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A new method to calculate residential consumer's consumption using computer modeling

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Abstract

One of the most important issues in modeling and simulation of electricity distribution systems is to know different customers' consumption, which depends on season, weekdays and hour day. So, load behavior pattern and determination of its value is of great importance. In this paper, a method is proposed to measure substation values using registers. Then, the method to obtain consumption pattern curve is presented. After that, a strategy is discussed to determine the peak and minimum values of load curve using normalized energy value consumed by customers. This method is implemented on a sample distribution system of Ashtian town in Iran. Obtained results verify the capability of the method to estimate load consumption value in each hour of a day.

Keywords: Computer Modeling, Consumption Demand, Consumption Pattern, Distribution Systems, Load Duration Curve

Introduction

Load flow studies are done to calculate values of losses, voltage, and current. They are also conducted in networks for different intentions such as loss reduction, reactive power compensation and very optimal development and network exploration (Khalesi & Javadian, 2011). One of the most important information for load flow studies in distribution systems is active and reactive power consumption values. This parameter value varied depending on different hours, day (weekdays or weekends), and climatic conditions, official or religious occasions. According to Modaresi *et al.* (1996), one of the most essential issues to determine consumption value of a customer in different hours is to know consumption pattern of that customer as per daily consumption.

Previously researchers have presented different load curve determination methods for a group of consumers: one of these methods to find residential load pattern is to recognize load components and time characteristics of their consumption (Chicco *et al.*, 2002). For this purpose, several residential customers have been selected and then some questions have been given to them, these components have been analyzed before the residential load coefficient and its curves are extracted.

Existent load curves for different tariffs determine these curves in times series (using pattern recognition method from load curve). Different costumer's consumption in different hours can be determined by obtained time series (Gerbec *et al.,* 2002). Another method is to measure and record information by data loggers. The essential point, which should be considered to use these data is reading time from them than causes to change load curve. For instance, in a study that has been conducted on an industrial costumer, depending on this fact that data reading interval is 2 or 60 minutes, load peak value in load curve is decreased up to 30%. This study shows that a 15 minutes sampling is not logic for all customers who have considerable load variation (like residential ones), sampling should be done every 5 minutes. According to Heydari *et al.* (2004), for customers who do not have significant load variations it can be done per 15 to 30 minutes. A technique based on linear programming to determine daily load curve of consumers without data logger has been presented by Valizadeh Haghi *et al.* (2009).

In this paper, a method to extract a residential customer consumption pattern and its values determination is presented based on customer monthly consumption. The obtained results are shown in a real network as a sample.

Load pattern of residential customers

Load pattern shows a customer consumption value through a day. One of the methods to extract residential customer load pattern is to consider costumer consumption in a year and record their data and finally to extract related load curve. However, studying a single customer cannot lead to behavior pattern and it can cause some error that it is due to several reasons, which are as follows:

- A single residential customer has less consumption and in some hours, it can be also be reached to zero.
- Large residential consumers such as washing machine, meat mixer, iron and so on do not enter to circuit at special time and it can vary from house to house.
- Data loggers have low precise for little consumption. For example, the least range of recording data is 5 minutes which can make error.
- Relationships and daily problems which are unpredictable (such as party occasions, travelling etc.) can be considered as effective parameters on load pattern.

To verify these reasons, power consumptions of two

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Fig.1. Load curve of costumer in first day

