Energy Management with Intelligent Plug and Socket

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Highlights
• This paper focuses on classification process for energy management in electricity field.
• A approach is proposed for classification plug and socket in the study.
• In the study, information was given about electricity consumption.

Abstract

Nowadays the devices that are used for electricity consumption by monitoring consumption values, and energy saving methods are supposed to identify and to develop them. To save the electricity people should know the consumption values of the devices and have idea about the consumed electricity.
In this study, RFID technology, which is an automatic identification system, smart plug systems are used after recognizing the identity of the device information about the electricity consumption of that device. In this way, I directed the user to use electrical devices, which can be used when the electricity tariff is cheap so that the user could save money.
For an average family, only the electricity consumption of the washing machine and dishwasher accounts for 30% of the total consumption. A family that uses a multi-time tariff will be able to save 10-15% by using the mentioned washing machine and dishwasher for example at night when the electricity tariff is low.

1. INTRODUCTION

The energy source usage has varied depending on the changing life conditions of the existence of humanity to the present. Especially with the Industrial Revolution, the increase in production and consumption and the phenomenon of growth has become an important target for economies, which has led to more use of energy resources in the production process and so energy consumption associated with growth. This situation has led to an escalation increase in the studies developed on the subject, and the relationship between energy consumption and growth has often been discussed from the perspective of electrical energy. Electricity consumption contributes significantly to the growth process as it has a wide area of usage in the production process and both as a single or complement of labor and capital factors. The relationship between electricity consumption and growth is important in terms of energy policies [1].

Using electrical energy to power devices all over the world, we use electrical energy in the fields of heating, cooling, communication, transportation and all kind of technological devices. With the produced electrical energy plug and socket systems, people can easily use the electrical power in various places. Plugs are such tools that are used to take electricity from sockets.

The industry has a great role in the development of countries, and industrial activities have progressed without slowing from the past to the present. Countries that keep pace with this development have expanded their treasures by processing cheap raw materials and selling them for high wages [2]. Electric energy, as the single-time tariff and multiple times in Turkey, offers people two different tariffs. The single-time tariff provides sole unit tariff price, and multiple tariffs offer three different unit prices for the consumers and

people who live in Turkey. While electricity is more expensive at certain times of the day depending on the intensity of use and it is cheaper at certain times in Turkey.

Turkey take place in the line of developing countries [3]. In developing countries, adequate and quality, energy supply has significant share in economic growth. Continuous increase in energy need also increases investments in this field, planning activities, and trade [4]. Electrical energy is important not only for developing countries, but also for all countries of the world. Urbanization is increasing in every country of the world. The acceleration in urbanization in all societies, intensification of migration from rural areas to cities that have entered the process of the metropolitan nation, along with the economic growth of countries, has increased the areas of warming, enlightenment, cooling, transportation, and the use of manufactured goods. This has increased the energy needs of developing countries as well as developed countries and their electricity consumption demands [5].

A significant portion of electrical energy is consumed in residences, workplaces, and public buildings in Turkey. There are approximately 20 million dwellings in Turkey. Considering these data, energy-efficient use of electrical household appliances plays great importance in this case [6-7].

Turkey is an industrializing country. The high population growth rate increases the energy need rapidly in parallel with the increase in energy consumption. Approximately 70% of the energy used in Turkey is supplied through import path. Therefore, increasing energy efficiency will reduce Turkey's dependence on foreign energy [8].

Consumers can save considerable amounts of money, optionally by delaying or advancing the usage of electricity of some electronic devices. The consumer could save money easier than in the past regards the amount of electricity consumption also the unifying power of electricity usage because of the currency used by the electronic device. RFID (Radio Frequency Identification) technology and smart plug systems were used in this study to give.

Gans and colleagues to provide better information and feedback for consumption, suggest combining the other traditional policy tools such as economic incentives, pricing, and regulation, to assist the improving energy efficiency in the residential sector [9]. Therefore, if the user knows his consumption and the price and cost of the consumption of the electrical device, it will be easier to save financially. Increased transparency in energy consumption can encourage private consumers to energy saving [10].

The aim of this study is to provide information on the electricity consumption of each device which is separate that could be recognized by all kinds of electrical devices to monitor the electricity consumption of all devices used when electricity is cheap. The electrics are used in homes, industrial establishments, public institutions, and organizations as well as everywhere where electricity consumption is realized. In this way, by knowing the consumption values transparently by the user, it creates a plug-socket system that encourages the consumer to save.

