Household Energy Consumption Monitoring

Peteris Apse-Apsitis (*PhD Student, Riga Technical University*), Ansis Avotins (*PhD Student, Riga Technical University*), Leonids Ribickis (*Professor, Riga Technical University*)

***Abstract* – continuous development of office and household equipment has changed the electricity end-consumer profile in latest years, and number of electricity consuming equipment is still increasing. To help households save electrical energy consumption, a new smart monitoring method is needed, which has low cost, can be used in existing installation and gives feedback to user. The article describes a different approach of power monitoring system that lowers the costs and price of needed metering equipment.**

***Keywords* Energy efficiency, Monitoring, Wireless communication.**

I. INTRODUCTION

Existing dwellings consume about 3 times more energy than it is prescribed in the current Latvian building regulations, which were developed before households became available with wide range of electrical appliances, as well as the classification of average consumption per device type has been changed.

At the same time, load growth forecast for the housing sector shows that, due to raising the quality of life, households are becoming increasingly available to a wider range of household electrical appliances, thus contributing to the electrical load increase, actualizing the problem. For example in Latvia, after local electrical energy supplier A/S Latvenergo and Riga Energy Agency data [4], comparing the year 2007 with year 2003, the electrical energy consumption has increased by 11%, and is expected to continue.

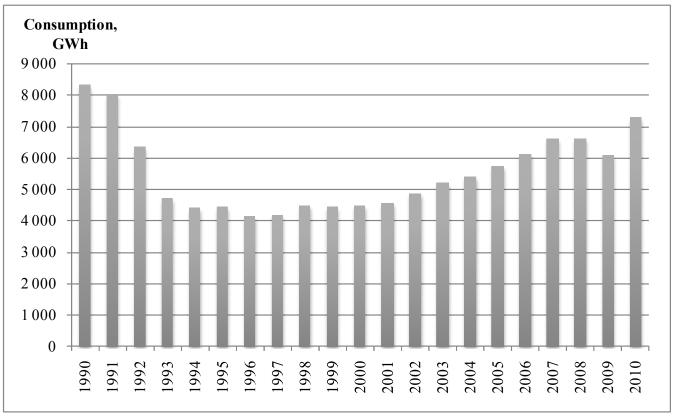

Fig. 1. Total electricity consumption 1990-2010 in Latvia.

Fig. 1. shows that a continuous increase in electrical energy consumption, starts from year 1997 and continues, also after the economical crisis at year 2008/2009, where consumption in 2009 Latvia decreased down by 7.3% compared to 2008. Production of electricity in 2010 increased by 19% comparing to 2009 (6627 GWh).

According to data of the A/S Latvenergo, consumption in 2010 industry sector grew by 5.3%, but consumption in households reduced by 3%.

It is obvious that in order to achieve global goals of energy efficiency, an additional economic and political stimulators will be needed to change consumer habits of conservative household, residential building in cities or rural region end-user. One of such economical stimulator is natural continuous rise of price for electricity, as it is connected with limited availability of fossil fuels.

As the prices for electrical energy are increasing, the idea of SmartMetering systems and SmartPlugs in recent years got attention from both sides – energy supplier and consumer, as it could greatly contribute to energy consumption reduction, by changing the habits of consumer, and thus creating more stable power grid in future.

It can be concluded that one of the fundamental problems in electrical household is non-saving energy consumer. In order to solve this problem, the end-user must be informed about his possibilities to save energy, which could be reached by implementing smart metering systems with graphical indicators on screen, or visualization on PC with help and tips for possible solutions of energy consumption reduction possibilities of each consuming device.

II. ENERGY METERING TOPOLOGY

This clearly indicates the need for much cheaper solution with much direct and understandable message to end-user. Also the metering device should have small dimensions, so that it could be integrated into back of socket or into luminary chuck (typically E27) (see Fig. 2 P2 load).

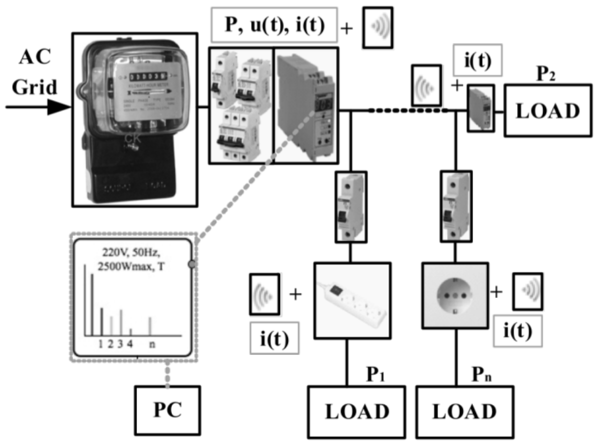

Fig. 2 Block diagram of energy metering method for household application.

