Chapter 35
Interactive Electricity Consumption System

Gresha Bhatia, Gurpreet Singh Nagpal, Samujjwaal Dey, Ashish Joshi and Nadiminti Sai Sirisha

Abstract Energy resources like fuel, water, and electricity form the fundamental requirements for the entire society to operate. It is observed that electricity is the driving force behind any society operations. As the energy requirements exponentially increase, there is a growing need for reliable and transparent power flow to the customers from the distributive end. One such transparent information flow is through the electricity bills that are generated after a month's power consumption. This bill does not provide a split up device wise about power usage. In other words, it can be said that the billing system is not as transparent as should be provided to the user. This paper thus focuses upon the various stages through which power reaches the consumer, the need for a transparent billing system followed by the proposed system. This would, in turn, enable the customer to monitor, analyze, and optimize its resources in order to optimize usage and reduce billing amount, in other terms save power. This paper further evaluates the system in terms of its power consumption, various notifications, and bills generated.

Keywords Slab structure · Power · Transmission grid · Billing values

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35.1 Introduction

The electricity which is delivered to any end consumer has to go through three important stages namely generation, transmission, and distribution before it reaches the consumer. Electricity generation is the first stage in the delivery of electricity to the end consumer [1]. Electricity is generated using various primary energy resources such as fossil fuels, wind energy, solar energy, etc. The next stage is the transmission. Electric power transmission is the bulk movement of electric energy from a generation station to an electrical substation [2]. The final stage is the distribution phase the distribution substations connect to the transformer system and lower the transmission voltage to medium voltage which is further lowered by the distribution transformers to the utilization voltage. This is then supplied to the end user [3].

However, it has been observed that the infrastructure of the existing system has remained unchanged over hundreds of years [4, 5]. Moving with the times, the overall system has to move from a static electromechanical grid to a flexible smart grid. In order to do so, the focus has to be on upgrading the infrastructure, management, control to ensure reliability, efficiency, and affectivity of the system [6]. One such domain relates to the transparent access and seamless communication of billing details to the consumers who get direct power from distribution [7].

Recently, there has been a flurry of activities on active monitoring, dynamic pricing of electricity and providing electricity in both directions with the intent of enabling consumers to use power in off-peak periods [8, 9]. This can be made possible through distributed generation and through demand-side electricity management using advanced metering and smart appliances. The evolution of this grid to achieve these requirements is commonly known as the smart grid [10]. Figure 35.1 shows a block diagram of the smart grid concept.

35.2 Need for the Proposed System

The current billing system follows a slab structure, where the consumption increases when the user crosses the current slab limit. The end user is unaware of this crossing over therefore increasing his power consumption and so its bill. Thus, it can be said that the current billing system is not transparent and convincing enough to the common man.

There is a need for a system wherein detailed billing information is provided to the user of the power consumed. This information would enable the user to plan his future power consumption in an optimized manner.

35.3 Proposed System

Prior to developing the system, a thorough literature survey was conducted. It was identified that smart meters form an important component to enable a 2-way flow of electricity and information, unlike traditional meters. However, these meters are found to be very expensive to be used in daily life. Another effective solution is through the utilization of smart IoT devices. These devices would collect data from appliances and send information to the analysis module through yet another module—i.e., Wi-Fi module. This analysis module further sends the data for report generation, i.e., graphical representation as represented in Fig. 35.2.

The proposed system consists of the Smart IoT appliances and web application, which will provide electricity consumption details in graphical and textual format generate an estimated bill and give alerts and notifications [11]. The user needs to first register to the system with his personal details and install the smart IoT devices.

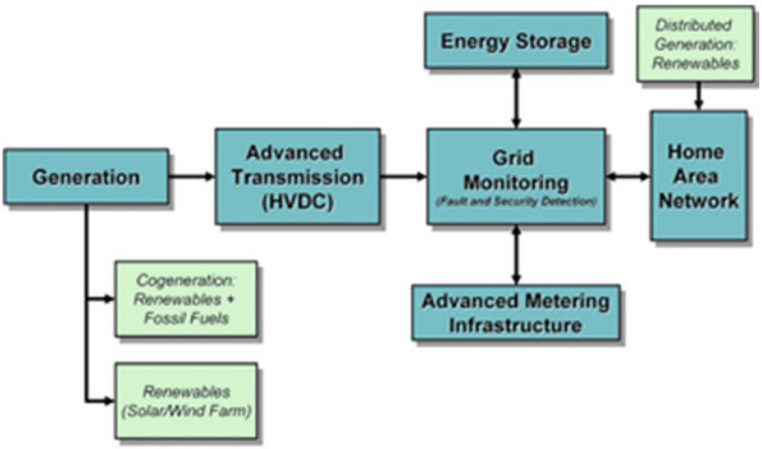


Fig. 35.1 Block diagram of smart grid concept. *Source* https://www.ecnmag.com/article/2011/07/trends-smart-grid-and-alternate-energy