Besides, in the usage's area, a new structure will be obtained that does not allow using of devices that are not defined. Additionally, another aim of this work is to create a system that allows industrial enterprises to monitor the electricity consumption amount of all machine groups and clarify the consumption expenditure of the production cost.

2. MATERIAL METHOD

RFID technology, which is used in the sense of radio frequency identification, can be used in many areas [11]. With RFID technology, the RFID tag is the system consisting of the chip, antenna, and protective film on which the defined information is stored. RFID technology is nowadays used in mobile phones, tablets and is significantly used in various electrical appliances. In the experimental studies of the research, to provide product-based energy management, firstly, the RFID tag with an identity card was placed on the receipt. In this way, information was obtained about the plug that consumes electricity, hence the electronic device.

Figure 1 shows an RFID tag in the receipt. The RFID tag is embedded in the receipt. There is a tag reader in the socket. The label reader reads the label and gives the information of which receipt to which device belongs.

Figure 1. Plug and socket produced by 3D printer

After the device recognition process has been completed, the current sensor embedded in the socket will read how much power the plug, the electronic device draws. The power values to be read as instantaneous data have taken from the micro-USB channel to the socket. Apart from micro-USB, the values to be read by the Wi-Fi Module can be sent to the host computer (Figure 2).

Figure 2. Side view of the smart plug

The label is positioned inside the plug; Label Reader is positioned inside the socket. The purpose of the label and tag reader in the study is to read the ID recognition on the receipt. A label printer identifies the label. For example; apple iPhone 11 64 GB chargers, Philips Azure Vacuum Cleaner, etc. after the recognition process, the power is drawn by the electrical device from the network will be drawn (Figure 3).
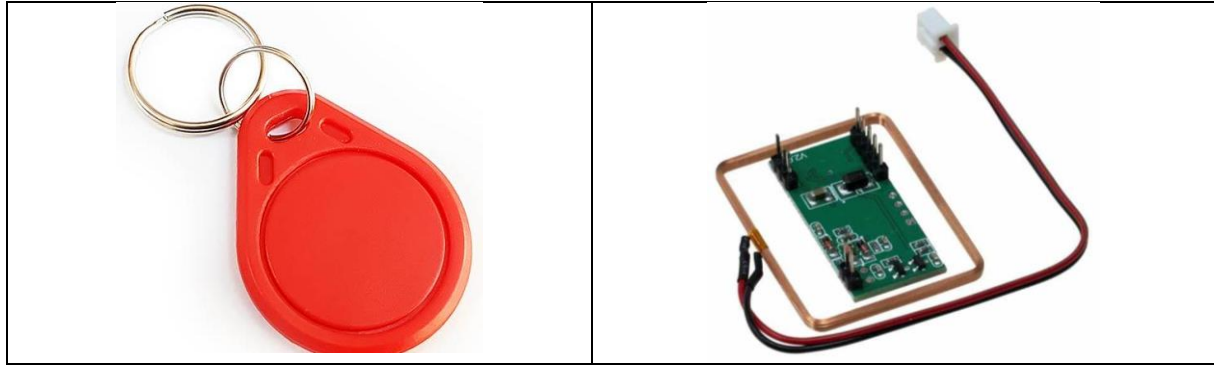
Figure 3. *Label and tag protector used in smart prized*

With the smart plug and socket, both device recognition process is performed and the consumption values of the device are read. After reading the consumption values, the values of the wired or wireless system are processed, converted, written and shaped into single-time, hourly, daily, and monthly tables.

Table 1 demonstrates the monthly consumption values of a normal dwelling. While calculating the consumption values, the current electricity prices of December-2020 were taken as the basis.
Current prices for the December 2020 are as follows:

- Day Time: 0,652238 TRY/kWh,
- Peak Time: 0,949665 TRY/kWh,
- Night Time: 0,414387 TRY/kWh.

