THEORETICAL & TECHNICAL ANALYSIS of E.M.I.R. System

- An innovative search Web Method-Machine to analyse and rank Energy Customers -

Energy Management and Intelligent Reporting

Patented Algorithm, System and Method

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Technical Abstract: Energy Information Systems (EIS), which monitor and organize energy consumption and related trend data over the Internet, have been evolving over the past decade and can be considered as a part of a specialized DSS. In this proposition, a modern and innovative web-based intelligent Energy Information System is described, for an optimal energy sources management and minimisation-control of home and factory-based energy consumption. The method is used for effective Energy Knowledge management in the newly opened Greek Energy Market. The system is designed and developed to analyze, optimize and manipulate energy data and energy practices, through a web portal. The energy data are accessed from ADSL databases and hypercubic grid structures or from internet-based heterogeneous sources, by using web services. The system adopts a powerful combination of current software frameworks based on the J2EE specification. Dynamic Java Server Pages and XML-XSL technologies provide effective energy data interoperability. The core intelligence of the on-line web system was developed using Matlab programming and the powerful MATLAB Web Server, connected in a clustered n-tier network. The system, which is currently on-line, was tested with real energy data and statistical graphical outputs were produced for result analysis and web-based reasoning demonstration.

- INTRODUCTION

A modern Decision Support System (DSS) can be defined as computer-based tool, or a more complex Information System structure, used to support and generate decision-making and problem solving. Although this definition applies very well to decision-making in many purely technical areas, it falls short of reflecting one extremely important aspect of the decision-making process in energy resource systems: the role of human factor. Energy Information Systems (EIS), which monitor and organize building energy consumption and related trend data over the Internet, have been evolving over the past decade and can be considered as a part of a specialized DSS.

The above concept performs key energy management functions such as organizing energy use data, identifying energy consumption anomalies, managing energy costs, and automating demand response strategies and focused customer profiling. In this proposal, a modern and innovative web-based intelligent Energy Information System, is briefly described, for an optimal energy sources management and minimisation-control of home and factory-based energy consumption. **As back-end knowledge management procedure, a powerful clustered hypercubic isomorphic topology is used for the first time, with the additional use of traditional database technology.**

As stated before, Energy Information Systems (EIS) refer to software, data acquisition hardware, and communication protocols administered by a single company, a partnership, or a collective to provide energy information to commercial building energy managers and electric utilities. In a typical EIS architecture the EIS server hardware and software located at the EIS service provider's physical site record interval data via the Internet. The EIS receives these data from signals dispatched by meters installed in a customer's building, or directly communicates with meters. The EIS users can access the server with a password, and access the archived energy data either in real-time or in hourly, or daily updates from anywhere via a web browser.
This web-based functionality can be enriched with many add-on services in order to create a complete Information System that will act as the basic "ad-hoc broker" between free customers and energy providers, in the future opened Energy market

- TECHNICAL BACKGROUND

Two different environments were involved in the development of the web-based energy IS interface (Fig.1): HyperText Markup Language (HTML) standards with the addition of some Java Server Pages (JSP) under J2EE specifications, and advanced Matlab code, which permits the dynamic mathematical development of the evaluation model described above. The Matlab web server toolbox was effectively used by combining Java language, to produce dynamic Matlab Server Pages (MSP).
Matlab Server Pages, permit the direct execution of Matlab functions directly from the JSP source code, by using specific tags, identical to the JSP Tags.

