and when user forgets to switch off the lights.

3 Results and Discussion

3.1 Building Prototype

The hardware components are packed in the carton box. Inside box there is ESP8266 module for Wi-Fi connection, ASC712 for sensing current, 2x HC-SR501 for motion detection.

Fig. 4. Prototype of HEMS

Cost of the prototype. The cost of the equipment is estimated for 1 year of operation; it covers expenses for 28 HEMS devises. These devises are planned to be installed for one floor in the Astana IT University dormitory.

Table 1. Prototype cost for 28 pieces

Cathegory	Discription	Amount	Cost ($)	Total cost ($)
Equipment	Arduino board	28	45	1260
	Wi-Fi module	28	15	420
	Occupancy sensor	28	36	1008
	Energy meter	28	139	3892
Electrical Components	Resistors (x20)	20	6	120
	Wires (x20)	10	6	60
	PCB	28	9	252
	LEDs (x5)	90	3	270
	Capasitors (x10)	8	2	16
	Transistors	156	7	1092
Delivery of Equipment	Shipping	4	50	200
Software	Server (yearly subscription)	1	320	320
	Application Interface	1	400	400
Total				**9310**

3.2 Case Study

The price of energy is increasing every year in Kazakhstan [14–16]. Highest consumption level price for electricity has reached to 19.04 tg/kWh. With this tendency more people will be interested in reducing their electricity bills. The product helps to reduce electricity bill by giving user warnings about unnecessary consumption. In case of two-zone differential electricity tariffs (with peak and off-peak hours) the user can set different energy limits to participate in DR program.

The main target is to successfully implement project in the campus and work towards minimizing product cost and sell ready devises in Kazakhstan and outside.

The product is aimed to reduce energy consumption of end-users, since majority of energy sources in Kazakhstan comes from traditional generation like coal the high penetration of product lead to reduction of environmental pollution.

Potential benefits for end-user
For 300kWh consumption per month:

4635.6 tg/month.
You can save *6930 tg/year* if you reduce consumption by 10%
In case of two-zonal tariffs for 250kWh/50kWh (day/night):
4333.5 tg/month.
You can save *7794 tg/year* if you shift 50kWh to night.
And *additional 4420.8 tg/year* if you reduce consumption by 10%
By the results, potential user without the HEMS could lose up to 8000tg/year.
Savings are estimated with reference to energy tariffs in Astana [14]:

AstanaEnergoSbyt: September 1, 2022 tariffs (NEW):
the minimum fare (up to 90 kWh) - 10.44 tenge / kWh.
Average rate (from 90 to 180 kWh) - 15.40 tenge / kWh.
the maximum tariff (from 180 kWh and above) - 19.25 tenge / kWh.
AstanaEnergoSbyt: January 1, 2016 tariffs (OLD):
night tariff zone (23:00 to 07:00 h) - 3.62 tenge / kWh.
daily tariff zone (07:00 to 23:00) - 16.61 tenge / kWh.

4 Conclusion and Future Work

The work is suggesting HEMS that can potentially help the problem with unconscious electricity consumption in residential buildings. The hardware IoT prototype were developed that can track energy consumption in households and send push-notifications through app in case of extensive or unconscious energy consumption. The potential monetary benefits for end-users that implements proposed system were estimated.

In the future work, case study on real residential buildings will be conducted, machine learning algorithms to identify type of loads can be implemented. Overall, the data obtained could be carefully analyzed and insights can be obtained from the results.

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