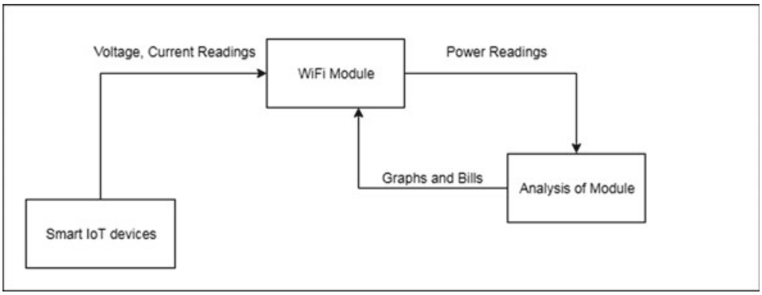


Fig. 35.2 Utilization of IoT devices

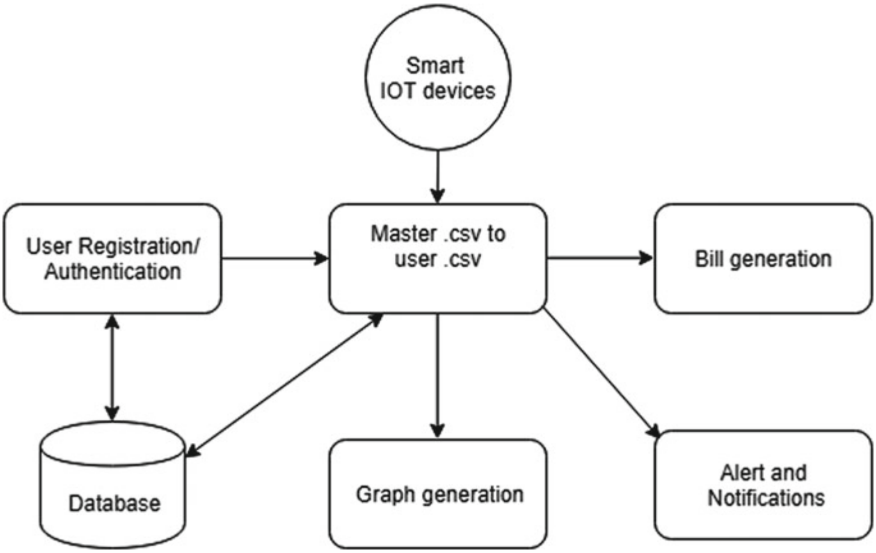


Fig. 35.3 Block diagram of the proposed system

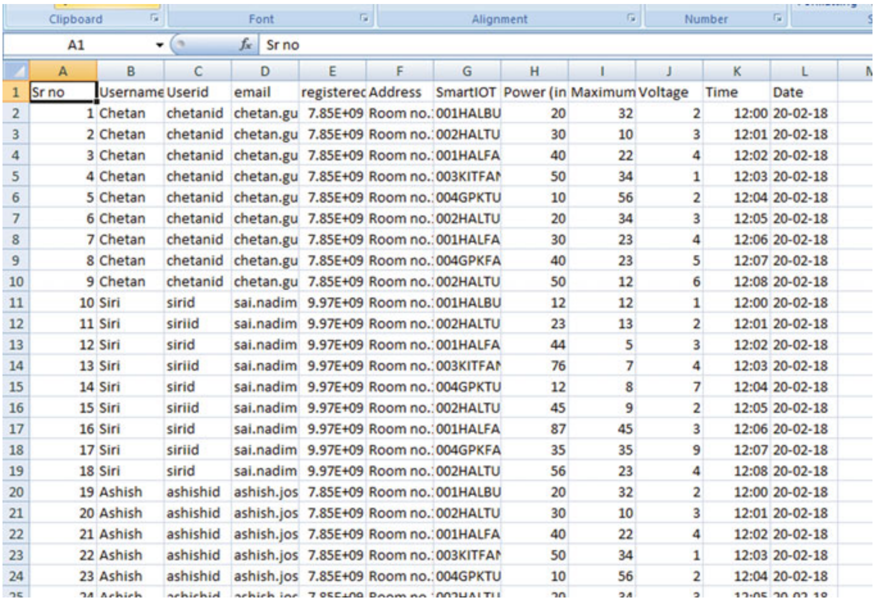
These devices would report their consumption to a server in the form of a master.csv file which will be pushed to the web application. This application would replicate this Comma Separated Values (CSV) file into the database and would generate a single user CSV on a daily basis. Once a day end this data would be passed to weekly data of the user which will be further used to establish monthly and yearly data. This data will be represented in a graphical format. Bill generation will provide bill on a daily, weekly and monthly basis. Alerts will be generated once the user crosses a slab of consumption or threshold set by him, as represented in Fig. 35.3.

35.4 System Development

In order to develop the system incremental model is utilized wherein every module developed passes through requirement gathering, design, and implementation and testing phase. In turn, working software is developed that is further analyzed and evaluated.