The main task is to provide energy consumption apportionment between consumers instead of precise energy consumption metering for each consumer type, as the distance between central measurement point, and monitoring point is less than 100m, the voltage u(t) practically is the same for each consumer and energy consumption can be characterized by just monitoring each consumer current i(t) value.

Central measurement point, which makes precise measurements of u(t), i(t) true rms values, receives relative current values from monitoring device, via wireless or power line communications, and makes indicative visualization of energy consumption per consumer on display or sends it to PC. 2,5%-5% precision is enough for monitoring task and such precision corresponds to 80 sec or 180 sec consumer state "ON".

Energy consumer power typically is within range from 10W up to 2250W (typical 10A wall plug), consumers have R or RL (also RC) load characteristics, current and voltage graphs are sinusoidal under normal conditions.

III. Power Measurement

Electrical power contains active and reactive components and they correspond to each other via cosφ. Energy supplier place bill just for active component consumption in the most of cases for individuals and legal person, for example in Latvia charges for reactive energy, when tg φ is greater than 0.4 (cos φ <0.929) and allowed load 100 kW and more, is additional 0,003 Ls/kVArh.

For sinusoidal voltage and current active power values can be calculated from equation (1):

$$P = U \times I \times \cos\varphi \tag{1}$$

Voltage, active and reactive current graphs under different cosφ values are shown on Fig.2.

Under EU regulations every consumer over 75W must reduce non-sinusoidal consumed current form due to rising problems in to the power transmission lines as well as for energy generating plants and equipment.

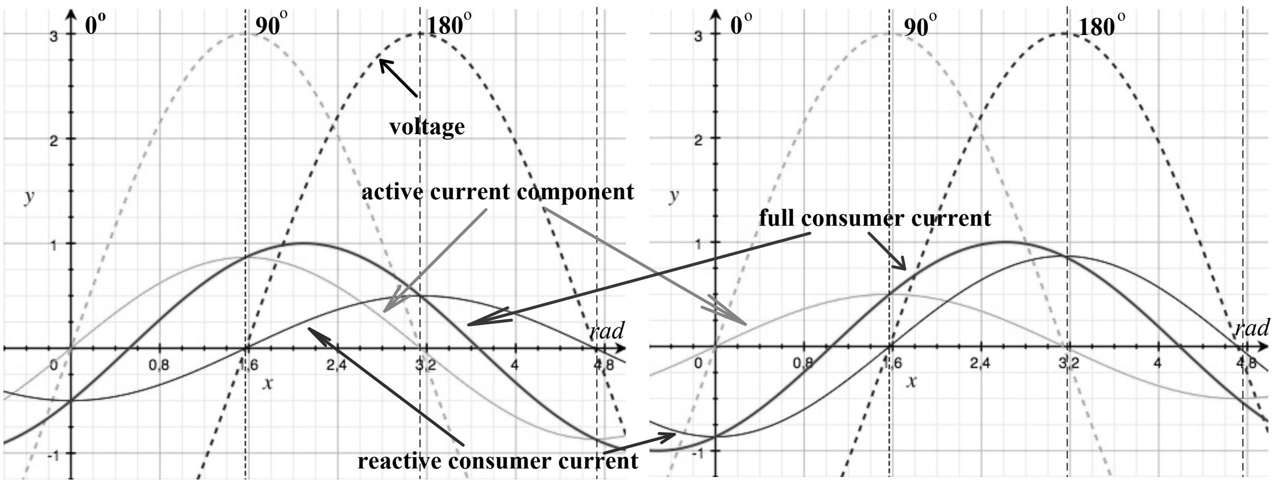

Fig. 3. Voltage, active, reactive and full current graphs, where a) cosφ=0,5; φ=60; b) cosφ=0,866; φ=30.

Every consumer rectifier-capacitor load produces non-sinusoidal current. Depending from each household consumer produced non-sinusoidal current (see Fig. 4, Fig. 5) form and value over different working cycles and time is difficult to predict total current form and value and total consumed power can be more than 75W in one household.