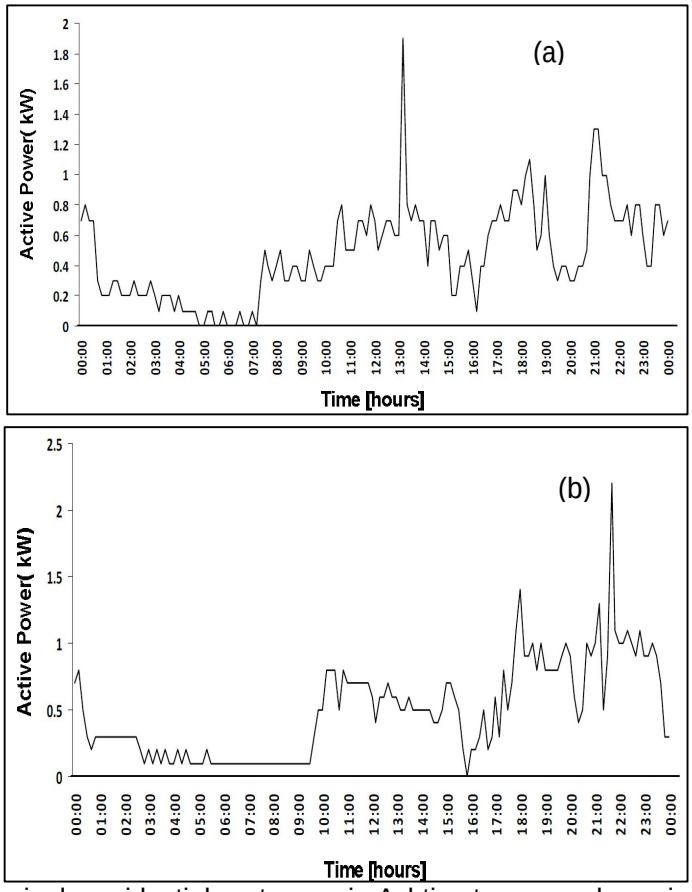
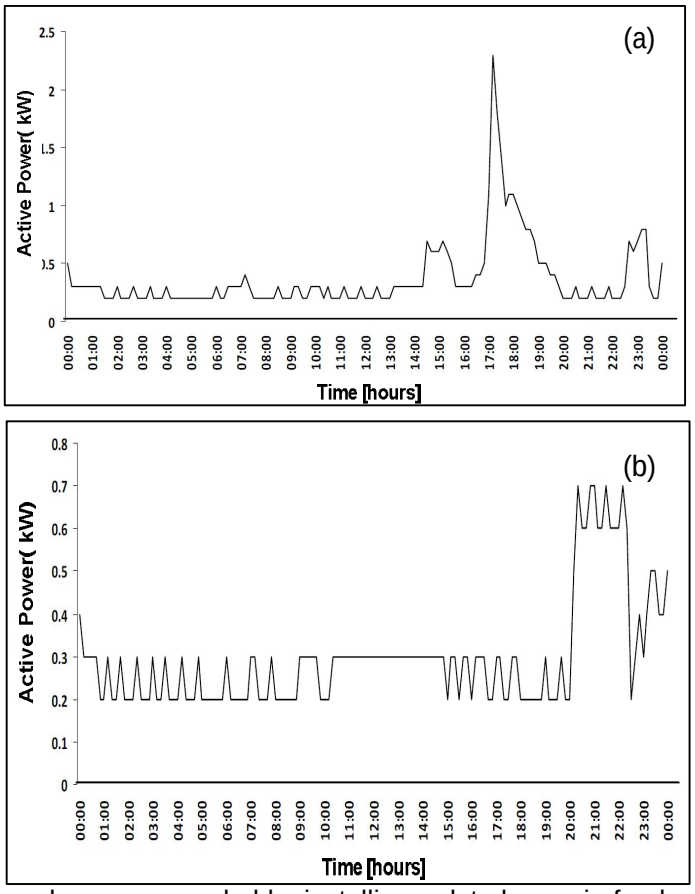


Fig. 2. Load curve of costumer in second day



single residential customers in Ashtian town are shown in Fig. 1 and Fig. 2 by installing data logger in their entrances. The load patterns of two customers differ from each other, but also for the same customer, consumption pattern in one day differs completely from another day. Hence, it cannot be considered as a criterion to find residential load pattern in this town.

As stated before, residential load behavior pattern cannot be obtained by studying only a single customer. Besides, season coincidence (cooling/ heating) and residential consumption (during day 7 night) together can create residential load behavior. Hence, a better solution is to use data of a group of customers to find their load patterns. In this study, to find residential customers load patterns, following steps have been done:

Full residential post selection: The objective is to determine residential customers' load profile. Therefore, a substation should be chosen so that it only supplies residential loads as better as possible. So, one of several feeders which supply residential places should be used for studies and it is better that there are no non-residential consumptions or if there be, it should be of so insignificant. It should be noted that, the more numbers of substation customers, the higher the precise of the method.

Feeder data recording: After choosing suitable substation, total substation consumption and its feeders values are recorded by installing a data logger in feeders output and total switch as well. This data recording should be done at least in a yearly period of time. So, consumption pattern can be obtained through a year and for different days of a year. To have better precise, sampling time should be at least 5 minutes.