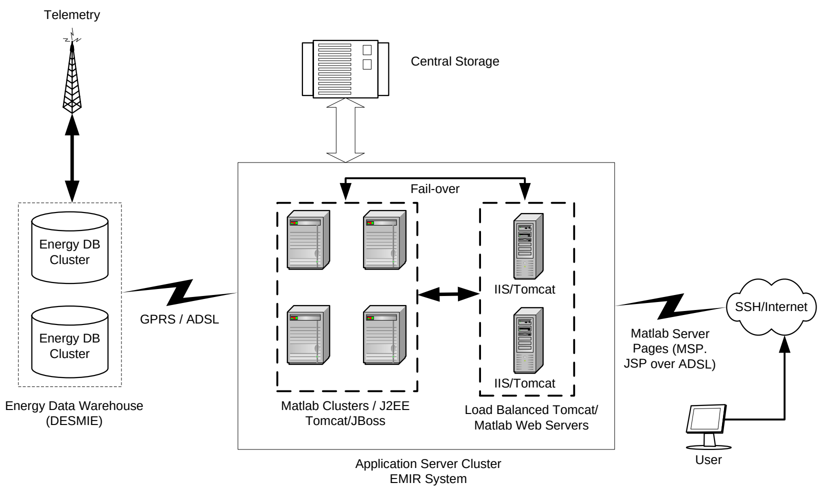


Fig.1 Technical Background

The communication was preserved, through internal Java objects, which are incorporated in the Apache Tomcat server. Remote Matlab Method Invocation (RMMI) was achieved by this way and by combining CGI-based POST methods to the Matlab Web Server; a very powerful Matlab Application Server (MAS) was produced. The developed system allowed the creation of compact programs, called Matlab Beans (MB) and the execution of those beans (interconnected m-files) under HTML and JSP pages, located inside the Apache Tomcat Server.

The application, using web GUI facilities sends data, through java calls and post methods to the matlab beans and vice versa. Energy log data received from the ADSL/MySQL database through Open Data Base Connectivity (ODBC), are processed inside the core matlab engine located on a clustered 2nd tier application server. The results are returned and presented on the Apache Tomcat web browser window at the client computer (evaluation statistical graphs and tables). With this configuration the client computer only needs to run the web Apache browser to access to the HTML and JSP document, since the matlab server and the web server run on different remote server stations.

Therefore the process is transparent to the user who does not need to know matlab scripting to generate and have access to the available energy logs and the statistical results. Thus, it can be said that the overall produced evaluation tool is based on the classical n-tier philosophy and uses a back-end database (MySQL), a central application server (Matlab server) and a front-end web container (Apache Tomcat). Concerning the front 'client tier', it can be accessed through several client types, such as standard web browser exchanging content in standardized ways.
The front-tier is based on the Apache-Tomcat web server with the addition of the MS Internet Information Server (IIS). Java Server Pages and ASP scripts, through dynamic forms, data fields and drop-down menus, gather user input and send the results to Matlab server, using RMMI.

- SOME BASIC ALGORITHMIC BACKGROUND (Patented)

This patented method **uses a different version of a clustering algorithm and a hypercubic grid in order to cluster energy pages and energy measurements in a distributed way**, not only by an energy count analysis but using a relevance distance calculation method from an optimal value, which is called **centroid**. The probable energy pages or measurements that will be used to measure distances, form a surrounding grid in a multidimensional space. For each possible energy measurement that is going to be assessed, we choose and construct an attribute vector describing some attributes that we have to take into account in order to decide if the page is relevant with a specific query. After the formation of the attribute vector, we assign weights (*wi*) to the attributes to distinguish the most important and we choose possible optimal values (optimal energy pages) that are described by various optimal attribute vectors. These optimal values are the centroids. After the formation of the centroids, we start to measure metric distances (*calculation of p-norm*) from each centroid and all the possible pages that we have gathered (energy *crawlers*) through internet (*identical to indexer*). This can be achieved by a hypercubic parallel network with moving agents, where the centroids are the vertices of a multidimensional hypercube. With this method, we create relevance tables for each centroid and the total system is called **Hypercubic Knowledge Grid (HNG)**. The algorithm generates the knowledge grid and by using search algorithms we can access the relevance tables and rank output data according to a specific query. The above algorithm will be also used for Data bases analysis and SQL query optimization. The above mentioned method, helps us a lot in order to **assign different optimal values to the various vertices of the hypercube and take these values as optimal centroid solutions for a multidimensional data mining application** that has as a result, ranked sets of information retrieval queries. In order to perform a distributed data mining and clustering algorithm inside a hypercubic network, we need to ensure that parallel communications between vertices follow some structured rules and that ranked output data will be available. A hypercube with dimension **N**, (GH (N)) is a network grid having 2^N binary vertices which are mapped on a binary space. The distributed agent hypercubic scheme that will be used in order compute the normed energy distance between an optimal centroid solution and a multidimensional energy vertex that represents a possible query to the energy search engine, will follow the above structure and a method of the probabilistic routing algorithm of Les Valiant. We will define a probabilistic random vertex permutation Π, using a uniform distribution. In each vertex there exists an agent that will measure the n-th dimensional topological norm between the vertex and the optimal centroid. The above mathematical procedure is being used in order to calculate all the topological distances between centroids and relevant vertices, by using hypercubic routing and distributed agents. The results of the calculations form a uniform multidimensional table which is called **Energy Relevance Table**. This table represents the degree of relevance of each vertex from the surrounding grid comparing with a unique optimal centroid (hypercubic node), **which can express an optimal solution, an optimal value or a suggested value to a problem or an Energy query**.