Table 1. *Template calculation*

Product's name	Consumption (w)	Usage time (Hours)	Monthly usage time (Times)	Monthly Consumption (kWh)	Monthly consumption daytime (06:00-17:00)	Monthly consumption peak (17:00-22:00)	Monthly consumption nighttime (22:00-06:00)
49 inch LED TV A+	100	5,00	30	15	9,78 TRY	14,24 TRY	6,22 TRY
Washing machine A+	300	2,50	10	8	4,89 TRY	7,12 TRY	3,11 TRY
Vacuum cleaner	1200	1,00	10	12	7,83 TRY	11,40 TRY	4,97 TRY
Dish washer A+	500	2,00	30	30	19,57 TRY	28,49 TRY	12,43 TRY
Iron	3000	1,00	4	12	7,83 TRY	11,40 TRY	4,97 TRY
Hair dryer	2200	0,20	20	9	5,74 TRY	8,36 TRY	3,65 TRY
Oven	2500	1,00	10	25	16,31 TRY	23,74 TRY	10,36 TRY
Tea maker	2200	0,20	30	13	8,61 TRY	12,54 TRY	5,47 TRY
Toast Machine	2000	0,20	10	4	2,61 TRY	3,80 TRY	1,66 TRY
Total					83,16 TRY	121,08 TRY	52,83 TRY

Table 2 demonstrates the ratio of electrical household appliances to total consumption. n particular, the cost can be reduced by ensuring that household appliances such as heaters, dryers, dishwashers and washing machines, which are used at the user's discretion, operate outside the peak period.

Table 2. *Consumption of electrical appliances [12]*

Product name	Ratio of total consumption(%)
Refrigerator and freezer	30
Other	26
Lighting	12
TV	9
Heaters	9
Dryer	7
Dishwasher	4
Washing machine	3

Table 2 shows the comparison of electricity consumption of electrical household appliances according to day, peak and night tariffs. When electrical appliances are not used during the peak period, the user can save 20-25% of energy.

Table 3. *Comparison of Products According to Multi-Time Tariff [12]*

Monthly energy consumption			
Monthly Energy Consumption for Standard Products (kWh)			
	Day (kWh)	Peak (kWh)	Night (kWh)
Dish washer	0	0	21,8
Refrigerator	15,68	7,11	11,376
Washing Machine	0	0	14,25
Oven	0	0	58
TV set	0	7,02	2,34
Lighting	0	20,16	13,44
Vacuum cleaner	36	0	0
Iron	0	0	9,6
Kitchen hood	4,05	0	0
Computer	0	0	5,4
Blender	0,825	0	0
Kettle	0,73	0,73	0,73
Hair dryer	0	0	4,8
Total energy consumption (kWh)	57,235	35,02	141,136

The values read by the smart plug socket system calculated by a software and programming language algorithm by the name of "JavaScript". Monthly consumption values have been calculated with the software.

The socket that used in this study was produced with a three-dimensional printer, that it could be inserted into the RFID tag reader socket. Further, the tag reader is commercially available. Again, a three-dimensional printer produces the receipt so that RFID tags can be inserted and the tag is positioned inside.

The purpose of the smart plug socket is to identify the device. In this way, when different devices are used on the same socket, it will be detected and the consumption values will be calculated. A current sensor is located inside the socket for consumption values. However, consumption values could not be taken from the socket as instant data. Besides, if identification standard due to international norms is determined based on the type of devices used on the plugs, it will be easier to determine the device types. In this case, it may be possible to give electricity or control it in public institutions or various institutions where the use of some devices is prohibited.

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The sockets that facilitate the remote or wired management of electrical devices and provide information to the user about consumption values are called smart plugs. There are many smart sockets on the market with various features that are sold at reasonable prices (Figure 4).
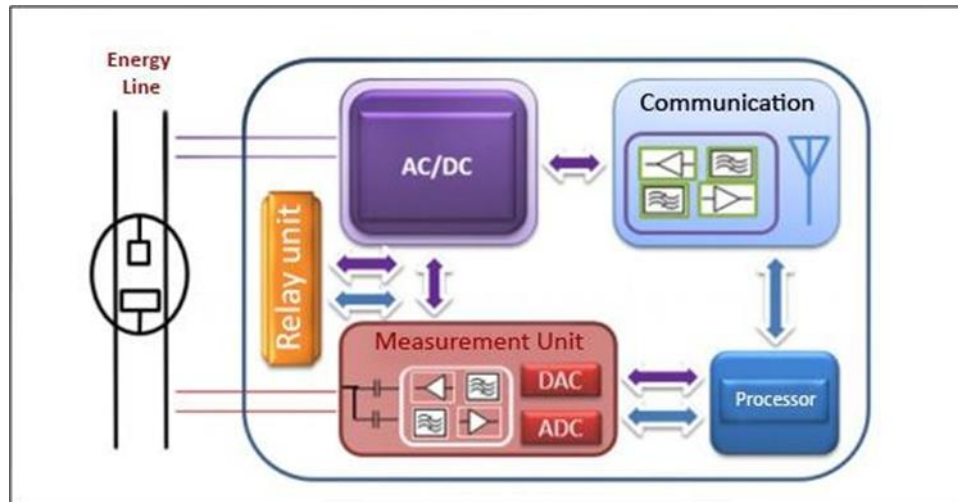

Figure 4. *The general structure of the smart plug [13]*

The consumption values of the electronic device were drawn with the smart plug and the consumption data was consequently obtained and entered manually. Calculation converted into Turkish Lira the research has done in Turkey the country currency is Turkish Lira.