Considering load of lighting and removing from total switch: Recorded value by data logger installed in switch includes the residential feeders and lighting feeders. However, our aim is to determine the load profile of residential customers' consumption. So, lighting consumption should be removed from switch that this switch information will be completely residential. Master switch load curve is shown before and after. According to Fig. 3, at 5:45 when lighting load is removed, power value is dropped to 16 kW. By viewing hours and consumed power value in lighting feeder and then removing that from total switch, master switch load curve without customers load profile can be obtained.

Load profile determination, maximum and minimum consumption on a special day: To determine load profile of a single residential customer, power and current values recorded by master switch logger (lighting load removed)

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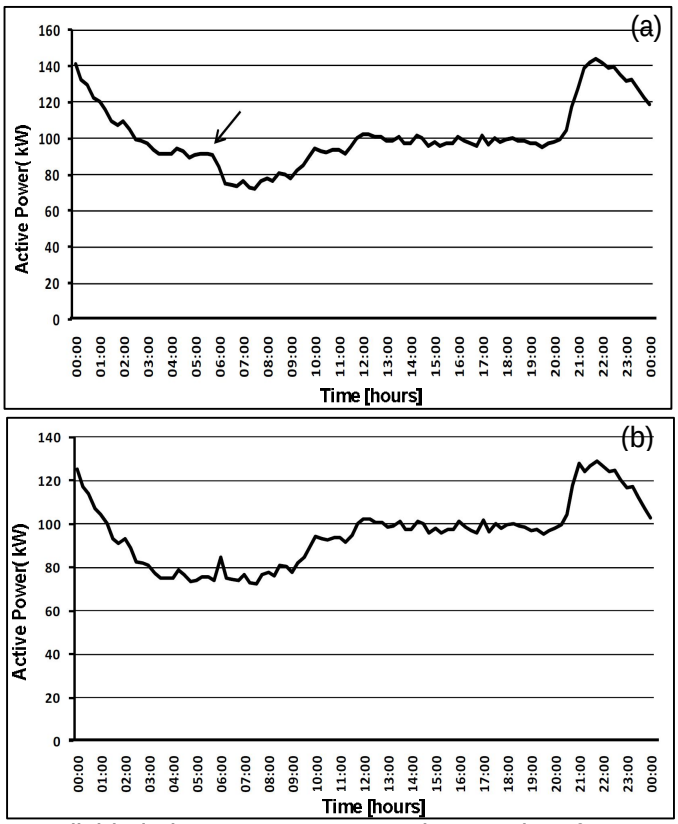
Fig. 3. Load curve of master switch with lighting load and without it



are divided into customer numbers. Therefore, an average load curve can be obtained. A sample load curve obtained from this method in July and November is shown in Fig. 4. This load curve can be considered as load profile for all customers in order to calculate consumed power of all customers in different hours. Consumed power value versus time is shown in Fig. 4. This function is a repetitive function and it may differ from one day to other (environment conditions, occasions, holidays, usual days, customer numbers) power value may differ too, but total figure does not change a lot. This

Fig. 4. Load curve of costumer in two different months

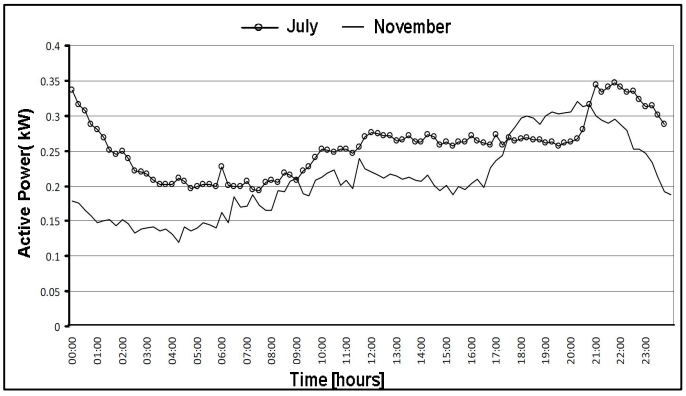
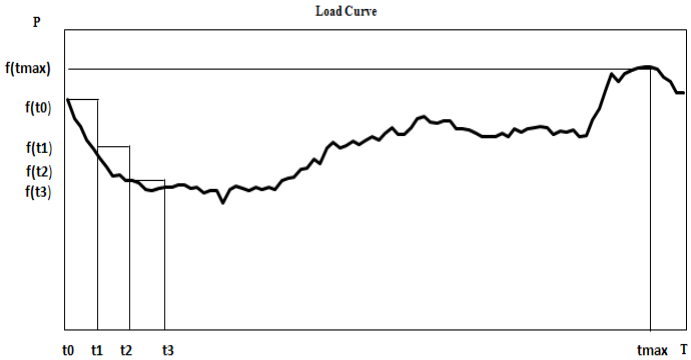