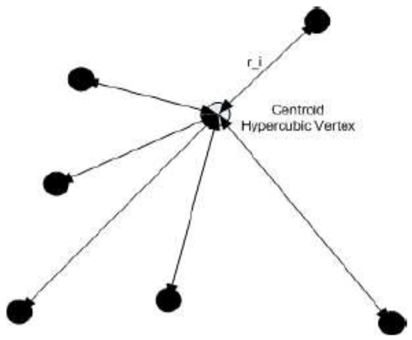


Fig. 9. Centroid vertex with surrounding grid

$$r_i(c_i, x_1) = \|c_i, x_1\|_p \quad (4)$$

$$r_i(c_i, x_2) = \|c_i, x_2\|_p \quad (5)$$

$$r_i(c_i, x_3) = \|c_i, x_3\|_p \quad (6)$$

$$r_i(c_i, x_4) = \|c_i, x_4\|_p \quad (7)$$

$$r_i(c_i, x_5) = \|c_i, x_5\|_p \quad (8)$$

$$r_i(c_i, x_6) = \|c_i, x_6\|_p \quad (9)$$

$$r_i(c_i, x_1) = \|c_i, x_1\|_p \Rightarrow [\sum_{(j=1)}^{(n=4)} (c_i, (x_1)_{j1})^p]^{\frac{1}{p}}$$

with $p \equiv N$ where *N: Hypercubic dimension*

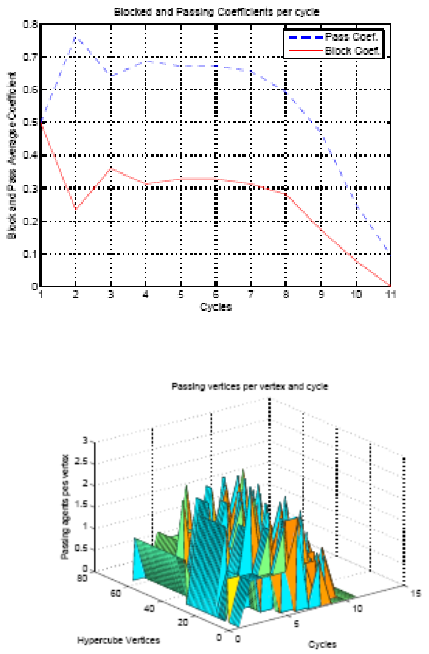


Fig. 10. 6th Dimensional hypercubic knowledge Grid Simulation

Often the class load is described in a table of percentages. The percentage of power used between midnight and 12:15, the percentage between 12:15 and 12:30, etc. Multiplying your total use by the percentages will result in a load profile for any facility. The EIS will then chart your actual use and compare it with the class load rendered to a common scale. We recommend a 15 minute profile giving 96 intervals per day. An hourly profile does not show enough detail and five minutes shows unnecessary detail for most people. While we are talking about electric loads, class loads also apply to gas, steam, fuel oil, and water. With the electricity market liberalisation, the electricity distribution business looks for better market strategies, based on adequate information upon the consumption patterns of the electricity customers. A fair insight on the customers' behaviour allows the distribution utilities to better address the operation of the distribution infrastructure and its future enhancement, not to mention the ability to design specific tariff options for the various classes of customers in tune with real operation costs. The customer characterisation can also be used for an integrated system planning, by considering the load management alternatives that can be performed to meet the system peak demand in a very effective way. For the load management, the effectiveness of each alternative strategy has to be evaluated by load research to identify the power consumption of each customer class. Information on the customers consumption patterns can be gathered through the use of the daily load curve, which has been extensively used for years, but the identification of the contribution of different classes of customers in the presence of an aggregation of loads belonging to different classes in the new open market scenario has yet to be refined.