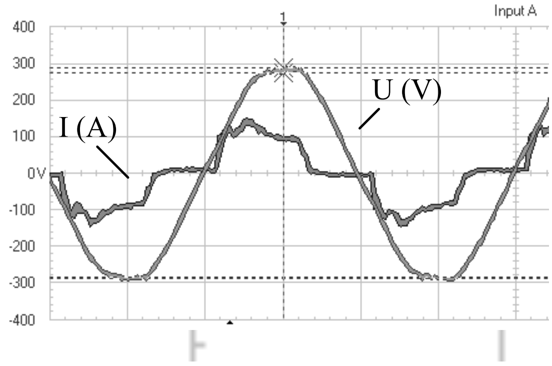

Fig. 4. Waveforms of PC consumed voltage and current.

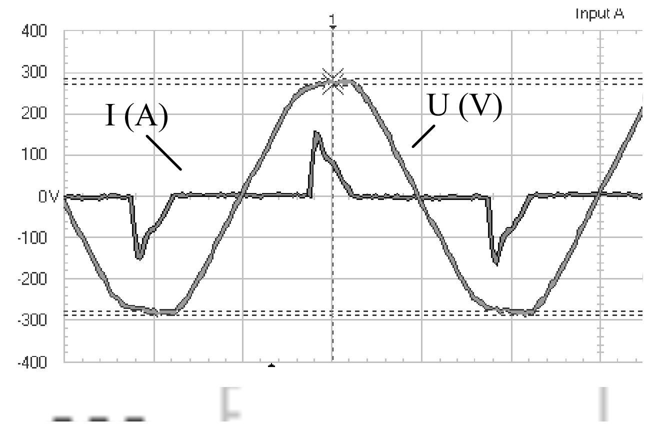

Fig. 5. Waveforms of laptop power supply voltage and current.

Each consumer practically has the same voltage value in household. Power apportionment in one household is proportional to current apportionment between consumers.

In order to get measurements and relative current value distribution in total energy consumption, the central measurement point, measuring both voltage and current values, must be synchronized with monitoring measurement point, which measures only current value, at the exact point.

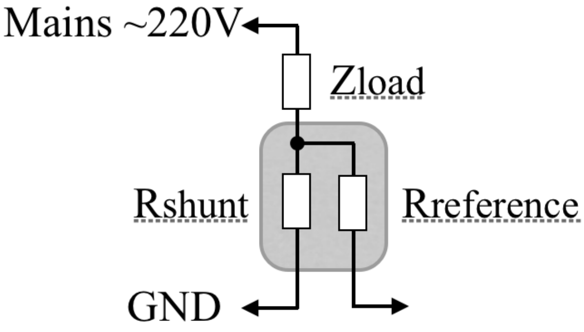

Fig. 6. Shunt and reference resistor.

Shunt was used as current sensor (see Fig. 6), and dissipated power in shunt must be taken in to account and this fact reduce shunt value and make more difficult to read voltage drop on it for low consumer energy (power). Unfortunately other current sensors like Hall effect (LEM FHS 40-P/SP600) etc. are more expensive, 3-8 EUR and cannot be applied in this case, as the goal is to get low-cost measurement device, the shunt resistors like ERJ-M1WSJ8M0U, PMR50HZPJU8L0, or similar, has price from 0,30-1,00 EUR, which is significant price.

Typically temperature stable shunt resistor cost more than 2 EUR as minimum and is too expensive for described solution. To decrease current measurement circuit price ordinary copper wire and resistance controlled gain of the amplifier was chosen instead.

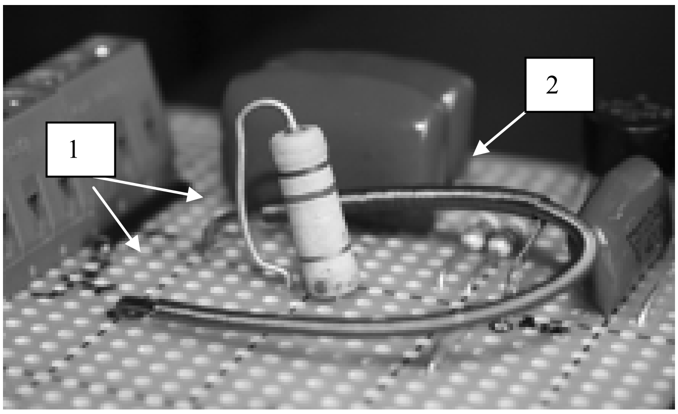

Fig. 7. Cooper shunt and reference resistor winding.

