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Building Automation Control System for Smart Grid

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Abstract

An advanced control method of Building Automation Control System (BACS), as part of home automation to interface with smart grid system. An optimization technique, Dynamic Programming, is employed to solve the scheduling of building appliances. The cost savings achieved by interrupting the cycle of building appliances has been explored within the optimisation suite. The BACS automation controller is using price signals made available by smart meters to shift and interrupt building appliances in order to maximize the benefits for theresidential consumers. Described optimization can be used in home automation for cost savings while allowing users different levels of control on the smart appliances. A case study carried out with Volt/Var optimization techniques, Binary Integer Programming and Dynamic Programming shows substantial cost savings under real time pricing.

1. Introduction

The world has a huge appetite for electric energy, consuming thousands of billions of kilowatt hours (kwh) annually, as more countries become industrialized, electric consumption has increased and is expected to grow to33.300 billionKwh by 2030.

To achieved energy target 20% energy from renewable sources 20% increase in efficiency and 20% reducing gas emission. In order to achieve these targets new polices and technologies such as Smart Grid are essential.

With the development of smart Grid technologies, both residential and commercial consumer will save their cost of energy also the losses during transmission to distribution as a result energy will also be saved. In this context, the suppliers will offer real time pricing(RTP) to its customers because it includes (a) more competitive market during peak usage hours.(b)customers have choice of resources available.(c)optimize the use of renewable energy sources.(d)reduces the frequency and magnitude of energy scarcity events.(e)customers provide valuable reliability services to the local area.

In this paper a review of different optimization process has been studied that schedules the operation of appliances loads is proposed. Building Automation Control System (BACS) module employed to provide real time pricing (RTP) tariff to consumers through smart meter. The BACS employs cost optimization to maximize the savings on consumed energy by shifting domestic loads as well as energy resources.

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2. Background

An extensive study of the potential benefits volt/var optimization (VVO), that is operating capacitor banks and voltage regulation in a co-ordinate manner to provide optimal voltage and reactive power usage to their distribution feeders. This reduces the cost of energy as a raw material, reducing overall production costs.

The cost savings achieved by interrupting the cycle of smart appliances has been explored within the optimization suite. The home automation controller is using price signals made available by smart meters to shift and interrupt smart appliances in order to maximize the benefits for the residential consumers. The owners were offered day-ahead variable electricity tariffs as an incentive to shift different loads. The system can automatically schedule appliances to operate in periods with low energy prices. Results from the trial are expected from the end of 2012.

By optimizing the schedule of appliances the use of price- based incentives promote renewable source of energy such as wind or solar. RTP tariffs have been used to simulate BACS which shifts the controllable residential loads to low price periods. The optimal schedule results from dynamic programming. Review of this study confirms that using BACS can reduce the household electricity bill and also the peak –to-average ratio in load profile.

3. Implementation

The present work is aimed at study and development of an energy management system (EMS) suitable for underdeveloped countries. Studies involve designing of a BACS module by using optimization method of dynamic programming which will accounting the energy and metering, managing the load in the premises, Sending reports to distribution control system i.e. smart grid, Display of required information to the user.

3.1 Function of BACS

The present work is aimed at study & development of an energy management system (EMS) suitable for underdeveloped countries. Studies involve designing of a BACS module by using optimization method of dynamic programming which will accounting the energy and metering, managing the load in the premises, Sending reports to distribution control system i.e. smart grid, Display of required information to the user. It will perform energy accounting, and control the load by making communication with smart grid. Practical study can be done on a simulated network. BACS may be tested on this prototype. The home area network (HAN) can be drawn for a typical house and load study under various conditions can be made by a computer. Dynamic programming makes the direct search feasible because instead of searching among the set of all admissible controls that cause admissible trajectories, we consider only those controls that satisfy an additional necessary condition—the principle of optimality.

3.2 Block diagram of BACS

Proposed building automated control system (BACS) is shown in block diagram below.