Fig. 5. Approximatly calution of costumer consumed power in one day



curve has average value of P_{av} and peak value P_{max} and minimum value P_{min}.

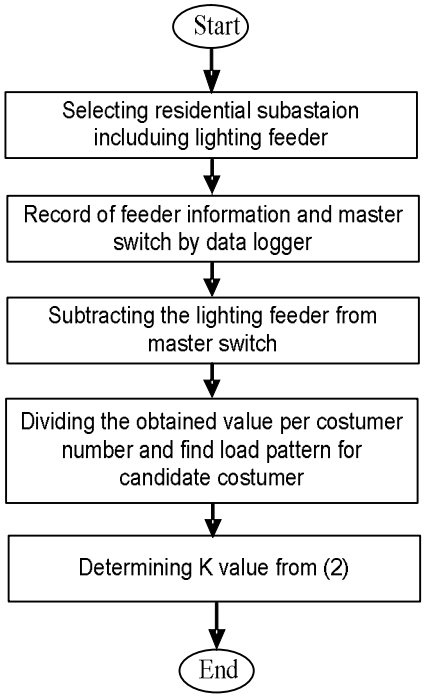
Consumed daily power calculation of a representative customer: By integrating of power versus time, can be obtained consumed power on a day. This energy can be obtained approximately as sum of composed rectangles in sample points of Fig. 5, which is written as Eq. (1).

$$E_{Daily} = \sum_{i=0}^{n-1} (t_{i+1} - t_i) \times f(t_i) \quad (1)$$

Where *n* is total sample numbers on a day. This energy value can be obtained as Eq. (2).

$$k = \frac{E_{Daily}}{p_{av}} \quad (2)$$

Fig. 6. Flowchart of sample costumer load pattern



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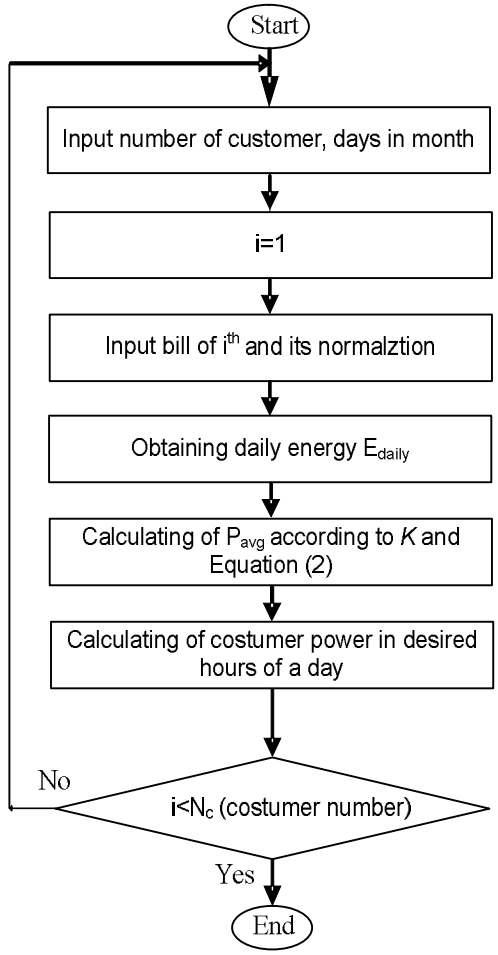
Above steps flowcharts is shown in Fig. 6 and Fig. 7.