Ordinary copper wire is characterized by resistivity ρ =1,68* 10-8 Ωm at 20 deg/C and temperature coefficient 0,0039 K-1. So, for example, resistance change from 0,00310 Ω at 0 deg/C to 0,00388 Ω at 60 deg/C or more than 25%. To exclude this reference resistor to control amplifier gain is applied. Reference resistor is made from copper and is close to shunt in the same housing Fig. 8 and Fig. 9. Practically reference resistor value have the same temperature changes as shunt and control amplifier gain.

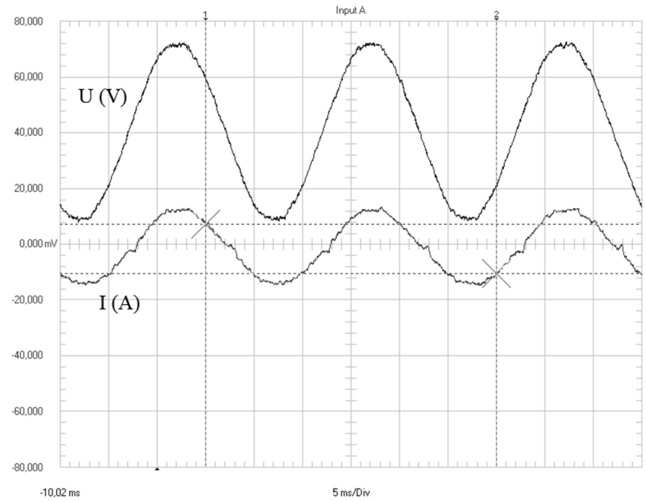

Fig. 8. Current and controlled gain of the amplifier output at 30 deg/C.

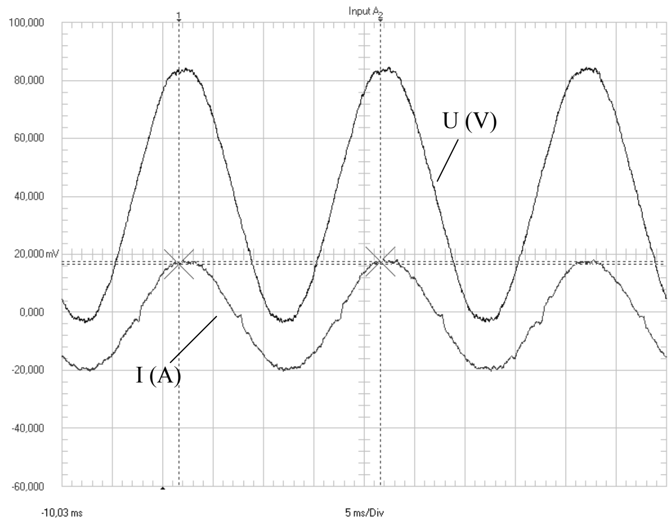

Fig. 9. Current and controlled gain of the amplifier output at 60 deg/C.

TABLE I
TEMPERATURE INFLUENCE ON SHUNT RESISTOR

Temperature, °C	Amplifier output without compensation, mV	Amplifier output with compensation, mV
30	19,2	17,38
60	21,4	17,7
Diference, %	10,3%	1,8%

Thereby amplifier output signal is directly proportional to current and shunt drop voltage change under temperature change is excluded. Fig. 8 represent load current and controlled amplifier gain output at 30 deg/C and Fig. 9 represent the same at 60 deg/C.

Graphs and Table 1 show acceptable temperature change influence on shunt resistor value compensation via resistance controlled gain amplifier (load current 2,1A)

The difference of 1,8% can be explained with non equal heating conditions during experiment, as the compensating wiring has heating up more (with fan) than the shunt resistor.

IV. Communication and Data Processing

For data processing, storage and computing tasks, a system shown in Fig.8. could be used. Main point is based on ATmega328 microprocessor and FTDI USB UART chip FT232RL mounted on Arduino Duemilanove board. Arduino Duemilanove allows several system developments: USB connection, WiFi and Bluetooth wireless connections as well as Ethernet connections via additional installations on Arduino board. Also small computation is available if it is necessary.

