ESM®'2009
The 2009 European Simulation and Modelling Conference
Modelling and Simulation ‘2009

October 26-28, 2009
Leicester, United Kingdom
MODELLING AND SIMULATION 2009

THE EUROPEAN SIMULATION

AND

MODELLING CONFERENCE

2009

ESM® '2009

EDITED BY

Marwan Al-Akaidi

OCTOBER 26-28, 2009

LEICESTER, UNITED KINGDOM

A Publication of EUROSIIS-ETI
The European Simulation and Modelling Conference 2009

LEICESTER, UNITED KINGDOM

OCTOBER 26-28, 2009

Organised by
ETI- The European Technology Institute

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Preface

Dear participants

It is my pleasure to welcome you to the 2009 European Simulation and Modelling Conference (ESM® 2009), the international European conference on the state of the art of modelling and simulation, which this year is being held at the Holiday Inn, in the city of Leicester, United Kingdom in cooperation with the de Montfort University.

Even though we live in harsh economic times with declining numbers in participation, this year’s event still has managed to attract some 65 high quality papers from 21 different countries spanning 4 continents, out of 86 papers submitted.

Further to the selected scientific presentations, EUROSIS and I are grateful to Professor Adrian Hopgood of de Montfort University for giving this year’s keynote speech entitled: “Hybrid Systems, the Future of Artificial Intelligence” and to our invited speakers; Ken Kahn from Oxford University with his talk on “The Modelling4All Project: A web-based modelling tool embedded in Web 2.0” and Simon Scarie from Warwick University with his talk on “Putting a Heart into a Box: GPGPU simulation of a Cardiac Model on the XBox 360”.

I wish to thank all those, who have contributed their time and effort in organizing this meeting. This goes out to the International Program Committee members who took care of the reviewing process. They have done a great job in arranging a strong technical program, which covers a variety of speciality areas covering present day methodological simulation research.

Recognition for this conference must go also to Philippe Geril, the EUROSIS coordinator, who was the main force responsible for the organisation of the meeting.

Furthermore, I would like to thank the Creative Technology Studios at de Montfort University, for accepting to have the conference participants visit the BBC research studios at the aforementioned site.

Finally, I would like to wish you a pleasant stay in Leicester and a successful conference meeting

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PARALLELISM OF CONTROL PROCESS OF ELECTRIC ENERGY CONSUMPTION IN A DISTRIBUTED POWER GRID SYSTEM

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KEYWORDS
Power modes model, DMS, smart grids.

ABSTRACT

The abilities of simulation applications give the powerful tools for the scientists and engineers. It is obvious that before implementation of some idea you ought to test it in simulation environment. In the article authors present the idea of new model of electrical energy consumer powering – the power modes model. The model is implemented in Matlab® environment and it has been tested for the real parameters and data of one Polish power supplier of 2007 rear spectrum. The proposed methods of data metering and acquisitions allows for the parallelity of control process of electric energy consumption in a distributed environment of a power grid system, or a part of that system.

INTRODUCTION

In the most, a power grid system could be presented as a hierarchical structure (fig. 1). Where the node on the top is a supplier, which distribute the power to the lower level of hierarchy. The nodes of that level represent e.g. the departments of the supplier, the power stations an substations, the sub areas of the whole geographical area where the supplier distribute the energy. At the lowest level of the hierarchy are the energy consumers. More:

- one node of energy consumer could represent an internal hierarchy of energy distribution grid, with similar structure to fig. 1, where the main node represents the consumer and the sub nodes are his production objects and the electrical equipments on the lowest level.
- and on the other side the whole structure of the supplier (fig. 1) could be an subsystem of the global power system, and then the main node of the hierarchy (fig. 1) become an node on the lowest level of the global hierarchy – the transparency of mark line-node functionality.

It is important that on each node of each level of the hierarchy the true is (Gladys and Malta 1999):

\[ p^S_{\text{level 0}} = f(x, \Sigma p^D_{\text{level -1}}) \]  \hspace{1cm} (1)

The power supply \( p^S \) ability (1) of a node on level 0 is a function \( f \) of sub nodes power demand summary and is also determinate by a technical condition \( x \) of power grid infrastructure. On the other hand the power demand \( p^D \) of one node of level -1 depends of the power supply of its supplier and its neighbours – the others nodes of the level -1. So the main node is interest to order/generate such enough power such his sub nodes demand. On the other side the sub nodes of the node couldn’t demand more power that the node is able to supply. In this situation it is necessary to introduce some power supply limitation. The sub nodes ought to calculate the risk of the lack of electricity situations.

![Figure 1: The hierarchical structure of electric energy distribution process – power system. The marked line-nodes presents the transparency of node functions – a node of the lowest lever - a consumer - becomes the supplier in its internal distribution grid.](image)

The cost of lack of electricity (Gabrysiak 2004; Paska 2005) and the newest blackouts history (Malko 2006) necessitate the need for change and a new better solutions developing. The power modes model - presented in the next chapter – is helpful for the solution researching.