The main purpose at this stage is to access the monthly total values of the consumption data based on the device and determine the amount of selected device usage at time intervals. Thus, the user will be able to know the amount of monthly electricity bill prices as total and additionally as details for each device. By using this method while a user who uses a multi-time tariff can save money as an arbitrary not mandatory by using optional devices, according to the timetable of the electricity prices and the electricity cheapest time.

Using devices with high electricity consumption, such as washing machines, can make savings dishwashers, andirons, which the user can use whenever he wants. However, since the user identifies the saving amount in the monthly bill, leads to paying much attention to using the devices and consumption. Therefore, the user should be warned while using the devices.

The total power drawn by the device during the usage could be converted into kWh, multiplied over the unit price; furthermore, the consumption values can be calculated. For example; the smart plug is inserted into the washing machine and the consumption-based value is obtained. The washing machine, which worked for about two hours, drew 0.652 kWh of power from the network. This consumption value obtained by multiplying the unit prices, according to the tariff.

The subject of work shifts to electricity consumption to hours when electricity is cheap, by placing a card or by software for electronic devices with the smart plug socket system. Many products on the market have been researched, but due to our research, no API-supported smart plug has been found. With the API support that is attached to the device, it is possible to reach the instantaneous consumption data of the electronic equipment. With instant access, our algorithm besides can retrieve data autonomously, consumption values can be calculated.

Housing accounts nearly for a fifth of global energy consumption [14]. Consequently, the energy efficiency of the residential market becomes an important target for policymakers and a promising tool for those wishing to comply with the Kyoto protocol [15]. The electrical energy used in homes presented to the user through sockets. Also, when the energy required, energy has drawn from the network by inserting the plug of the electrical device into the socket.

3. THE RESEARCH FINDINGS AND DISCUSSION

Energy Market Regulatory three separate tariffs in electricity prices in Turkey and had applied by the Authority. These separate tariffs are day, peak, and night tariffs. However, end-users of electricity in Turkey are sold by two different systems. The mentioned tariffs are multi-time and single-time tariffs. Three-time and multi-time electricity tariffs are determined by the Energy Market Regulatory Authority (EPDK). For calculating electricity prices, the unit price is calculated over 1 kWh.

The three-time multi-time tariff prices vary according to the three-time zones of the day [16]. Also, the mentioned three time zones are adjusted according to the electricity demand of the consumer. In countries with different summer and wintertime, the hours of the time zones expressed are certain, while the house in certain months change in countries will not be deferred. The unit price of electricity is higher when the electricity consumption of the users is high, and it is lower during the low hours. For example, because there is not much demand at night, the unit prices may decrease by half while in comparison to the evening hours while there is a lot of demand. In the decision of the Energy Market, Regulatory, Board dated December 2016; meters are read in a way that varies according to the application of summer. If the clock of the meters is changed according to the continuous summer application, consumption measurements will be made throughout the year according to the following time zones [17]. Tables 3 and 4 demonstrate the clock pattern of different periodic times in March and October.

Table 3. *Clock pattern of the last Sunday in October and the last Sunday of March*

Clock patterns of October and Sunday	
Daytime Period	07:00- 18:00 Hour
Peak Period	18:00- 23:00 Hour
Night Period	23:00- 07:00 Hours

Table 4. *Clock pattern between the last Sunday in March and the last Sunday in October*

Clock pattern between the last Sunday in March and the last Sunday in October	
Daytime Period	06:00- 17:00 Hours
Peak Period	17:00- 22:00 Hours
Night Period	22:00- 06:00 Hours

In the three-time tariff (multi-time tariff), the highest amount belongs to the peak period [18]. During the peak period, all people are generally at their homes. Devices with high electricity consumption, such as oven, washing machine, tea maker, dishwasher, and iron are used during peak hours [19]. When the demand is also high, the unit price of electricity is quite high compared to the night period, which the demands are so low. In Table 5 EPDK (Republic of Turkey energy market regulatory authority) reveals the statistics of the distribution system users in different fields.