Currently USB connection was chosen to communicate with FileMaker database installed on PC (any kind of personal computer operating Microsoft Windows or Apple OS X operating system).

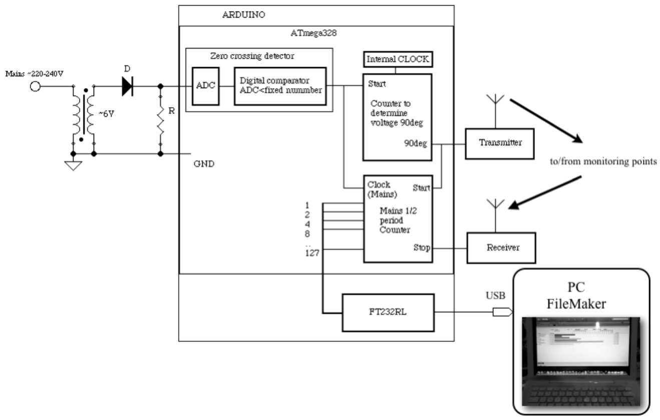

Fig. 10. Block diagram of data processing, storage and computing system.

FileMaker database was chosen due to several advantages, it is well known and developed during last 20 years, it has practically unlimited number of data tables and table fields, which means practically unlimited amount of data that can be easily processed, FileMaker network allows easy communicate via internet, instant web publishing engine allow to view data as well as interact with collected data, PHP or XSLT web publishing (web server must be installed), Microsoft ODBC, mainly OpenSource JDBC and OpenSource MySQL connections available.

To use FileMaker there is no deep programming knowledge necessary, it has also user friendly layout design, advanced Script technique, it also allows chart data representing - Gantt, bar or line (possible directly in FileMaker or Google Charts live), one FileMaker installation simultaneously can run several databases - energy consumption monitoring, CRM, people etc. Thus it is possible to develop database for typical "Hints", for example "Please check the fridge doors", if there is non-typical increase in energy consumption.

V. Conclusions

Described method allows designing and implementing low cost consumed energy monitoring for several consumers. Achieved price level is 4,55- 4,70EUR per measuring point and 29,88-32,77 EUR per main point unit. Overall costs are less than ~71 EUR and it is acceptable for average household or small office. A data communication between two MRF24J40MA and two RFM12B based transceivers were established and can be used for electrical energy monitoring device communication purposes.

References

[1] Grob Bernard (1997), Basic Electronics, eight edition, The McGraw-Hill Companies, 936 Eastwind Drive Westerville, Ohio 43081, pp. 416.-456.

[2] Bourdeau Luc (2009). Presentation „The key role of ECTP and collaboration with other ETPs". ECTP & E2BA Secretary General. 29.04.2009.

[3] EIA (2008) - Energy Information Administration (U.S.), International Energy Annual 2006, Table (6.2.) Posted: December 8, 2008 (www.eia.doe.gov/iea/).

[4] Golunovs J. (2008). Riga household specific electrical loads – planning instrument for improvement of energy efficiency. Energy and Automation. 10/2008 (publicity of research results of J.Golunovs) (in Latvian).

[5] http://www.csb.gov.lv/en/notikumi/consumption-energy-resources-latvia-2010-31967.html

[6] http://www.csb.gov.lv/category/statistikas-temas/vide-un-energetika/energetika

Peteris Apse-Apsitis is 1st course PhD student, researcher of Riga Technical University Institute of Industrial Electronics and Electrical Engineering. Main fields of scientific interests are power electronics, robotics and mobile ICT applications. He is author of many industrial solutions and applications and patented inventions. A member of IEEE association.

Ansis Avotins is 2nd course PhD student at the faculty of Power and Electrical engineering study program „ Computer Control of Electrical Technology". Master degree of Science in Electrical Engineering achieved in 2005. Main field of study is autonomous lighting systems. From 2004 working as chief Laboratory Manager at RTU, IEEI. A member of IEEE and ACM associations.

Leonids Ribickis is a professor, Vice Rector for Science of Riga Technical University. Received Dipl.El.Ing. qualification in 1970 (Riga Polytechnic Institute), in 1980 received PhD. In Belorussian Polytechnical Institute and in 1994 – Dr.Habil.Sc.ing. at RTU. Main research fields: Electric Drives, Power Electronics, Intelligent Electronic Equipment. Full member of Latvian Academy of Science, IEEE Latvia section Chairman, Board Member of EPE.