IDENTIFYING THE NATURE OF DOMESTIC LOAD PROFILE FROM A SINGLE HOUSEHOLD ELECTRICITY CONSUMPTION MEASUREMENTS

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ABSTRACT

Detailed electricity load profile for domestic building is an important requirement for the accurate analysis of demand side management. The use of electrical appliances within domestic buildings varies significantly with respect to time, mainly in accordance with the activity and behaviour of the occupants.
This paper presents results from a monitoring study of electrical energy consumption profiles for One UK household (two adults with children).
Measurements for whole household electricity consumption have been obtained over a period of ten months. They were all obtained at one minute interval. Monthly energy consumptions, daily and overall profiles were derived for this household type from the monitored data. It is intended that the results presented in this paper can be used in the quest for a precise forecast method for electricity consumption for occupants living in the same type of household in the UK. This will allow greater confidence in the sizing of, e.g., adopting renewable energy sources in this type of household. Further investigation is needed for a large sample of households to improve the understanding of monitoring high resolution domestic energy consumption.

Index Terms— Electricity consumption, load profiles

1. INTRODUCTION

The Detailed electricity load profile for domestic building is an important requirement for the accurate analysis of demand side management. The use of electrical appliances within domestic buildings varies significantly with respect to time, mainly in accordance with the activity and behaviour of the occupants. The main factors that determine the Electricity consumption in domestic buildings are the number and type of various electrical appliances in the building; and the use of these appliances by the occupants of the building.

There are numerous ways to obtain time series energy consumption data. Usually, energy consumption data is derived from utility bills on a quarterly or monthly basis. Billing data are sometimes provided as estimated readings when actual readings of electricity meters are unavailable, and the billing period is variable. In order to get more accurate energy consumption data the alternative is to take the meter reading regularly monthly, weekly or daily.

Most available information on electricity consumption in the UK is for a half hourly time resolution, which is the measure interval for load profile analysis. A half hourly resolution is satisfactory to show variations in consumption and is totally suitable for domestic profiles used for billing. In houses particularly, the consumed loads can vary each hour of every day, weekdays and weekends, and for different months of the year, and also can vary significantly over a few minutes due to the small number of appliances and types of use. Monitoring can provide up to date data on electricity consumption of individual household and the monitoring generally take two approaches. Monitoring equipment can be used to record the consumption of individual appliances or of aggregation of consumption of appliances.

There have been numerous investigations dealing with domestic electricity consumptions load profiles in the UK [1-10].

A monitoring campaign was undertaken by Newborough [1] where the 1 min interval energy demand data of 30 homes were collected in order to modulate electricity demand emanating from individual dwellings to reduce the peak demand. A survey data among a sample of more than 1000 adults has been conducted and a questionnaire was designed in the south-east of England by Mansouri et al [2] in order to collect information from consumers about environment, Ownership of appliances, Usage-patterns in UK households. Wright and firth [3] described exploratory analysis of domestic electricity load profiles measured at a high time resolution of 1 min on eight dwellings. Abu-Sharkh used high resolution data for one house and suggests a simple model to produce load patterns for a set of hypothetical dwellings and households [4]. A simple method of formulating load profile (SMLP) for UK domestic buildings was presented by R. Yao and K.A. Steemers [5]. R. Stokes developed a domestic lighting demand model that is based on half hourly data measured for 100 UK homes in the UK [6]. V.Hamidi and F. Li [7] presented a generalized tool to assess the responsiveness level among domestic consumers by studying load profiles for different domestic consumers which are composed of power consumption of end-use appliances. A measurement of electrical energy consumption profiles for social sector in the UK, obtained over a period of 2 years was presented by Kreutzer [8]. The measurements were all obtained at 5

minute intervals. Annual energy consumptions, daily and overall profiles were derived for the dwellings from the data. Yigzaw, et al [9] studied The patterns of electricity consumption and how occupancy and housing characteristics affect domestic electricity use for 27 homes in various locations throughout Northern Ireland (city, town and village). The results of this study showed that there is a strong correlation between average annual electricity consumption and floor area. S. Firth, et al [10] presented results from a monitoring study of the electricity consumption of a sample of 72 houses UK domestic buildings recorded on 5 min interval over two years period.

