STOCHASTIC MODEL FOR HOUSEHOLD LOAD PROFILE

Sara Ghaemi, Günther Brauner

Institute of power systems and energy economics, Technical university of Vienna,

Gusshausstrasse25/373-1A-1040Vienna, Tel: 01-5880137313, Email: ghaemi@ea.tuwien.ac.at, Website: www.ea.tuwien.ac.at

Abstract: There are different sort of physical and behavioral parameters to influence the energy demand and load profile. For making the energy balance especially in autonomous decentralized energy system, suitable method for formulating the load profile is needed. In this paper stochastic model for generating load profile of domestic building considering different family type has been presented.

The model makes the possibility of assessing the energy saving potential through replacement of energy efficient devices and changing the traditional user behavior.

Keywords: building, stochastic model, Autonomous decentralized energy system

1 Introduction

Nowadays growth of electricity consumption, lack of traditional fossil fuels for providing enough energy and increasing CO2 emission making the environment polluted, cause more research in the field of renewable energy sources to provide clean energy for end users.

Integration of renewable energy supplies into the public energy grid needs a new infrastructure not only in the transmission and distribution grid and its security and reliability but on the end-use sector as well.

To meet the growing demand and making the energy balance in the new infrastructure, an intelligent and flexible grid infrastructure, smart generation, and smart consumer will be essential.

In traditional power grids, power generation follows load. But in autonomous decentralized renewable energy system (ADRES), power consumption will follow generation rather than vice versa. In this regard the total load forecasting over a year using the old data base which is obtained from measurement of old infrastructure energy system will not be enough. A new method is needed to predict energy consumption in an intelligent building with intelligent appliances.

As the energy use in the household sector accounts for significant proportions of total energy consumption in developed and developing countries and the variety of appliances with different power consumption and usage cycles and diversity of user behavior is exist in the household sector it is decided to apply end-use model for a settlement only with households.

In this paper an end-use model for new infrastructure has been suggested. Description of appliances used by customers, house occupancy time, the age of equipment, technology changes and customer behavior are the parameters which are supposed to be included in this approach.

2 End-use Model

The end use approach directly estimates energy consumption by using extensive information on end use and end users such as appliances, the customer use, their age, size of houses and etc. statistical information about customers along with dynamics of change are the basis for this model.

This model is based on the principle that electricity demand is derived from customer's demand for example refrigerator, TV, light, kitchen devices and etc. thus end-use model explain energy demand as a function of the type and number of appliances in the households.

This model is very accurate but sensitive to the amount and quality of end-use data. This model requires less historical data in comparison with traditional energy system but more information about customers, their behavior and their appliances.

As the implementation of end-use model for load predicting is a new approach, the needed data is also not available from the other studies. In this regard we have decided to gather the data from electricity customers in Austria.

2.1 Survey on household devices and user behavior

For gathering the basic information for end-use model a questionnaire has been prepared and distributed among electricity customers in Austria. The first phase was started from November 2008 and finished on March 2009 and the second phase was started from March 2009 and finished on July 2009. We got almost 3500 filled questionnaire back.

The survey provided various information such as household demographics (number of adults, children and retired people), building's surface area and location, number and age of various household appliances and average use duration of white goods, regularity of using the other electric devices at home and data about lighting.

As the use of lighting appliances and the corresponding implications for electrical energy use, is obviously linked to the presence of users, we have decided to make a family type category regarding to the different availability time in the household.

Table.1 indicates the family type and their distribution among our sample.

Table 1 : distribution of family category among sample

Family type	Job	%
single	full time	5
	part time	1
	Retired	8
Couple	full time	8
	part time	0
	Retired	30
family	2 full time + children without retired member	12
	1 full time +children	24
	family with retired member	11

All the data analysis has been based on this family category in this paper.

2.2 Electricity measurement

For analyzing user behavior the detail information about using the individual devices is necessary. This kind of information is not available from survey. We decided to monitor the electrical energy consumption of the some selected households via consumption measurement in these households. For extracting the user behavior from electricity measurement, the usual 15 min. measurements of total consumption is not enough.

A detail measurement including monitoring the energy consumption of each individual electrical device is needed. From this type of measurement required data about how, when and for how long customers use their device at home can be obtained.

In this regard we have used the Möller measurement system which is included a central logger and energy measurement sensors which connect to the central logger via radio frequency waves. It is planned to have this measurement for 40 selected household from our sample households.

