TESTING OF SMART HOME SYSTEMS BY APPLIANCES SIMULATOR

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Abstract
The contribution describes a system for testing of control systems used in smart home or in intelligent installation. Lot of control systems are existed and new are created at present. This control systems monitored behaviour of part of installation and control it. Testing of these systems is realised individually and it is depend on development company possibilities. Usually system is tested after installing to installations or it is tested only partially. The paper describes a created simulator for testing of these control systems by virtual house with virtual appliances. Simulation conditions and tests can be created with this simulator tests quickly and variability of simulator can editing parameters according to actual requirements.

Keywords
smart home, appliance simulator, smart grid, testing, intelligent installation, virtual house, control system, monitoring system

1 INTRODUCTION

Installations of houses are changing ceaselessly in order to improve user comfort and raise efficiency. The results of those efforts are creation of ever new and new control systems form smart installations.

Creating of editing of control systems require lot of testing cycles. These tests are complicated and every new application is specific. New test conditions and new environments creating in each case of test is very technical and financial difficult. In practise control systems for installations are tested in real conditions on real house installations. For this type of testing changing of appliance parameter is nearly impossible. Not always tests implement are possible in real installations. The other problem is limited modularity of installations for testing.

For creating and comprehensive testing of control systems is required use fully modular test system.

Large companies have conditions for testing and usually use real model of installations or house. In this case problem is about limited management and reconnection of household appliance.

Issue about fully modular testing system is not solved. Smart metering and smart grid technology brings new possibilities and requirement of new control systems. On the present new control and monitor systems are created for smart installations. Tests of these applications are realized only partially or debugging is realized in situ on final installations. This methods increase time and financial requirements.

Methods described in this paper eliminate negative attributes described above. Aim of this paper is describe new fully modular simulation system, which can simulate and monitor using of home appliances. It is useful for testing the impact home appliance using to other systems and devices like smart meter. Consequently, testing of algorithms and communication is also possible.

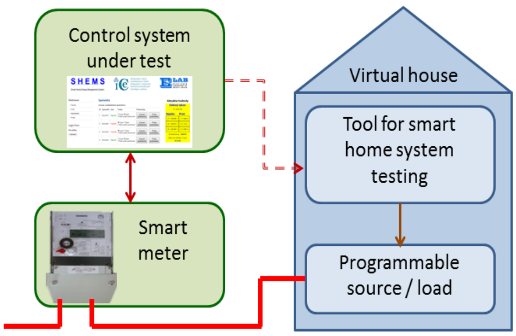

Fig.1 Tool for smart home systems testing

The described system testing has been developed for virtual house simulating. In this system are operated virtual home appliances by the specific rules. Aim of this system was testing possibilities in installations with smart meter.

Next used application for simulation system was small off grid network. In this network was photovoltaic and inverter. System tested behaviour of installation during various operation of virtual house.

2 METHOD OF SIMULATION

Created system is based on assumption that appliances with main impact to the energetics aspects are big appliances and thermic appliances. This appliances (and especially thermic appliances) create potential for optimizing of operation by their inertia. Efficient operation of appliances by control system can reduce demand for energy sources and their regulation.

Aim of this paper is not create algorithms of control but create system for testing of control systems and create system for testing with minimal limiting factors like the testing on real installations.

Simulation of house appliances is realised in created system by two methods:

- Thermic appliances are simulated by numeric constant of heating or cooling,

- Other appliances are simulated by time profile of using.

These two methods create conditions for simulating of operation preponderance appliances. It create possibilities for appending human factor to operation of appliances.

2.1 Heating and cooling appliance simulation

In simulation of operation thermic appliances is used knowledge from physic about energy transform. The output of simulation is operation of virtual appliances that corresponds to real situation in the home. Time of appliance running is calculated from supplied (transmitted) heat Q and electric power P:

$$t = \frac{Q}{P}\eta = \frac{V\rho c_v |T_v - T|}{P}\eta \qquad (1)$$

where

c_v - Specific head capacity of the medium (J $kg^{-1}K^{-1}$)

T_v - Boiling point of the medium (K)

T - Initial temperature of the medium (K)

V - Cubature of heating or cooling medium (m^3)

ρ - Density of heating or cooling media (kg m^3)

η - Efficiency of appliance (-)

Appliance user behaviour is necessary to take account. For example, user can during boiler using hot water drain. Next example is appliance operation depend on distribution network tariff. Other example is windows opening during room heating. These factors can be included to simulated operation by time function. It can bring to operation the human factors.

2.2 Other appliance simulation

Appliances which cannot be simulated as heating or cooling is possible simulate by defining time profile of operation. The time profile can be created on the basis of requirements or from results of measurements in real conditions (in real installations). Examples of such measurements are in Fig. 2 and Fig. 3.