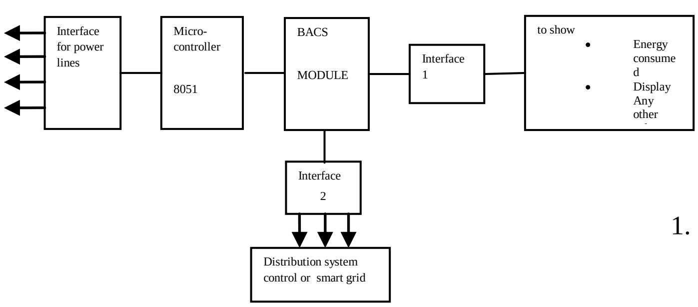

Fig: 1. BACS Block Diagram

BACS block diagram consists of three interface unit namely interface unit 1 which is placed between BACS module and display to show energy consume as well as any other information. Interface unit 2 to make output communication channel of BACS compatible to smart grid if required. Interface unit 3 connected with the power lines and residential load which are placed in Home Area Network (HAN). The energy accounting and load control as par user demand achieved by microcontroller. BACS module is used to access all the electrical appliances such as lightning load, heaters, air-conditioner, motors etc. installed within the house.

It will perform energy accounting, and control the load by making communication with smart grid. Practical study can be done on a simulated network. BACS may be tested on this prototype. The home area network (HAN) can be drawn for a typical house and load study under various conditions can be made by a computer.

- Development of hardware and software for BACS for domestic or industrial consumers [or Low-Tension or High-Tension consumers].
- Particulars or Technical details of interface on input and output side of BACS
- Choice of communication channel from BACS to smart grid on the basis of
  - Reliability
  - Cost considerations and
  - Installations

Common type of communication lines are normally power line wiring, Telephone wiring, Ethernet or Wi-Fi. However telephone lines are not present in all the premises and may not be suitable under such conditions.

3.3 Module of BACS

It records the consumption of electrical energy on interval basis of an hour and communicates the information to the utility for monitoring and billing purpose. Smart meters are two way communication between the user, central BACS module and service provider. BACS has more information about the operation and the state of the distribution network. The BACS module consists of operational information, functionality distribution and distribution network operation (DNO) module. The following functions are performed by BACS module.

1. Real time or near time registration of electricity use and possibly generated to interface with the renewable energy resources.
2. Meter reading is achieved by mobile

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3. communication and computer communication
4. Limitations for user and service provider.
5. Inter communicate to grid connected service provider network.
6. Ability to read other commodity meters such as gas, water etc.

This interface unit must be able to perform different typesofcontrol for different types of 240V appliance. As perthedem and response, the A Cload will be controlled by changing the module of its level point.Thewater heater and other heavy electric home appliance loads will be controlled by changing their status. The algorithm will monitor the home appliances load on the basis of demand response.

Application of BACS module helps to interface with the smart grid and will:-

- Improve the efficiency of electrical distribution system
- Control the energy consumption of consumers
- Create awareness to users to minimize their demand during peak hours thereby reducing the overall peak demand
- Help the Government in forming an energy policy to increase the operational efficiency.

3.4 Control algorithm for BACS module

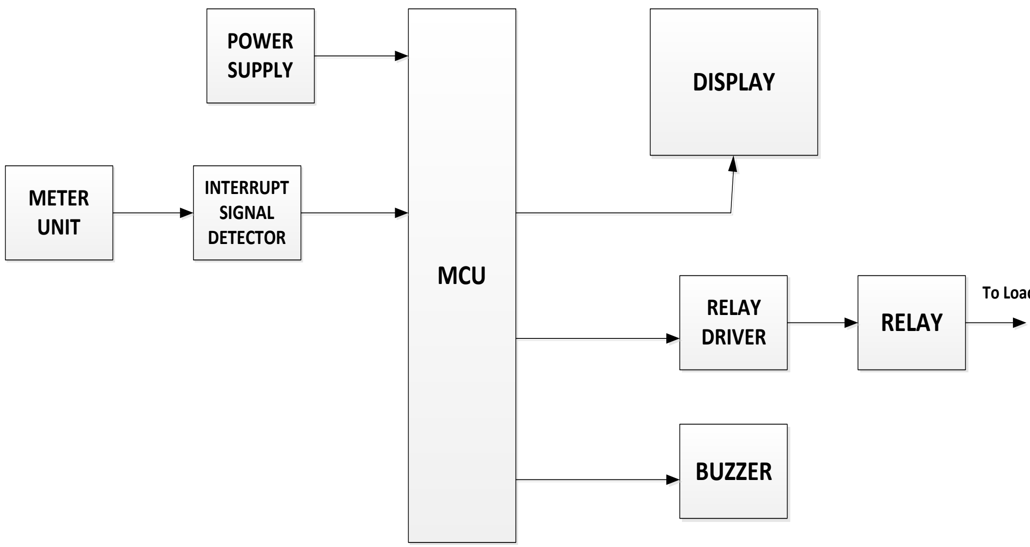

Fig: 2. Block Diagram of BACS module

Block Description:

Meter Unit: Digital energy meter is used for this.As soon as one unit of energy is spent, the meter unit sends an interrupt signal to the microcontroller via the interrupt signal detector.