Thus, the system developed comprises of a number of modules:

A. Data collection
B. Data sorting/Distribution of data
C. Bill Estimation
D. Alert generation.



	A	B	C	D	E	F	G	H	I	J	K	L
1	Sr no	Username	Userid	email	registerec	Address	SmartIOT	Power (in	Maximum	Voltage	Time	Date
2	1	Chetan	chetanid	chetan.gu	7.85E+09	Room no.:	001HALBU	20	32	2	12:00	20-02-18
3	2	Chetan	chetanid	chetan.gu	7.85E+09	Room no.:	002HALTU	30	10	3	12:01	20-02-18
4	3	Chetan	chetanid	chetan.gu	7.85E+09	Room no.:	001HALFA	40	22	4	12:02	20-02-18
5	4	Chetan	chetanid	chetan.gu	7.85E+09	Room no.:	003KITFAN	50	34	1	12:03	20-02-18
6	5	Chetan	chetanid	chetan.gu	7.85E+09	Room no.:	004GPKTU	10	56	2	12:04	20-02-18
7	6	Chetan	chetanid	chetan.gu	7.85E+09	Room no.:	002HALTU	20	34	3	12:05	20-02-18
8	7	Chetan	chetanid	chetan.gu	7.85E+09	Room no.:	001HALFA	30	23	4	12:06	20-02-18
9	8	Chetan	chetanid	chetan.gu	7.85E+09	Room no.:	004GPKFA	40	23	5	12:07	20-02-18
10	9	Chetan	chetanid	chetan.gu	7.85E+09	Room no.:	002HALTU	50	12	6	12:08	20-02-18
11	10	Siri	sirid	sai.nadim	9.97E+09	Room no.:	001HALBU	12	12	1	12:00	20-02-18
12	11	Siri	siriid	sai.nadim	9.97E+09	Room no.:	002HALTU	23	13	2	12:01	20-02-18
13	12	Siri	sirid	sai.nadim	9.97E+09	Room no.:	001HALFA	44	5	3	12:02	20-02-18
14	13	Siri	siriid	sai.nadim	9.97E+09	Room no.:	003KITFAN	76	7	4	12:03	20-02-18
15	14	Siri	sirid	sai.nadim	9.97E+09	Room no.:	004GPKTU	12	8	7	12:04	20-02-18
16	15	Siri	siriid	sai.nadim	9.97E+09	Room no.:	002HALTU	45	9	2	12:05	20-02-18
17	16	Siri	sirid	sai.nadim	9.97E+09	Room no.:	001HALFA	87	45	3	12:06	20-02-18
18	17	Siri	siriid	sai.nadim	9.97E+09	Room no.:	004GPKFA	35	35	9	12:07	20-02-18
19	18	Siri	sirid	sai.nadim	9.97E+09	Room no.:	002HALTU	56	23	4	12:08	20-02-18
20	19	Ashish	ashishid	ashish.jos	7.85E+09	Room no.:	001HALBU	20	32	2	12:00	20-02-18
21	20	Ashish	ashishid	ashish.jos	7.85E+09	Room no.:	002HALTU	30	10	3	12:01	20-02-18
22	21	Ashish	ashishid	ashish.jos	7.85E+09	Room no.:	001HALFA	40	22	4	12:02	20-02-18
23	22	Ashish	ashishid	ashish.jos	7.85E+09	Room no.:	003KITFAN	50	34	1	12:03	20-02-18
24	23	Ashish	ashishid	ashish.jos	7.85E+09	Room no.:	004GPKTU	10	56	2	12:04	20-02-18

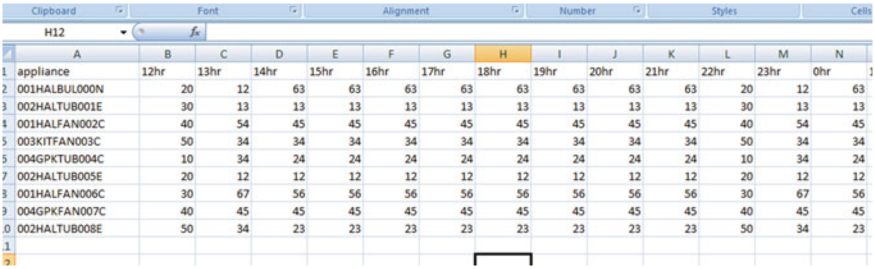
Fig. 35.4 Master CSV file obtained through sensors

35.4.1 Data Collection

In this module, the data obtained through smart IoT appliances is as represented by the master.csv file represented in Fig. 35.4. This dataset consists of the details of all the users, i.e., the username, user id, electrical appliance, current, voltage and the power consumed by each appliance stored in .csv format. Queries are run on this master dataset by using PHP. Smaller CSV files pertaining to each user are formed separately after the query processing.

35.4.2 Data Sorting/Distribution

The master.csv file obtains in the first module contains data of various users. This data is sorted in this module according to username and a user .csv is created for each user as shown in Fig. 35.5. This CSV file is replicated in the database. The data is updated whenever a new master.csv is pushed by smart IoT devices. This data is represented in a graphical format. Moreover, this data is used to calculate the bill and generate alerts.



appliance	12hr	13hr	14hr	15hr	16hr	17hr	18hr	19hr	20hr	21hr	22hr	23hr	0hr
001HALBUL000N	20	12	63	63	63	63	63	63	63	63	20	12	63
002HALTUB001E	30	13	13	13	13	13	13	13	13	13	30	13	13
001HALFAN002C	40	54	45	45	45	45	45	45	45	45	40	54	45
003KITFAN003C	50	34	34	34	34	34	34	34	34	34	50	34	34
004GPKTUB004C	10	34	24	24	24	24	24	24	24	24	10	34	24
002HALTUB005E	20	12	12	12	12	12	12	12	12	12	20	12	12
001HALFAN006C	30	67	56	56	56	56	56	56	56	56	30	67	56
004GPKFAN007C	40	45	45	45	45	45	45	45	45	45	40	45	45
002HALTUB008E	50	34	23	23	23	23	23	23	23	23	50	34	23

Fig. 35.5 Power consumption of a user on an hourly basis

35.4.3 Bill Estimation

This module generates a bill for the user based on the data received from the IoT device. The bill generation is on a weekly, monthly and yearly basis, which is compared with the actual bill received from the electricity board. Based on the comparison output, an alert notification is sent to the user as shown in Fig. 35.6.