REMODELING OF THE ELECTRIC ENERGY CONSUMPTION STRUCTURE

The researches (Bober 2008a) of the households’ consumers’ preferences and decisions of energy consumption limitation in the situations of power deficit allows for introduce new model of electricity consumer powering “the power modes model” (Bober 2008b), where “a part” of consumed energy \( E \) is associated with a quality parameter \( q \):

\[ TR = g(E, q) \]  \hspace{1cm} (2)
The quality parameter q describes some individual principles of each power mode TR and the conditions (eq. energy price, hours of access, degree of reliability, etc.) of energy consumption by the stuff powered in the power mode. So, the described households could be powered by three power modes: protected power mode TRp, standard power mode TRs and economical power mode TRE. The energy consumed by the households in the new model (2) will be the sum of the modes:

\[ E = E_{TRp} + E_{TRs} + E_{TRE} \]  

(3)

The model of power modes significantly simplifies the process of energy consumption control. There is no necessity to detail control of each node of each level of the power system grid (see, fig. 1). Each node of the grid could process the control itself and the same it could manages the energy consumption structure in this part of hierarchy where it is the main node. The idea of distributed control of energy consumption structure in a hierarchy of a power grid system is presented at fig. 2.

![Figures 2: The structure of a power system hierarchy with the power modes model implementation (Bober 2008c).](image)

Although the presented idea looks promising, but there is a lot of conditions to be fulfilled before the power modes model will be introduced into practice. Some aspects of the solution implementation were described in (Bober and Kapron 2009). In this paper, we concentrate on simulations of possibilities of the power modes model in the implemented in the Matlab environment.

**SIMULATIONS OF THE POWER MODES MODEL POSSIBILITIES**

We have implemented one of the polish electricity distributor structures (see, fig. 3). The distributor (with code name SD2) has divided his administrative area into seven divisions’ sub-areas, with symbolic name ZEs. He distributes energy to many types of consumers, but we divide them into two groups: households, which buy the energy in tariff “G” and the other which do not belongs to tariff “G”. For group of consumers who ∈G we have linked the standard power mode TRs.

![Figures 3: The structure of controlled object (Bober 2008a).](image)

For this structure of the controlled object we have received the real data of day-hour power demand of 2007 year from the distributor. We decide that the distributor hypothetical day-hour power supply for this year will be his data of day-hour demand prognoses. The received data we have imputed into the Matlab® simulation environment as 24hours x 365days matrixes and we minus them to see the research area (see fig. 4). The problem to be resolved is the power demand decreasing to reduce the dark areas on deficit matrix.

![Figures 4: The power “deficit” matrix. The dark areas points the hours where the customers’ power demand overloads the distributor’s demand prognosis.](image)

We will research how the knowledge about the power modes’ structure of the households’ customers will help us to resolve the problem. We try to find out how the volume of power mode TRE of energy consumption returned to the power system will help us in the power “deficit” compensation? It is interest, because the “deficit” is generated by the whole distributors’ clients, not only by the households. If by the power modes model we control the energy consumption of households and in this way we significantly change the power demand of the whole distributors’ consumers – it will be a very good result. And as it is presented in the next subchapter this target has been achieved.

We define the indicators of the object state measurement:

- TR – id’s of ZE nodes where the TR model was implemented;
- \( \Sigma u \in G \) – numbers of households where the TR model is implemented;
- avPr – the average power demanded by households powered in the TR model;
- $E(Pr, T)$ – the total energy consumed by households powered in the TR model in the period of the whole year;
- $q$ – numbers of situations where the supplied power do not balance the demand of the consumers, in this situation there is necessity to buy some more energy/power from the generators;
- $avPn$ – the average power “deficit”;
- $E(Pn, q)$ – the total energy “deficit”.

The initial object state is presented at fig. 5.

![Initial state of the object](image)

Figures 5: The state of the object before power modes model implementing, the whole nodes/consumers consume the energy without restrictions. The picks of the graph corresponds with dark areas of fig. 4.

In the consequence of series simulations of the power modes control of the object hierarchy (see, fig 5) we received the state of the object as is presented at fig. 6.

![Simulation results](image)

Figures 8: The final state of the object.

As you can see, the indicator $E(Pn, q)$ of the whole year energy consumed over the prognosis demand decreases from 32.06 GWh at the state before any control simulation (see, fig. 7), to less than 1 GWh after the restriction of TRe mode simulated on selected division-nodes. The other state indicators also look better.

The details of the experiment are described in (Bober 2008a).

**CONCLUSIONS**

There is common interest of the power systems improvement (Billewicz 2007, Kapron 2007, Malko 2009, Sroczan 2007) especially in the aspects of the system reliability and electricity sufficiency. The presented results of simulation of the power modes model implementation in the condition of real distributor shows that the model is helpful for the electric energy control. By distribution of decision-making process of control into dispersed “smart” nodes, the process of control could be parallelized into numerous independent processes. In consequence, that will increase the object control process performance.

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