Interrupt signal Detector: This unit actually recieves the signal from the meter unit, detects it and finally forwards it to microcontroller.

Microcontroller: When the microcontroller unit recieves the interrupt signal from the detector, it increases the meter reading count by one and resets the pulses count.

Display Unit: A LCD is used for the display unit.

Relay Driver: It interface the relay with the microcontroller.

Relay: It is the interface between the prepaid system and the main supply. When the balance amount decreases to a critical value, the relay is indicated by the driver to snap the main supply.

4. Power Theft Detection Algorithms

The following algorithms has been deisghn and developed in module for BACS in C programming.

4.1 Detecting Unmetered Consumption

The unmeterd consumption detection method comprises installing a utility AMI with a tree of meters so that a meter closer to the root measures the power consumed by the loads beow it. By placing a 'Sum Meter' at a node of the residential power grid and additional meters below it that measures the consumption of branches or specific loads in the tree below, the system performs a comparison between the sum meter and the brach/ load meters sum.If the sum meter measurement is greater than the sum of the down stream meters measurements, it is a strong indication of an illegal load that consumes power. Sum meter 2 measures consumption that is greater than the sum of the two branch meters. We can see that branch meter detects the excess consumption of illegal load 2 by comparing its measurements of the three load meters shown below in fig 3.diagram.

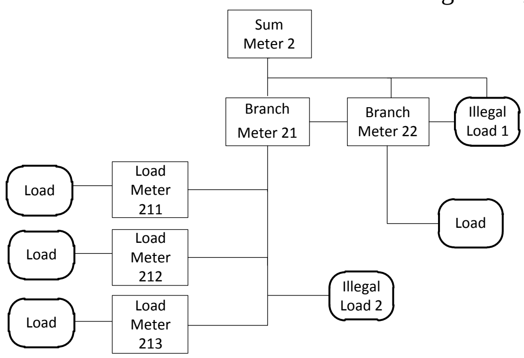

Fig: 3. Power theft detection- Unmetered consumption

4.2 Detecting Excessive Load

The second theft detection method is used in case it is not possible to ins tall a meter for each load (e.g., lighting grid). In this case the thief can hook onto the utility grid and not be detected by the first method. To resolve this case, we use the inherent capability of smarts to indicate power level in excess of preprogrammed value.

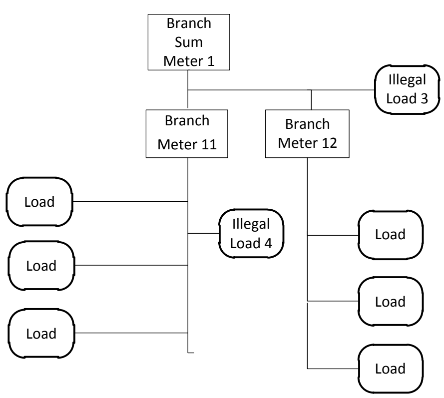

Fig: 4. Power theft detection- excessive power

In the above fig.4. illegal load 3 is detected by branch sum meter 1, however, illegal load 4 goes undetected. To detect illegal load 4 we program the maximum allowed consumption of the three loads under Branch Meter11. Once illegal load 4 is active, branch Meter 11 measures the excess power and indicates problem.

Using both methods for detecting power theft, an alert is sent to the utility that can then check the specific section of the grid and search for the reason for the alarm.

4.3 Profile to Identify Theft Detection

Profile becomes more and more accurate over time as additional data is accumulated when a meter's consumption varies above or below the profile; an "out of profile" notification appears. The profile tool is very useful in situations when;

- Consumption is lower than usual for a long time. This may indicate that the consumer is stealing energy.
- Consumption is higher than usual for a long time. This may indicate that somebody is stealing from the consumer.