The estimated bill according to the user's slab structure will be calculated and shown to the user on an hourly basis [12]. In the slab-based billing structure, when a user's electric power consumption crosses a predefined threshold of the price per unit of electric power increases slightly. The pricing of the slab structure varies in different cities and for each electricity board [13, 14]. The user will be able to know the cause of discrepancies between the bills generated by the electricity board, hence reducing the malpractices. The pseudocode for bill calculation is as mentioned below:

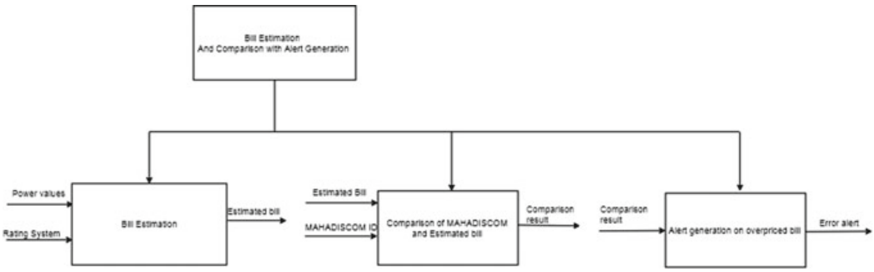


Fig. 35.6 Bill estimation module

```
for(each hour h)
{
  if ( total_power < threshold_1 ){
total_power = total_power + power generated in hour h;
          cost=cost + total_power * price_1;
          }
else if ( total_power < threshold_2 ){
total_power = total_power + power generated in hour h;
cost = cost + (total_power - threshold_1 ) * price_2;
          }
else if ( total_power < threshold_3 ){
total_power = total_power + power generated in hour h;
cost = cost + ( total_power - threshold_2 ) * price_3;
          }
else if ( total_power < threshold_4 ){
total_power = total_power + power generated in hour h;
cost = cost + ( total_power - threshold_3 ) * price_4;
          }
else{
total_power = total_power + power generated in hour h;
cost = cost + ( total_power – threshold_4 ) * price_5;
    }
}
```

35.4.4 Alert Generation

The user will be asked for the power threshold after which alert will be sent to him through his registered email address that the maximum power threshold has been crossed and he must henceforth, use electricity resources judiciously. For the same, the pseudo code is determined for the particular user, who has registered, to be as follows:

```
Step 1 :- Input the threshold power from user
Step 2 :- Specify the time granularity G
                   where G = time gain
Step 3 :- For each i in G
           if (power > threshold)
           echo the alert
Step 4 :- End
```

35.5 Results

Once the user logs into the system, through his credentials, the daily power consumption dashboard can be visualized as shown in Fig. 35.5. As observed in Fig. 35.4, the user will get the output through a graphical output indicating the consumption on an hourly, weekly, monthly basis as explained below. Based on the master CSV file represented in Fig. 35.4 and a number of input captured from the IoT device and the users, graphical output with respect to daily, weekly, and yearly consumptions are generated as shown in Fig. 35.7.

35.5.1 Consumption and Analysis of Graphs

The power consumption of each user is represented using graphs so that the user can make a quick and easy decision without reading all the reports. This application will help the user view the graphs based on an hourly basis, daily basis, and monthly basis. The graphs are easily downloadable in .png, .pdf, .jpeg formats into the user's computer as shown in Fig. 35.8a–c.