***Table 5.** EPDK (Republic Of Turkey Energy Market Regulatory Authority) prices between 01.10.2020 - 01.01.2021*

Distribution system users	Single Time Retail Energy Fee	Daytime Retail Energy Fee	Peak Hour Retail energy Fee	Retail Night Time Energy Fee	Distribution Fee	Single Time	Day Time	Peak	Night Time
Medium Voltage					Medium Voltage				
Double Termed					Double Termed				
Industry	52,3469	53,0581	87,0600	25,6153	9,3758	61,7227	62,4339	96,4358	34,9911
Business	57,1457	57,7917	94,7940	28,3504	14,6119	71,7576	72,4036	109,4059	42,9623
Residence	39,6655	40,4338	68,4152	18,0576	14,4731	54,1386	54,9069	82,8883	32,5307
Agricultural watering	51,6935	52,2765	85,5525	25,6857	12,0340	63,7275	64,3105	97,5865	37,7197
Lightening	52,3331				14,0243	66,3574			
Single Termed					Single Termed				
Industry	52,2106	52,9220	86,9239	25,4791	10,3564	62,5670	63,2784	97,2803	35,8355
Business	57,5550	58,2010	95,2034	28,7596	18,2267	75,7817	76,4277	113,4301	46,9863
Residence	39,3760	40,1443	68,1254	17,7679	17,8705	57,2465	58,0148	85,9959	35,6384
Agricultural watering	51,9669	52,5499	85,8259	25,9588	14,9836	66,9505	67,5335	100,8095	40,9424
Lightening	52,7130				17,4942	70,2072			
Low Voltage					Low Voltage				
Single Termed					Single Termed				
Industry	53,4358	54,1469	88,1488	26,7042	16,0234	69,4592	70,1703	104,1722	42,7276
Business	58,2674	58,9133	95,9156	29,4720	21,7152	79,9826	80,6285	117,6308	51,1872
Residence	39,2701	40,0385	68,0197	17,6620	21,2381	60,5082	61,2766	89,2578	38,9001
Martyrs' families and War Veterans	14,6019				14,4043	29,0062			
Agricultural watering	52,5506	54,0773	86,4098	26,5426	17,8429	70,3935	71,9202	104,2527	44,3855
Lightening	53,3873				20,7984	74,1857			
General Lightening	29,6902				20,7984	50,4886			

Devices that are free to use with integration with the help of a remotely connected assistant before usage, will provide information and suggestions to the user on their screen. For example; a user who wants to run the dishwasher during the peak period will be able to suggest "you can start it after 22:00." However, by setting up an alarm system, the device will operate at the adjusted time. As a result, users will be able to follow their consumption values in terms of money and the costs, instantly or for use, and they will be made more conscious of savings.

4. RESULTS

As a result of the first study, it has been planned to integrate the RFID tag and tag reader supplied into the plug and socket produced with a three-dimensional printer (3D printer), to recognize the plug and to draw the consumption values. Subsequently, the consumption values of the devices were obtained from the products sold as "smart sockets" and calculations had applied. The RFID tag can cause heating in the smart plug socket system. For this reason, the recognition process can be provided by other technologies such as bar code and data matrix.

- Ensuring learning people about their electricity consumption transparently could be achieved in a more conscious community.
- The different electricity tariffs to improve the better services for users have been applied by the electricity supplier.

- By integrating the planned card or software on the electronic devices, the user will be informed at that moment and more effective savings will be achieved.

Although the word saving is perceived as being thrifty, it has been understood that saving can be achieved by using some devices more wisely, and it has been determined that smart systems that can be alerted the consumers about this issue should be produced.

In this study, most of the electrical devices that can be used on-demand in a family with four members have been examined. The total consumption of electrical devices that can be used on-demand is the same as below;

- Iron 9%,
- Washing machine 6%,
- Vacuum cleaner 9%,
- Dishwasher 23%,
- Oven 19%,
- Tea maker 10%.

Also constituted the remaining 24% of others (Television, hairdryer, toaster, etc.). Users who use a multi-time tariff will be able to save 25-30% by planning the use of appliances such as washing machines, dishwashers, and ovens only at night, without sacrificing their comfort.

CONFLICTS OF INTEREST

No conflict of interest was declared by the authors.

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