Fig. 7. Flowchart of approximatly calculation of daily consemded power in 24 hours



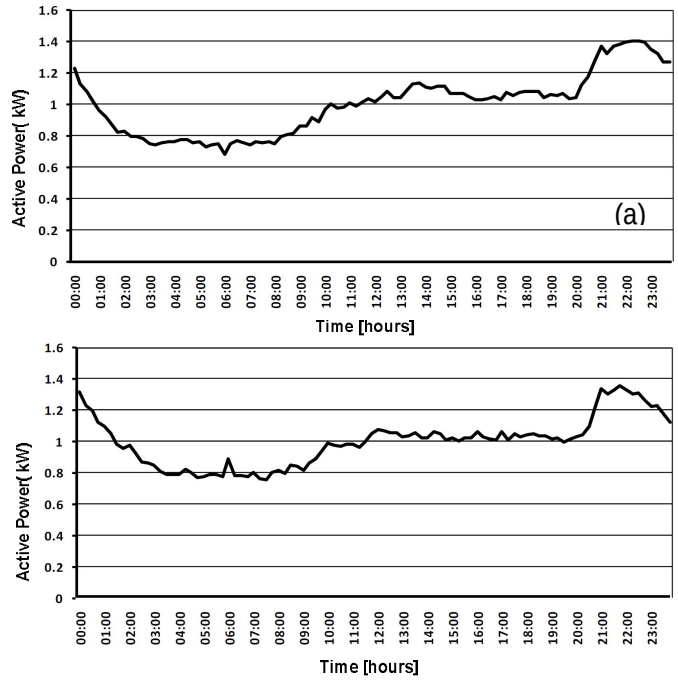
Residential customers consumption in each hour of a day regarding electricity bill of normalized monthly consumption

Using presented method, load profile curve for residential representative customer can be obtained for each desired day of a year. Then, using this function and normalized monthly consumption of each customer, consumption value at different hours of a day for all customers can be obtained. To determine average, peak and minimum power values of a special customer, energy measured by Energy Measurement Device (EMD) which is normalized monthly, should be fitting with this curve.

If a special customer has normalized monthly energy consumption of $E_{monthly}$, this energy can be changed to energy for a day (daily energy) regarding number of days in a month (29, 30 or 31 days). By obtaining this daily energy and dividing it by *k*, average power can be calculated. Then, using P_{av} of this customer and also load profile obtained for representative customer (normalized versus average power) and fitting of them, hourly consumption value can be obtained, consequently load curve of this special customer can be determined.

Sample study

Fig. 8. Behavior of residential load pattern in date of 2-July-2010 and 6-July-2010



To show these steps, a residential substation in Ashtian distribution systems is selected and six data loggers are installed (four data loggers for residential feeders, one for lighting feeder and master switch and their information are recorded.

In two days of holiday and weekday (02/07/2010 and 06/07/2010), data loggers information are recorded and according to first flowchart, *k* value for these two days are listed in Table 1.

Table 1. K value for candidate costumer in two different days

Date	K value Obtained from (Khalesi &Javadian ,2011)
2-July-2010 (Weekend)	23.72
6-July-2010 (NO weekend)	23.68

Average, maximum and minimum values of representative customer power value are listed in Table 2. In addition, representative residential load profile on two days is shown in Fig. 8. Besides, average, maximum, minimum consumption values of a single residential customer in two different days according to normalized monthly bill and load profile are obtained and listed in Table 3.

Conclusion

In this paper, an algorithm to determine residential customers' load profile and their consumption in different hours has been recommended. This algorithm is based on consumption values measuring in a feeder that includes many residential loads and estimation of consumption pattern. Precise consumption values have been obtained by fitting normalized monthly energy

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Table 2. Average, minimum and maximum power for candidate costumer in two different days

Day type	Average daily power for candidate costumer [pu]	Maximum daily power for candidate costumer [pu]	Minimum daily power for candidate costumer [pu]
weekend	1	1.355126	0.756227
normal	1	1.403502	0.679821

Table 3. Average, minimum and maximum consumed energy for single customer for two days (weekend and normal day) using consuming pattern and bill

Monthly consumed energy (kWh)	Date	Average Daily consumed energy (kWh)	Maximum Daily consumed energy (kWh)	Minimum Daily consumed energy (kWh)
394	2-July-2010 (Weekend)	0.53582	0.7261	0.40520
	6-July-2010 (NO Weekend)	0.53665	0.75319	0.36482

consumption of customers with load profile curve. Presented method has been examined on a sample network. Obtained results have shown that customers' consumption power information can be obtained for each hour of a day and then they can be used in simulation software.

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