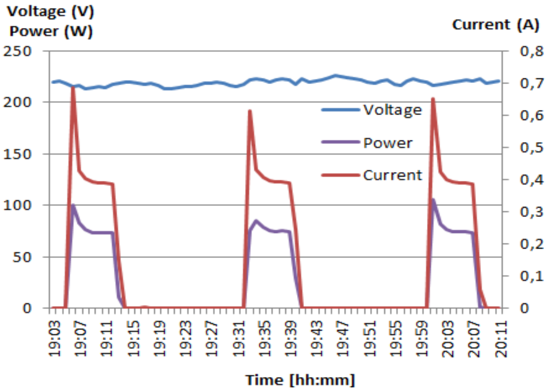

Fig.2 Measured values of refrigerator operation

Measured values of electrical parameters showed on Fig.2 indicate that simulation of this appliance is possible both methods, like cooling appliance and also by time profile.

Interior light of refrigerator can be added for more detailed simulation of operation. This is small increase but for some applications it is necessary.

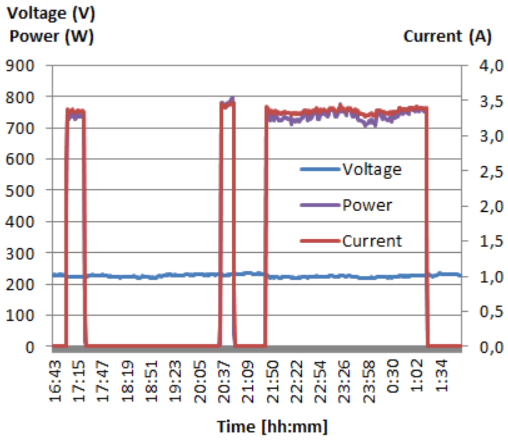

Fig.3 Measured values of boiler operation

Results of realized measurements show small variation of current and deviation from ideal value. It is consequence of start-up current during starting of appliances. Start-up current is transient state, which has impact to operation of protection and overloading of installations. For majority simulating of house appliance is this state insignificant. For very accurate simulating is possible add function of current behaviour to appliance specification or to specification of behaviour of programmable source.

3 APPLIANCES SIMULATOR

Applying of the methodology described above is through the created house appliance simulator.

For maximizing variability of simulator is created in modular system LabVIEW. This programming environment allows simply connection between programmable source (programmable load) and other devices or systems. Values are input by house appliance simulator screen. Adding or editing virtual appliances is easy thanks to modularity of LabVIEW.

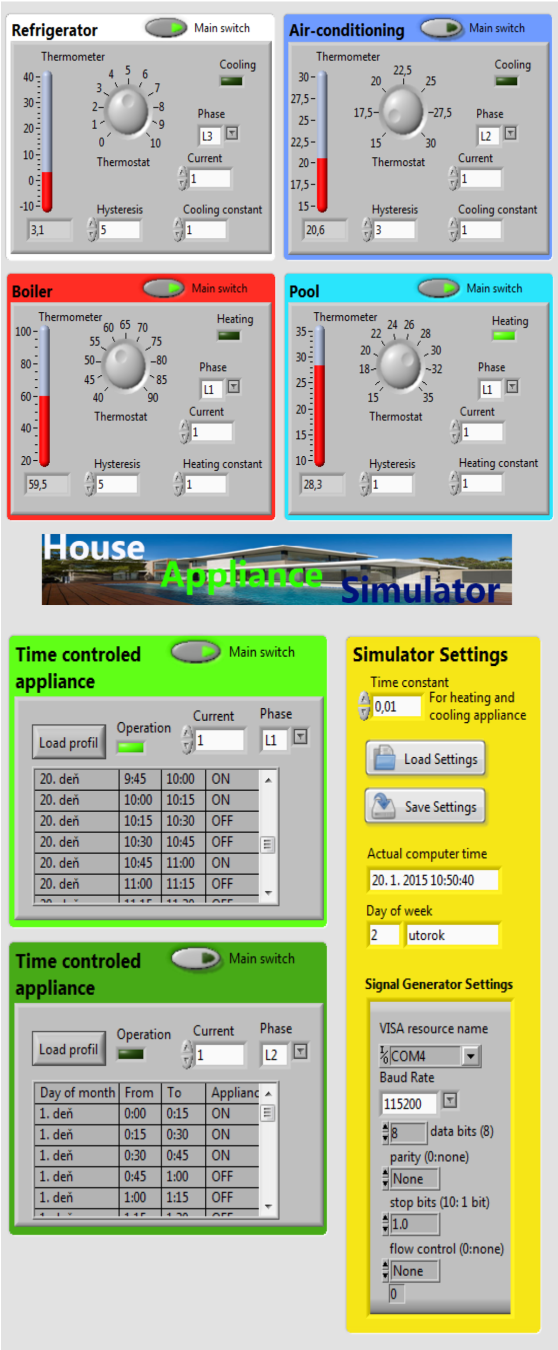

Fig.4 Main screen of simulator

Green marked parts of simulator screen are for input and editing parameters of appliances defined by time profile. In Fig. 4 are two time profile defined appliances.