In each household about 10 sensors are installed and measure the electricity consumption of individual devices each second. Regarding some problems for measuring the fix installed devices especially in the kitchen like built-in refrigerator and electric cooker and lighting system which is not possible to measure so easily we measured the total energy consumption of the households with Fluke 1760 or Topas 1000.

This type of measurement gives us the possibility of extracting the probability function of using each individual device in different family type.

3 Household electrical appliances and their distribution

Information gathered from questionnaire shows that there are varieties of household electrical device which are used with customers. For making the data analysis easier we have categorized household divided into 5 groups.

1- Entertainment such as Sat/DVB, DVD player, Play station, HiFi and etc.
2- Communication such as coreless telephone, answering machine, etc.
3- Office such as PC, Laptop, printer and so on
4- Kitchen such as water boiler, toaster, mixer and so on
5- Other miscellaneous devices such as Iron, sew machine, hair dryer and etc.

Our sample data-base helps us to discover the average amount of devices which exist in each appliances category for each family type and get the distribution of each device in its category.

Table 2 shows the distribution of household devices in different device category for single fulltime job family type. This table has been prepared for other 7 family types which is mentioned in table 1.

Table 2: percentage of household devices in family category 1

Entertainment		Communication		office		kitchen		others	
Beamer	3 %	Answering	9%	PC	43%	Coffee machine	83%	Vacuum	100%
Sat/DVB	45%	Coreless Tel.	23%	Laptop	41%	Water boiler	71%	Iron	85%
Recorder	41%			Fax	2%	Toaster	64%	Sew	38%
DVD player	55%			Scanner	17%	Grill	39%	Heating	36%
Play station	5%			Printer	50%	Mixer	67%	Moisture	22%
HiFi	70%			Hardware	10%			Hair dryer	78%
								toothbrush	44%

Another data which is necessary for the end-use model is the average number of devices in each device category which are used in each family type.

Fig.1 and 2 are the histograms which show how different amount of household electrical devices are distributed in the single fulltime job family type. The same diagrams exist for other device category and other family types.

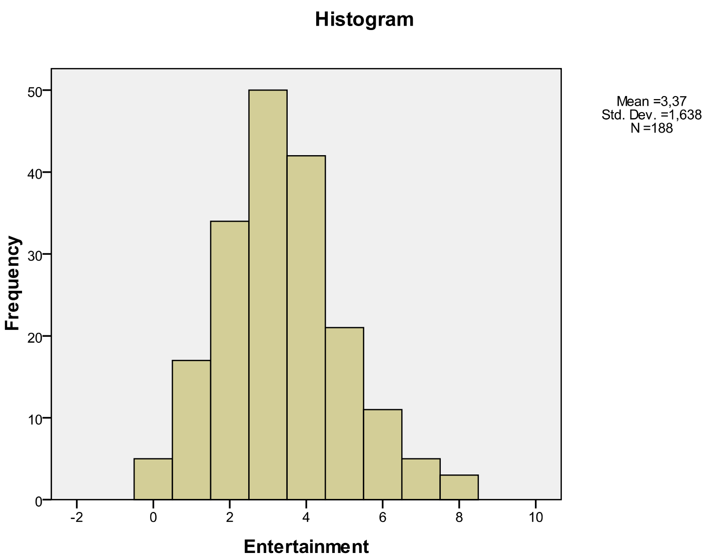

Fig 1 : distribution of number of Entertainment devices in single fulltime family type

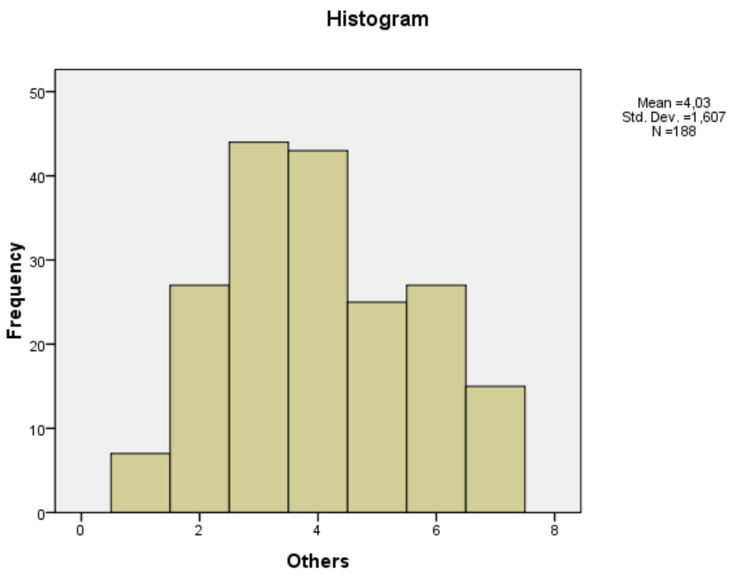

Fig 2 : distribution of number of others device category in single fulltime family type

4 End-use model

For building load profile of a defined settlement in traditional power system total consumption of settlement regarding historical data would be prognosticated.