4.4 Unpaid Bills

The phenomenon of unpaid bills is another major reason for power utilities' revenue loss. While current prepaid billing meters use some kind of physical token (coin, scratch, card etc.), smart meters offers a "virtualization" capability so that users can " purchase electricity" without using a tangible object.

Algorithm

The following steps have been framed in the proposed algorithm.

Level 0: Initialization of user and service provider.
Level 1: Integrate home appliances of building/user.
Level 2: Integrate with distributed resources, generation and renewable energy resources.
Level 3: Demand and rate of energy required.
Level4: Up gradation of demand with timely information provided to consumer/user.
Level 5: Detect, respond and address emerging problems on the system before they affect the service.
Level 6: Centralized the diagnostics and feedback to user.

To achieve the above levels an intelligent demand management through software is required tomeet the requirement of smart grid.

In Delhi Tata Power known as NDPL is one of the service provider has joined hands with IBM to become member of global Intelligent Utility Network to develop a common standards for smart grid.

The below figure represents the transmission system model simulated in MATLAB for no illegal load/tapping

The simulation results no difference in the voltage when no illegal load/tapping is done on the transmission line. The waveform is shown below.

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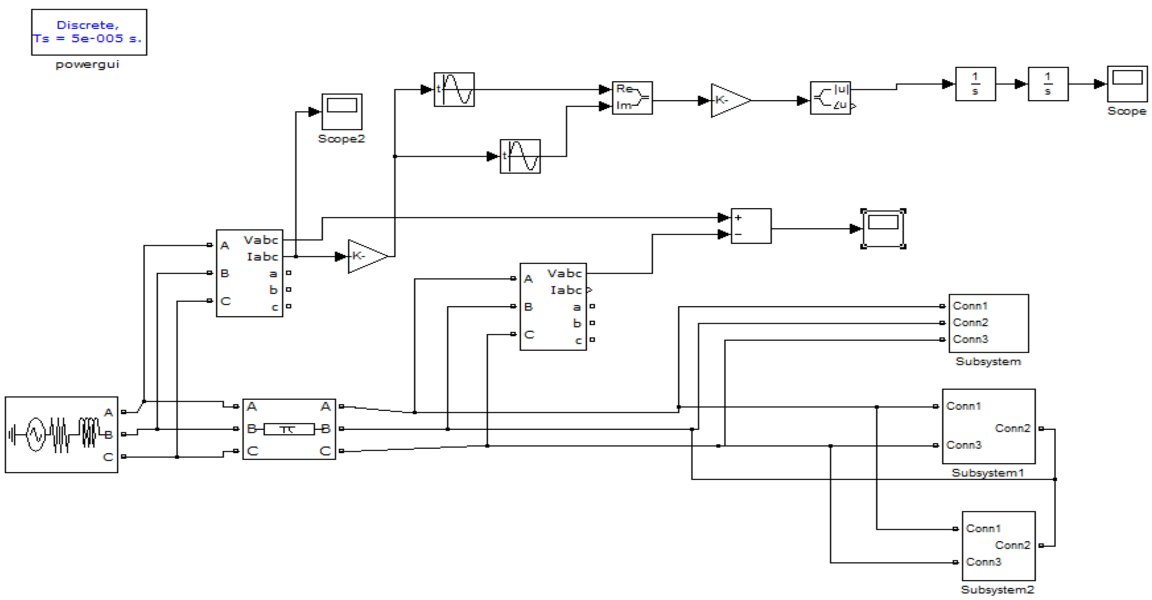