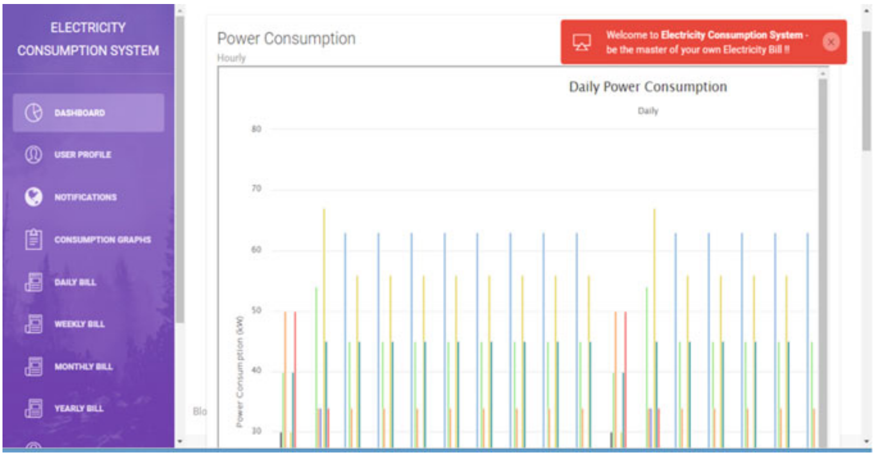


Fig. 35.7 Dashboard

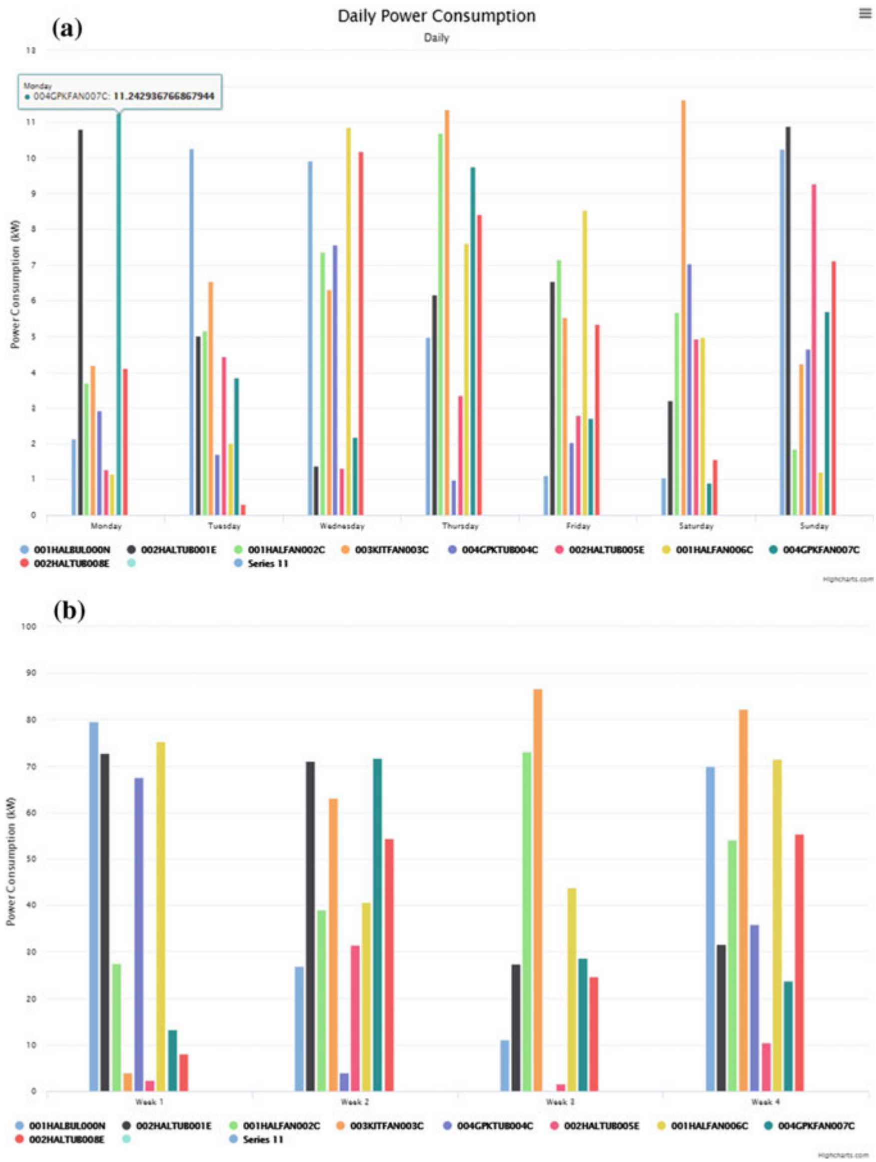


Fig. 35.8 **a** Consumption graph on a daily basis, **b** consumption graph on a weekly basis, **c** consumption graph on a yearly basis

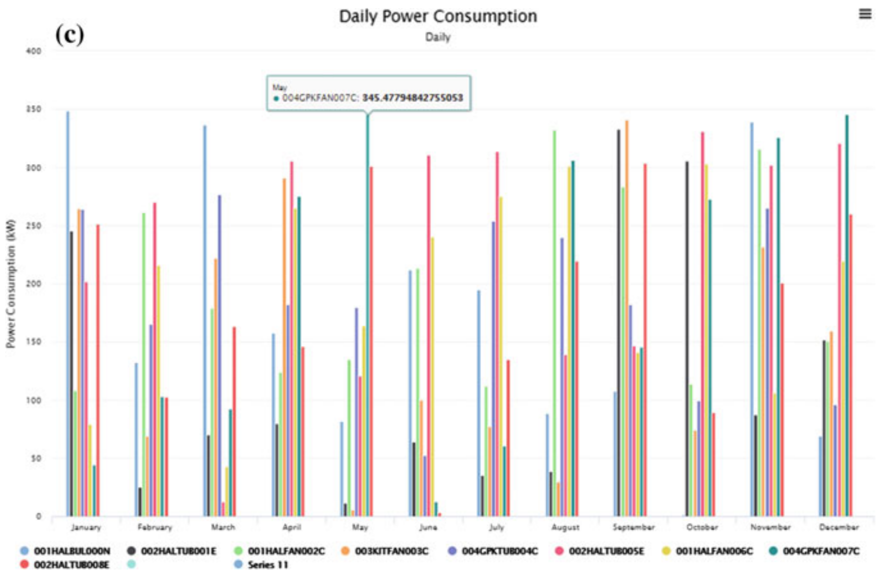


Fig. 35.8 (continued)

35.5.2 Alerts and Notifications

The user does not need to keep checking the graphs every time he needs to know the electricity consumed by him. The notifications will give the summarized information of the power consumption to the user after every hour as shown in Fig. 35.9.