In ADRES settlement total load profile will be sum of individual load profile of each household. Regarding the statistical data gathered from measurement and questionnaire a probable load profile for each day of each household will be built up.

From histograms which have been explained in section 3, a normal probability distribution function (PDF) has been defined for getting the number of various devices in the household. This function, get its mean and standard deviation from histograms.

By running the program the number of devices which is probable to be at each household is predicted. But Table.2 shows the different distribution of each device in each device category. For predicting which device is probable to be at household a weighted vector has been defined which is filled in by one with related percentage amount from Table.2 and other cells of the vector are filled with 0. Using a weighted random function helps us to get the existence or absence of this device.

So the devices are fixed and now we need to have their power consumption, time and duration of their use.

From the questionnaire we get the time duration of some of devices like microwaves, TV, PC, electric cooker and how often each household use wash machine, wash dryer and dish washer during the week.

Fig.3 and 4 indicates the duration of TV watching during the week days for single and couple fulltime job family type respectively.

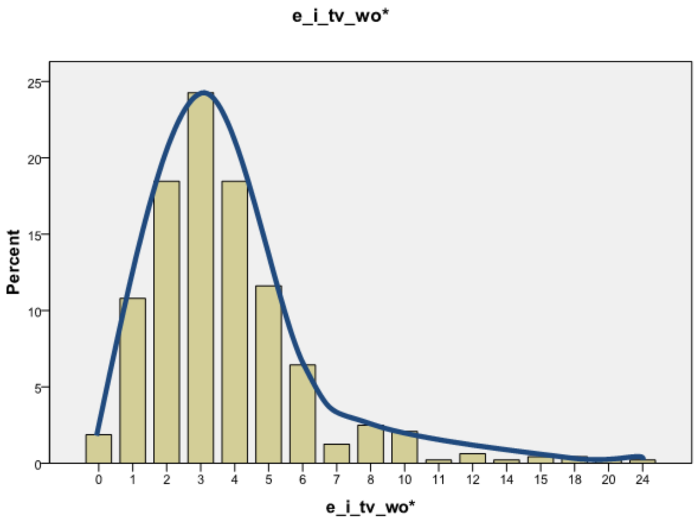

Fig 1: probability distribution curve of TV operational hours in single family house

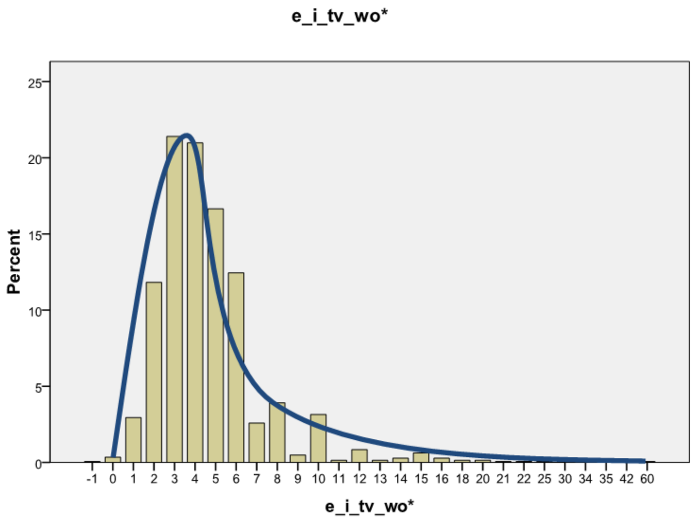

Fig 2: probability distribution curve of TV operational hours in 2 person family house

The probability distribution function for time of using each device is extracted from second based time interval monitoring of each household.

Unfortunately the measurement has not been finished yet and all the information about user behavior such as probability function of starting time of using each device and their using duration for all the family type has been not completed.

Fig.5 shows an example output of end-use model for single fulltime job family type.