This paper describes an analysis of data measured at one minute intervals over a period of ten months for one UK two adults with children household type. Data is analysed in detail. Following the description and background of the data sets, the general characteristics of domestic loads is discussed, and the effect of time averaging is described. Further investigation is needed for a large sample of household to improve the understanding of monitoring high resolution domestic energy consumption.

2. DATA COLLECTION AND MEASUREMENTS

A typical English terraced three storeys house with a total floor area of about 100 m^2 (excluding basement) was selected for the electricity consumption monitoring. The number of occupants in the house is six (two adult and four children who are of school age). One of the adult is a full time student, the other one is a part time in the morning period in order to take care of the children after school.

The monitoring has taken place during the period Jan 2010 to Oct. 2010 in BD7 area in Bradford, in Northern England. The house space heating, Domestic Hot Water **(**DHW) and cooker have been provided by means of gas. The whole home electricity consumption has been measured and monitored at a high resolution; moreover the consumption patterns of some individual appliances were monitored at a high resolution (1 min interval). The data has been collected by using owl wireless energy monitor which enabled remote downloading of stored electricity consumption in KWh during 1 minute interval. The owl wireless monitor uses current transformer sensing technology to sense a small magnetic field around the house power cable. It measures the value of current (A) being passed through the cable and, by reference to the system voltage (230 V), calculates the amount of power being used, the quantity of greenhouse gas emissions and the cost, then transmits this information as Comma Separated Values (CSV) files from the Sender Box to a wireless remote monitor on a wireless frequency of 433MHz, from up to 30 m away (uninterrupted transmission). The data are transmitted periodically to individual computer via a USB Receiver and displayed using OWL Home Energy Monitor program. The collected data are exported to as CSV file that can be opened up with spreadsheet type applications.

The data presented are complete ten months files enclosed over 340,000 individual data values. Due to missing of some data, the missing data have been replaced by assumed data that have the same characteristics (e.g. a missing weekday has been replaced by another existing weekday data). This replaced data is marked in the excel file by a different color.

3. HOUSEHOLD LOAD CHARACTERISTICS

According to the UK department of energy and climate change (DECC), the average domestic electricity consumption was 4,198 KWh in 2008, which matches to an average load over the year of about 0.48 KW. In the UK, the modern houses have a typical peak load of less than half of which what is catered for according to the fuse rating of 100A [7].

Line plots are most commonly used to present the time-series energy data. Fig.1 shows the line plot of mean daily consumption for electricity consumption in the monitored house for ten months of 2010. The plot presents the average (arithmetic mean) electricity consumption for ten months, complemented be the maximum and minimum daily electricity use for each month. The blue line represents the average value, i.e. the daily mean electricity consumption for each month. The red line represents the daily minimum value, and the green line represents the daily maximum value for each month. From the monthly plot it is possible to extract information about the annual variation in the mean energy consumption, and the corresponding maximum and minimum values. The mean and maximum consumption in winter months is higher than in summer months. However, the minimum consumption (which probably occurs on weekdays) is relatively constant over the year.

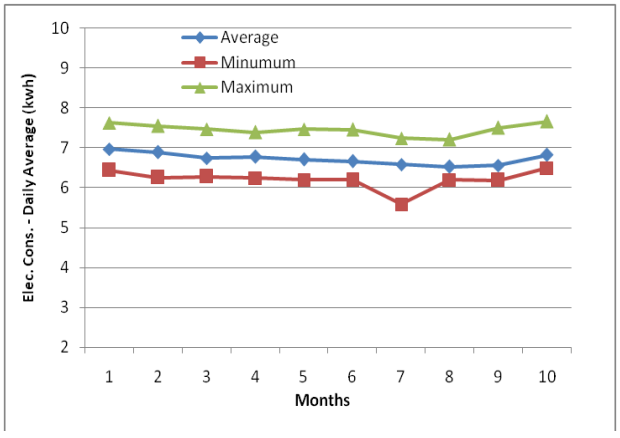

Figure 1. Monthly energy consumption line plot

A similar line plot to monthly periods might be produced for weekly periods. These are similar plots, but weekly average, minimum and maximum values for a year will be calculated instead.