Fig. 35.9 Daily notifications

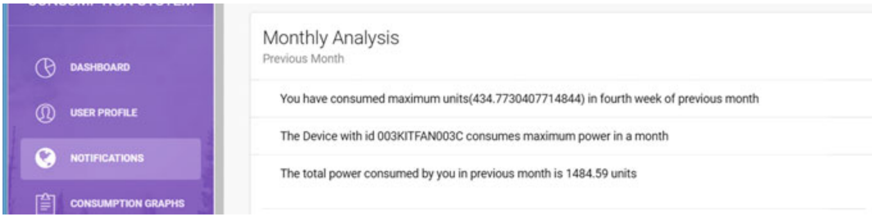


Fig. 35.10 Monthly notifications

Based on the user's preference settings, alerts are provided to the users, when power consumption crosses the threshold value. Figure 35.10 shows the alert notification when the power consumption crosses 310 W and 1484.59 units of total consumption in the previous month.

35.5.3 Billing

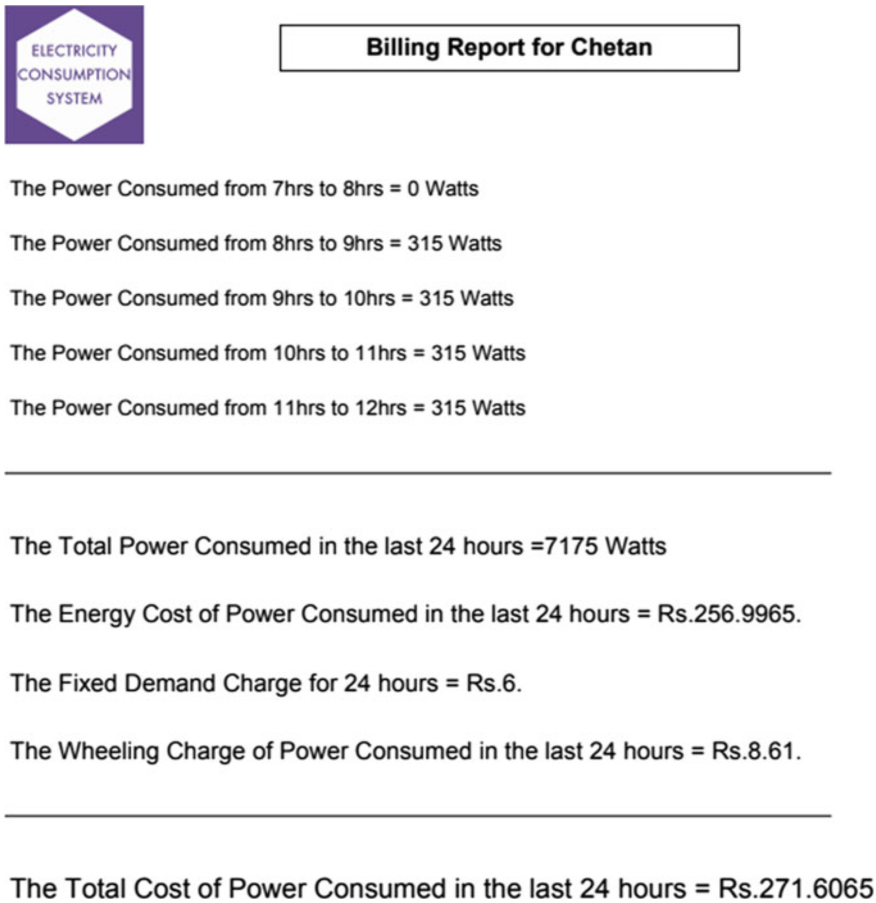
The system generates electricity consumption bills at various time intervals in order to maintain greater transparency, contrary to the conventional electricity billing system. The bills displayed to the user are on a daily, weekly, monthly and yearly basis. Moreover, all bills generated by the system are downloadable as PDF files to the user's computer. This could act as a permanent record that can be used by the user as evidence for lodging legitimate complaints to the electricity board.

Figure 35.11 shows the bill generated for a single day. The daily bill provides the user with an hourly analysis of the power consumption of the previous day and the charges the user will have to pay for the day. It provides the complete breakup of the payable amount in terms of the fixed demand charge, energy cost of power and the wheeling charge.

Figure 35.12 similarly shows the bill for a particular week. The weekly bill provides the user with an analysis of the power consumption of each day of the previous week and the charges the user will have to pay for that week. It provides the complete breakup of the payable amount in terms of the fixed demand charge, energy cost of power and the wheeling charge. Additionally, the weekly bill also mentions the days of the week on which the power consumption was maximum and minimum, and the average power consumption per day of the week.

As expressed earlier, the users are billed based on the slab system. Figure 35.13 represents the slab system used currently by the state-owned electricity regulation board operating in Mumbai.

The cost for the first 100 units is Rs. 3 per unit at a wheeling charge of Rs. 1.21 per unit which remains constant throughout. The cost of next 200 units (101–300) is Rs. 6.73 and so on. The cost of a single-phase connection is Rs. 60 per month and Rs. 170 per month for three-phase connection.