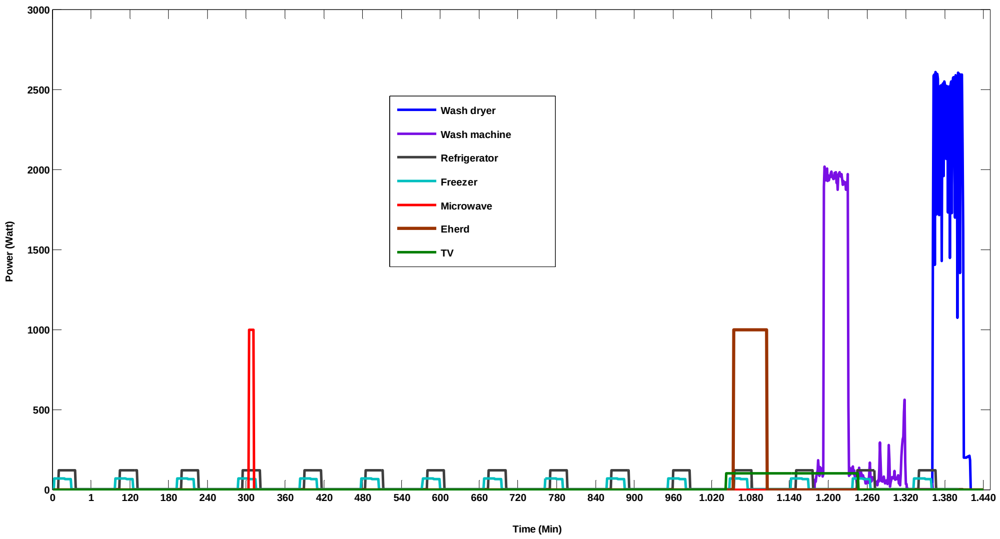

Fig 3 : sample of load profile for one single fulltime job household

Fig.4 indicates the energy consumption of each device category for a sample single household with fulltime job for one sample day.

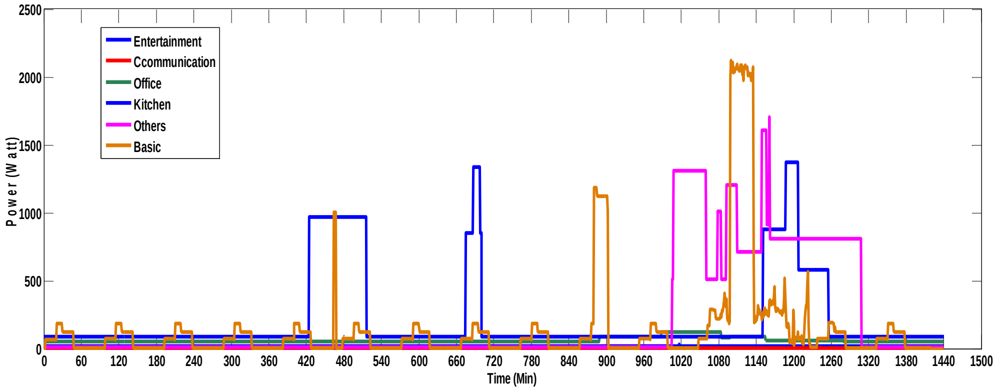

Fig 4 : Load profile of sample single fulltime job household according to device category

5 Conclusion

In this paper stochastic model for building the load profile of a settlement including households has been introduced. Although it is really difficult getting detail information about user behavior and making electricity consumption monitoring in second basic intervals for individual devices in the household but the result of model based on this information in really useful for autonomous decentralized renewable energy systems.

Considering the smart appliances in the household which adopt their function with frequency changes in the grid and using proposed end-use model give us the possibility of assessing the saving potential during the unbalanced grid via reducing the power of electrical appliances in the way that the consumer doesn't realize it.

Finishing the detail measurement and consumption monitoring by the end of September 2010 would help us completing the result of end-use model and considering the effect of seasons and different working days in the model.

6 Acknowledgments

The funding for this work by the Austrian Research Promotion Agency (FFG) is gratefully acknowledged.The authors would like also to thank the utility Companies, EnergieAG Oberösterreich, Wienenergie, BEWAG and EVN with their support in distributing the questionnaire, installing the smart meters and making different type of load measurement for this study.

7 References

[1] J.Page, et al., “A generalized stochastic model for the simulation of occupant presence”, energy and buildings 40 (2008) 83-98

[2] g.Michalik, w. Mielczarski, ”modeling of energy use patterns in the residential sector using linguistic variable”, IEEE, 1996, p.278~p.282

[3] G.Wood, M.Newborough, “Dynamic energy-consumption indicators for domestic appliances: environment, behavior and design”, Energy and Buildings 35 (2003) 821-841