To identify with the variety of electricity demand, the use of half hourly daily load profiles is more effective in

capturing the variations over the whole day (24 hours). The x-axis is positioned to one day, 24-hour included 48 data points, one for each half hourly interval (30 minutes), the daily Winter (from Jan. to Mar) and Summer (from July to Sep) load profiles logged at 1 minute interval are averaged over 30 minutes interval for weekday and weekend days as shown in fig. 2 (this has been done in Microsoft Excel spreadsheet). From fig.2, it can be seen that the base load of the demand occurs overnight and is mainly from cold appliances, Continuous appliances and appliances in standby mode. The standby appliances are actively switched on by the occupant and their power consumption might not be zero when not in use (e.g. TV). Furthermore there is no a significant difference between summer and winter and weekday or weekend base loads.

The key difference between the weekday and weekend profiles is the period between 09:00 and 18:00, where the load during weekend profile is higher because of higher occupancy.

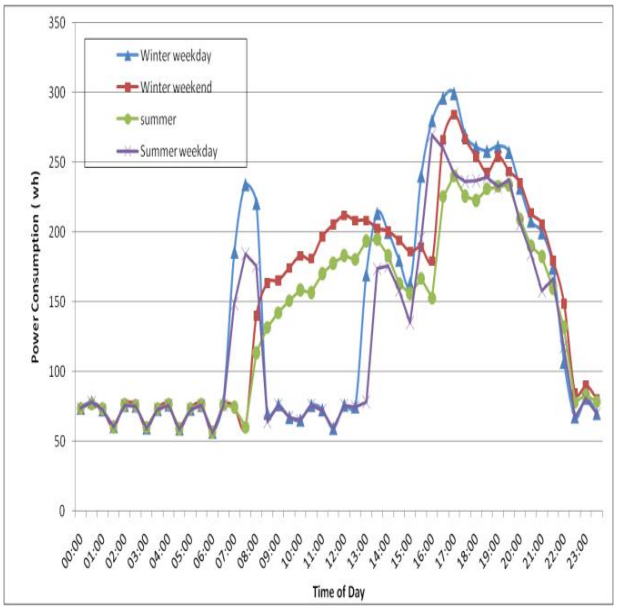

Figure 2. Daily winter and summer profiles.

Fig.3 presents an example of the total electricity consumption recorded over a particular day at 1 min and averaged over 30 minutes intervals, the 1 minutes time resolution average total power consumption shows a typical domestic electricity use pattern. During the period from 00:00 to 07:00 there was a constant cyclical pattern of power consumption between around 30 W and 60W which represents the base load. The minimum power consumption of 30 W represents the power consumption of the continuous appliances and the appliances in standby mode. The continual raise up to 60 W was caused by the cold appliances power consumption. This pattern would be noted regularly throughout the day. From 07:00 to 09:00 the energy consumption was going up as other appliances started to be in use.

As there is no one at home for the period from 09:00 to about 13:30 the base load pattern would be repeated again. However, as the second adult is working as a part time (from 8.00 to 13.00). So, the energy consumption is slightly increased again from the period 13.30 to 15.00. The evening peak period occurred between about 15:30 (time of return home from school) and 21:00 which are more pronounced compared to consumed power at other times that not all occupant are in home during that times. There were several high peaks (spikes) above 1kw that were caused by switching on some electrical appliances with high consumption such as an iron or kettle. The half hourly load profile is lower and much smoother than the one minute interval.

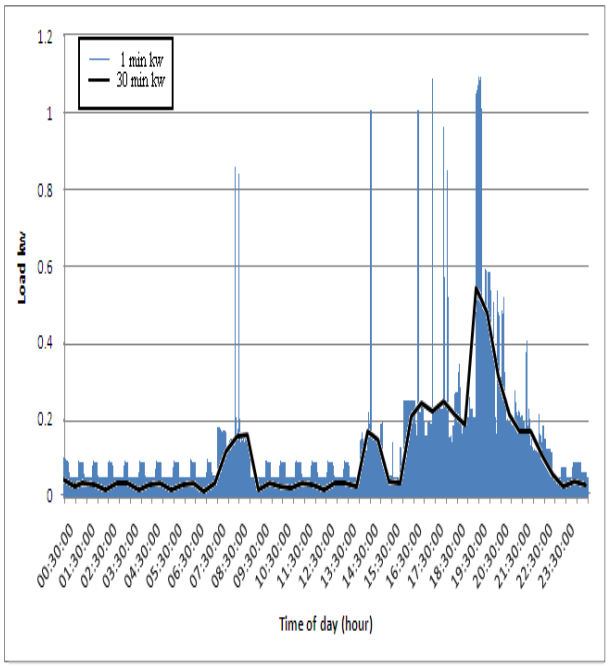

Figure 3. Daily load profile at 1 min and 30 min intervals

Because of the measured data records only the total power consumption of the house, it was difficult to differentiate the participation of individual appliances. However, the electricity consumption profile of a washing machine which has characteristic that its usage time is fixed as it works with predefined program was measured as shown in fig.4. The washing machine is characterized by one heating stage which takes a duration of about 20 min depending upon the feed water temperature and the selected washing program. The length of the wash cycle is ranges from 1h to 1.5h.