Yellow marked parts of simulator screen are for editing and reading system information. Time constant allows changing of the speed of program running. It is good way for accelerated simulation but is necessary to correctly set the parameters of appliances. By the time constant is possible to reduce time of simulation.

Red and cyan marked parts of simulator screen are for management of appliances that are used for heating.

Blue and white marked parts of simulator screen are for management of appliances that are used for cooling.

For appliance that are used for heating or cooling is necessary input required temperature, hysteresis and thermal constant. These constants take into account the amount of the medium and speed of thermal changes.

Virtual appliances are specifying by electrical parameters. Each appliance is described by current and connection phase. If appliance is running then is current generated by programmable source or programmable load in selected phase.

Time profile defining is possible by table in simulator screen or by other software. Loading from other software is by loading button.

Simulating is influenced by various factors. Totally exact simulating is very difficult. Described simulation tool allows connect devices from partial modules and approximate to real values. The engineers have to decide which accuracy is necessary. For most of testing is possible to ignore some described influences.

4 INFLUENCES TO RESULTS

Precision of simulation is influenced by several factors. All described effects van by simulated adding modules to simulation.

Standby consumption of appliance

Effect of standby operations of appliance is not significant because consumption is during this operation very low. For precision simulating is possible add next module for generating this consumption.

Harmonic distortion of current

Most appliances during operation generate distorted current. If is necessary generate exact waveform, then define current by harmonic for each virtual appliance is necessary. This exact solution is more complicated because is necessary use programmable source with harmonic generation possibilities.

Consumption auxiliary circuits

It means light in refrigerator. For testing of simulation tool was this influence ignored. If is needed for precision then is possible to add module for generating this consumption.

Influence operation levels

For example it means different levels of operation of washing machine. At different time is operated different part of device like motor, heating or pump.

Influence voltage fluctuation and other electric parameters variation

Voltage fluctuations in distribution network cause fluctuation parameters of appliance. This effect takes to simulation require deep knowledge about reason and information about network. For simulating with current and voltage circuits is possible generate fluctuation or distortion of voltage. Problem can be about relevant information about appliance and network which is simulated.

5 RESULTS OF TESTING

Created home appliance simulator was connected to programmable source. It was generated 3 phase current and it was connected to smart meter. On Fig. 5 is showed current flow to virtual house.

Testing was realised by accelerated simulation. Not all virtual appliances were turned on for all time. Simulated operation show one of solution how can be house controlled. For variable settings is current flow different. Aim of this testing is show possibilities, simplicity and variability of created model.

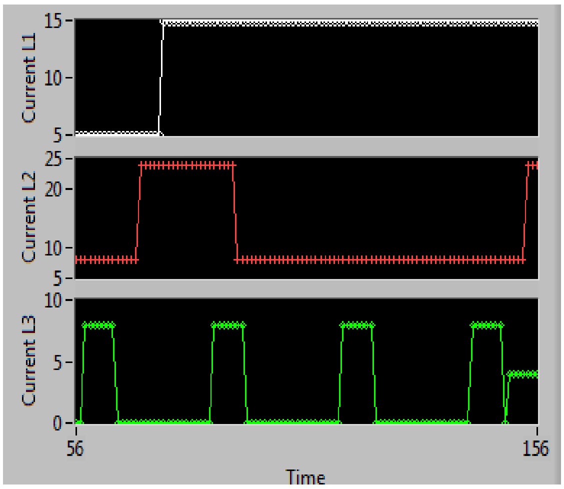

Fig.5 Current flow to virtual house during tool operation

6 CONCLUSION

Created methodology and created simulation system is simply and fast tool for simulating house appliance. Results are not exact like real house but for testing control systems are result sufficiently exact. Main advantages are modularity and fast creating virtual appliance house.

Additional module that are planned to add to simulator is photovoltaic power plant. It is reaction on demand from praxis, because small renewable energy source are increasing.

The described simulator could be used for the monitoring of the real house and transmit measured values to the virtual house. This solution is good for applique real state to the virtual house. This solution is demand on technical solution of monitoring and measuring parameter in real house.

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