ELECTRICITY CONSUMPTION SYSTEM

Billing Report for Chetan

The Power Consumed from 7hrs to 8hrs = 0 Watts

The Power Consumed from 8hrs to 9hrs = 315 Watts

The Power Consumed from 9hrs to 10hrs = 315 Watts

The Power Consumed from 10hrs to 11hrs = 315 Watts

The Power Consumed from 11hrs to 12hrs = 315 Watts

The Total Power Consumed in the last 24 hours =7175 Watts

The Energy Cost of Power Consumed in the last 24 hours = Rs.256.9965.

The Fixed Demand Charge for 24 hours = Rs.6.

The Wheeling Charge of Power Consumed in the last 24 hours = Rs.8.61.

The Total Cost of Power Consumed in the last 24 hours = Rs.271.6065

Fig. 35.11 Daily bill

Further, the customer/user can report an error or pose their queries the customer care utility as shown in Fig. 35.14. The customer's query is transmitted through an email.

35.6 Evaluation of the System

The user will be able to compare the power consumption of any number of devices in any manner, i.e., compare two devices as shown in Fig. 35.15. This will enable the user to make a more wise decision for consuming electricity. For example, he can choose the fan that uses less power as compared to switching on the AC.

ELECTRICITY CONSUMPTION SYSTEM

Weekly Billing Report for Chetan

Device-id	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	Total
001HALBUL000N	2.13257	10.25716	9.90527	4.96929	1.11352	1.05682	10.23507	**39.66973**
002HALTUB001E	10.79604	5.02480	1.37243	6.17070	6.54249	3.21882	10.88646	**44.01177**
001HALFAN002C	3.69388	5.16451	7.37380	10.68929	7.15690	5.67443	1.85162	**41.60446**
003KITFAN003C	4.19089	6.53951	6.30879	11.34470	5.52529	11.62514	4.24139	**49.77571**
004GPKTUB004C	2.92353	1.70042	7.57804	0.99439	2.04154	7.03516	4.65591	**26.92901**
002HALTUB005E	1.28441	4.44858	1.31896	3.36278	2.79871	4.92802	9.26782	**27.40937**
001HALFAN006C	1.15993	2.01014	10.86580	7.61264	8.54154	4.98457	1.22260	**36.39725**
004GPKFAN007C	11.24293	3.85228	2.18001	9.75194	2.72011	0.91317	5.70768	**36.36816**
002HALTUB008E	4.10875	0.31012	10.19050	8.41955	5.34344	1.56517	7.11070	**37.04827**
Total	41.53296	39.30756	57.09365	63.31532	41.78363	41.00131	55.17929	**339.21376**

The maximum Units of Power Consumed on Thursday equal to 63.315 Units.

The minimum Units of Power Consumed on Tuesday equal to 39.307 Units.

The average Units of Power Consumed per day = 48.428571428571 Units.

The Energy Cost of Power Consumed this week = Rs.1908.47.

The Fixed Demand Charge for the week= Rs.42.5.

The Wheeling Charge of Power Consumed in this week = Rs.410.19.

The Total Cost of Power Consumed in this week = Rs.2361.16

Fig. 35.12 Weekly bill

35.7 Conclusion

This paper focuses on the distribution end of supplying power to the customers, the major aim is to provide transparency and bring awareness of power consumption to the common man The proposed system would collect information from various home appliances and store them in .csv format. The file is replicated in the database and is used for further analysis. The proposed approach is used for handling power billing

Consumption Slab(kWh)	Demand Charge (Rs/Mth.)	Wheeling Charge (Rs/kWh)	Energy Charge (Rs/kWh)
0-100 Units	For	1.21	3.00
101-300 Units	Single Phase = 60	1.21	6.73
301-500 Units	(Rs/Mth.)	1.21	9.70
501-1000 Units	Three Phase = 170	1.21	11.20
Above 1000 Units	(Rs/Mth.)	1.21	12.48