Fig: 5. Simulation model without illegal load

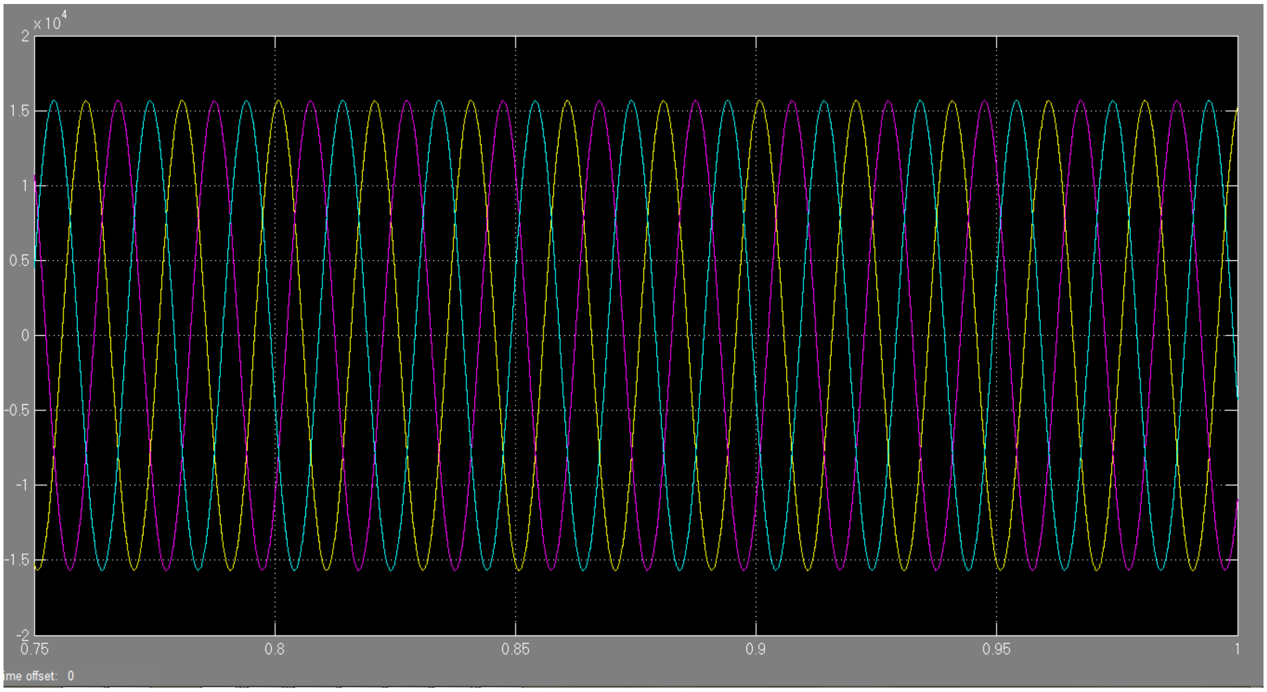

Fig: 6. Simulation model without illegal load

It shows that the voltage levels (in the order of 10 e 4) are almost equal in case when only transmission losses are occurring and no illegal tapping is made on the line.

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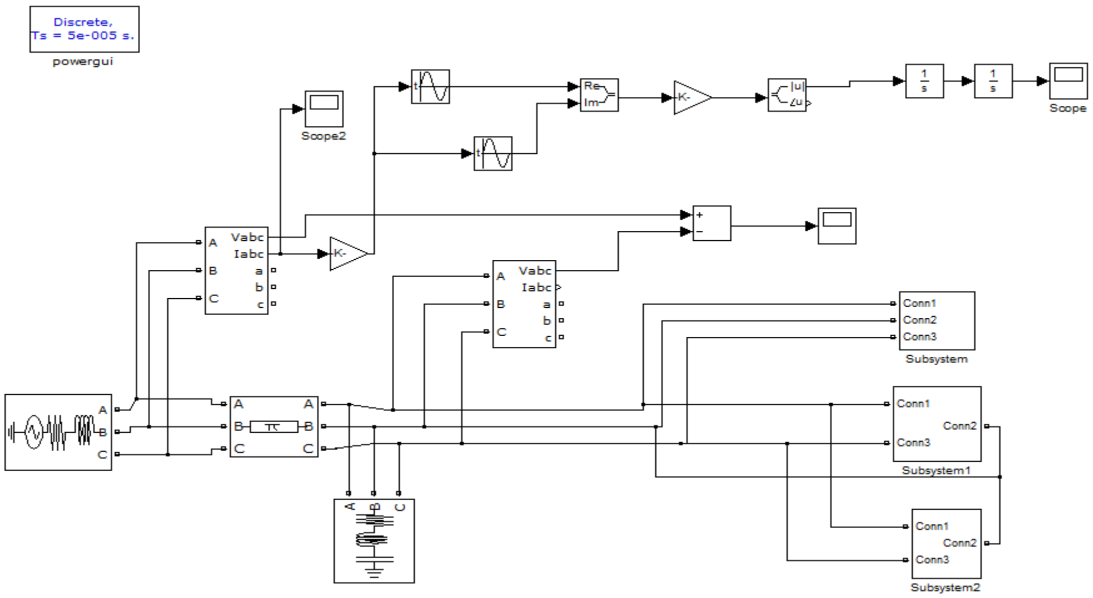