3. RESULT ANALYSIS AND DISCUSSION

The monthly electricity consumption was calculated. The results for the ten months are shown in Fig. 5 where each bar represents the consumption for an individual month. The lowest monthly electricity consumption was about 193 KWh in Feb. The highest monthly electricity consumption was about 220 KWh which occurred in Jan. The average monthly electricity consumption was 205

KWh which is lesser than the UK Government estimate of average monthly electricity consumption of all UK houses (340 kWh in 2008) which reflects the fact that the house space heating, Domestic Hot Water (DHW) and cooker have been provided by means of gas.

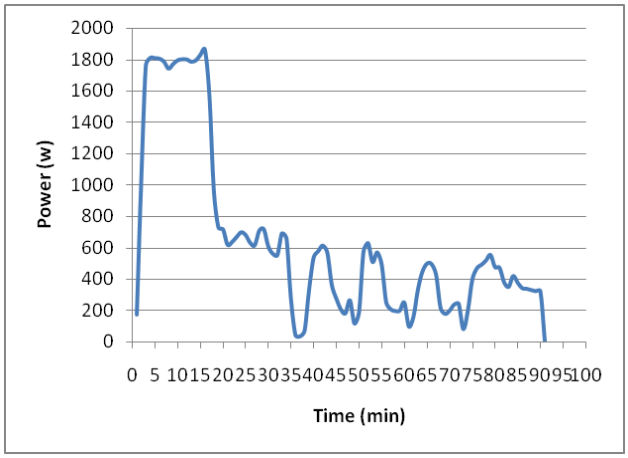

Figure 4. Washing machine electricity consumption profile

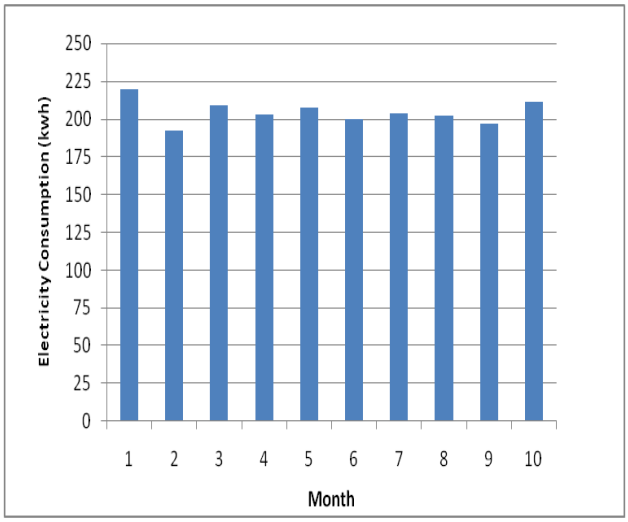

Figure 5. Monthly electric energy consumption

4. CONCLUSIONS

In this paper the analysis of electricity consumption data measured at 1 min interval over a period of ten months for a sample of one UK household (two adults with children household) has been described and investigated. The application of monthly and daily line plots has been studied. These plots are derived from aggregated data, in monthly and daily era, and from the use of average daily electricity consumption values.

The effect of time averaging was considered. The daily electricity load profile logged at 1 min interval is averaged over half hourly interval. Visual check of the plotted load curves for different intervals of 1minute and 30 min obviously shows how spikes are reduced as the period of time averaging is increased. Although only one household is investigated, it still provides some useful information on the electricity usage behaviour. The result has shown a reasonable agreement compared with the typical national load profile. The average daily electricity consumption from the measured data in the winter season is about 7 KWh, and about 11 KWh from a national load profile. The profile from monitored data is slightly lower than the national profile; because the house space heating, DHW and cooker have been provided by means of gas.
This work is continuing to determine the suitability of using microgeneration in domestic buildings and adopting real time pricing scheme on consumer's behaviour.

5. REFERENCES

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