Fig. 35.13 Slab system

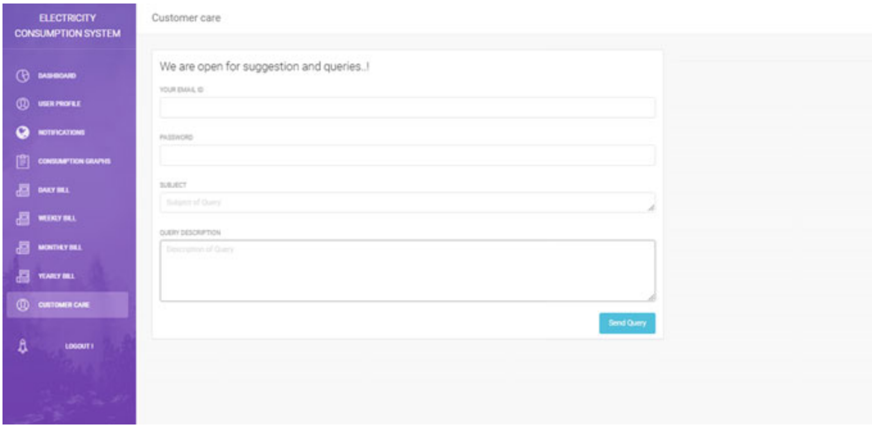


Fig. 35.14 User query utility

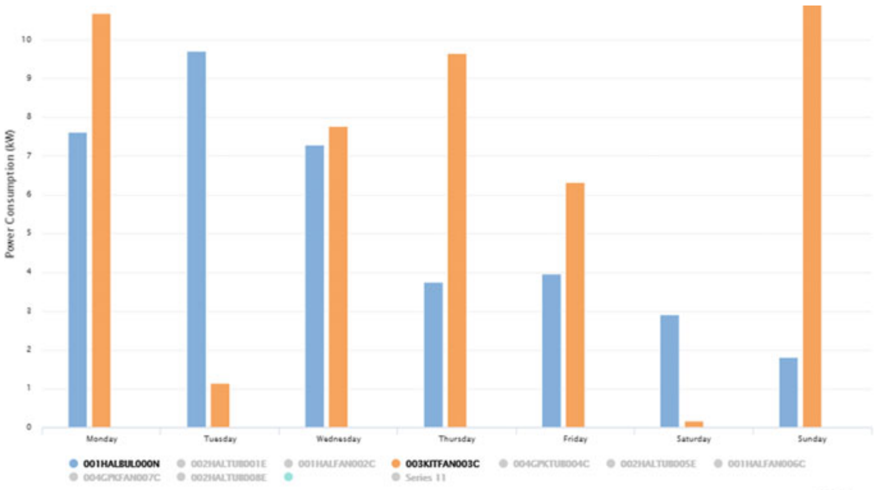


Fig. 35.15 Comparison of two devices' power

operations. It further evaluates the method to provide graphs for easy understanding of the consumer. User can take the required steps to optimize and reduce the power usage.

35.8 Future Scope

This system can be extended on a social networking platform so that social awareness activities can be conducted in the form of competitions that analyze the electricity consumptions of the users of a certain area. Manufacturers can embed this system in the appliances so that energy optimization can be done. Surge pricing and smart grid are the concepts which can be developed effectively by extending this system. In surge pricing, the rate of electricity will be varied dynamically according to the power usage in that area. Smart grids are the power grids which contain local energy suppliers who contribute by selling solar or wind energy. So in smart grids, the user will have multiple options for buying electricity when the price goes high due to surge pricing. Moreover, electricity consumption can be reduced and thus, power can be conserved by implementing smart grids and surge pricing.

References

1. Shi, W., Li, N., Chu, C.-C., Gadh, R.: Real-time energy management in microgrids. IEEE Trans. Smart Grid **8**(1) (2017)
2. Electric Power Transmission [Online] (2002). https://en.wikipedia.org/wiki/Electric_power_transmission
3. Mukhopadhyay: Towards electricity for all. Power Energy Mag. (IEEE) **5**(5) (Digital Object in 2007)
4. Khanzode, P., Nigam, S., Prabhakar Karthikeyan, S., Sathish Kumar, K.: Indian power scenario—a road map to 2020. In: 2014 International Conference in the Circuit, Power and Computing Technologies (ICCPCT), March 2014
5. Karmacharya, S.B., de Vries, L.J.: Addressing the supply demand gap in India's electricity market: long and short-term policy options. In: Developing 21st Century Infrastructure Networks (INFRA), 2009 Second International Conference on Infrastructure Systems and Services (2009)
6. Sun, Q., Li, H., Ma, Z., Wang, C., Campillo, J., Zhang, Q., Wallin, F., Guo, J.: A comprehensive review of smart energy meters in intelligent energy networks. IEEE Internet Things J. **3**(4) (2016)
7. Balijepalli, V.S.K.M., Khaparde, S.A., Gupta, R.P.: Towards Indian smart grids. In: 2009 IEEE Region 10 Conference, TENCON 2009, pp. 1–7 (2009)
8. Beidou, F.B., Morsi, W.G., Diduch, C.P., Chang, L.: Smart grid: challenges, research directions and possible solutions. In: 2010 2nd IEEE International Symposium on Power Electronics for Distributed Generation Systems (PEDG), pp. 670–673 (2010)
9. Jhala, K., Natarajan, B., Pahwa, A.: Prospect theory based active consumer behavior under variable electricity pricing. IEEE Trans. Smart Grid **99** (2018)
10. Bala, S.K.: Study of smart grid technology and its development in Indian scenario. http://ethesis.nitrkl.ac.in/5146/1/109EE0253.pdf

11. Zhang, Q., Li, H., Sun, Q., Tezuka, T.: An integrated model for the penetrations of EV considering smart electricity systems with real-time-pricing mechanism. In: the 5th International Conference on Applied Energy, 1–4 July 2013, Pretoria, South Africa (2013)
12. Narayanan, V.: | TNN | Jul 15, 2010, 00:27 IST, Times Of India Article. Corruption remains plugged into Tamil Nadu Electricity Board
13. Mallet, P., Grahstrom, P.-O., Hallberg, P., Lorez, G., Mandatova, P.: Power to the people. IEEE Power Energy Mag. **12**(2), 51–64 (2014)
14. Vijay, M.: Improving electricity services in rural India. In: Working Paper Series. Centre on Globalization and Sustainable Development, The Earth, Institute at Columbia University, Dec 2004