Fig: 7. Simulation model with illegal load

5. Conclusions

The controller takes advantage of new technologies such as smart metering and home automation together with services such as RTP tariff to minimize the cost of running smart appliances. BACS has been used for avoiding the illegal theft, hooked the transmission lines and minimization of energy cost for end users. It is concluded that the end user has a provision to select the service provider depending upon the availability of the power at low cost.

References

[1] European Regulators Group for Electricity & Gas, "Final Guidelines of Good Practice on Regulatory Aspects of Smart Metering for Electricity and Gas", Feb. 2011. http://www.energy-regulators.eu-/portal/page/portal/EER_HOME/EER_CONSULT/CLOSED%20PUBLIC%20CONSULTATIONS/CUSTOMERS/Smart%20metering/CD/E10-RMF-29-05_GGP_SM_8-Feb-2011.pdf

[2] EU WG3 on Demand and Metering from ETP Smart Grids, "Energy Retailers' Perspective on Deployment of Smart Grids in Europe", 2010. http://www.smartgridsflanders.be/sites/default/files/nieuws/-ETPSmartGrids_EnergyRetailers_ White Paper_Final_v1.0.pdf

[3] C. W. Gellings, "The Smart Grid: Enabling Energy Efficiency and Demand Response", the Fairmont Press, 2009, p. 148

[4] EU Smart-A Report, "Smart Domestic Appliances Supporting the System Integration", Nov. 2009, www.smart-a.org/SmartA_Project_Final_ Brochure_ 2009.pdf

[5] K. Kok, S. Karnouskos, J. Ringelstein, A. Dimeas, A. Weidlich, C. Warmer, S. Drenkard, N. Hatziargyriou, V. Lioliou, "Field- Testing Smart Houses for a Smart Grid", Proceedings of the 21st International Conference on Electricity Distribution CIRED, Frankfurt, 2011, http://www.smarthouse-smartgrid.eu/fileadmin/templateSHS- G/docs/publications/CIRED_FieldTesting.pdf

[6] P. Finn, C. Fitzpatrick, D. Connolly, M. Leahy, L. Relihan, "Facilitation of renewable electricity using price based appliance control in Ireland's electricity market", Energy, 36 (5), May 2011, http://www.sciencedirect.com/science/article/pii/S0360544211001162

[7] A.-H. Mohsenian-Rad, A. Leon-Garcia, "Optimal Residential Load Control with Price Prediction in Real-Time Electricity Pricing Environments," Smart Grid, IEEE Transactions on, 1(2),

pp.120133, Sept. 2010, http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=5540263&isnumber=5552162

[8] EU Smart-A D2.3 Report, Synergy Potential of Smart Appliances, Nov. 2008, http://www.smart-a.org/WP2_D_2_3_Synergy_P-otential_of_Smart_Appliances.pdf

[9] Bliek, F.; Albert van den Noort, Roosien B., Kamphuis R., Johan de Wit, Power Matching City, a living lab smart grid demonstration, Oct. 2010, http://static.progressivemediagroup.com/

[10] Real-time pricing for residential customers, Ameren Illinois Power Co., Mar. 2010, https://www2.ameren.com/RetailE-nergy/realtimeprices.aspx

[11] Iman Mansouri, Marcus Newborough, Douglas Probert, "Energy consumption in UK households: Impact of domestic electrical appliances", Applied Energy, 54(3), Domestic Demand- Side Management, July 1996, Pages 211-285, ISSN 0306-26190306-261, http://www.sciencedirect .com / science /article/pii/030626 1996000013

[12] I. Richardson, M. Thomson, D. Infield, "A high-resolution domestic building occupancy model for energy demand simulations. Energy and Buildings", 40 (8), pp.1560-1566, 2008, http://hdl.handle.net/2134/3112

[13] S. Nisor, J. Wu, M. Sooriyabandara, "Cost optimization of smart appliances", IEEE, PES, conference 2011