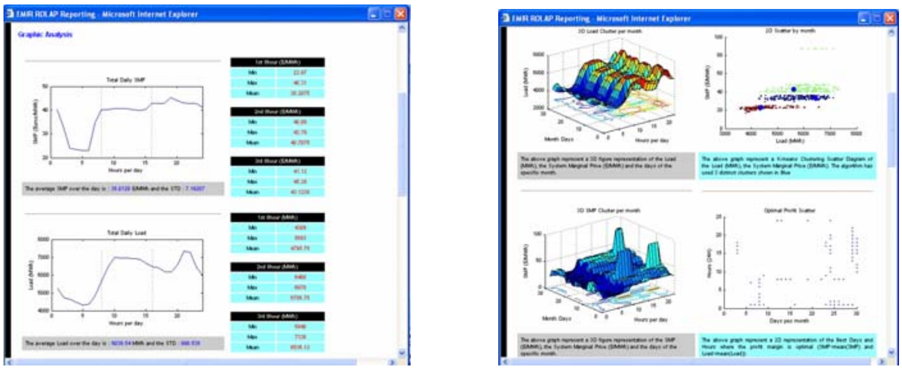


Fig.2 - Already obtained web Reports from on-line portal

Efforts to put some order in the tools to analyse the load diagrams have been produced for quite some years. We can mention the systematic approach used in UK, according to which several subclasses are defined within each major class of customers, for each of them a different tariff being assigned. This approach is backed by .some extensive field measurement campaigns that span over two decades. A rather similar approach has been implemented in Taipei, together with a comprehensive survey system.

The load diagram associated to each average customer is the **load profile** of the corresponding customer class. The economical aspects related to the possible tariff diversification for the various customer classes are investigated by using the load profiles for providing suggestions on possible market strategies seen from the point of view of the electricity utility. Traditionally, most utility companies classified their customers according to a few electrical parameters and some commercial codes. In the liberalised electricity market, there is a strong need for classifying the electricity customers on the basis of indicators able to characterise their true electrical behaviour.

So it can be said that traditionally most utility companies classified their customers according to a few electrical parameters and some commercial codes. In the liberalised electricity market, there is a strong need for classifying the electricity customers on the basis of indicators able to characterise their true electrical behaviour.

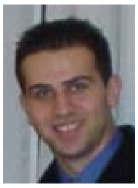
A possible scenario of the interactions among customer and supplier could be the following:

- the customer comes to the supplier, states its type of activity and is assigned/free to choose a starting tariff; the supplier monitors the customer for a specified period (e.g., 3-6 months) and establishes a reference pattern for its load diagram;
- the supplier fits the reference pattern to one of the customer classes already defined and identifies the appropriate tariff;

Hence, the supplier performs a continuous monitoring of the daily load curves of all customers, periodically updates the reference patterns and the composition of the customer classes by automatic clustering and adjusts the tariffs applied to each customer class such as to maximise its foreseeable profits in the respect of possible price caps.

- BULLETED CONCLUSIONS USED FOR FURTHER DEVELOPMENT

- Better on-line management of total energy usage
- Get details about the amount and timing of your energy use, so you can adjust accordingly and save money
- Advanced meter data can be stored and used to compare costs between competing utilities and to arrange for bulk-rate purchasing
- Identify and implement operational strategies to control load factor
- Understand and improve consumption Clustering and Statistical patterns
- Measure and verify anticipated energy savings
- Secure a better variable **cross-correlated** pricing from the retail energy markets
- Highlight anomalies in electric consumption
- Identify and assess on a real time basis the fiscal impact of energy consumption
- Advanced notification via email of a higher peak demand being set
- Energy suppliers can acquire faster data enabling proactive energy management
- They can immediately turn this data into valuable knowledge for them and their customers and offer improved services to their commercial and industrial clients
- Track in real time usage and load. Compare that to what has been scheduled and initiate any localized demand reduction during high market prices
- Manage peaks efficiently to avoid spot market energy purchases
- Reduce and limit the risk out of the energy business.
- Reduce the risks in a volatile energy market.



VASSILIS NIKOLOPOULOS was born in 1975 in Athens and graduated from the French School "Lycee Leonin". He graduated as Valedictorian of 3 Engineering departments (Civil, Electrical, Mechanical) from the Polytechnic School of Dundee University (Scotland), with a 1st class 4year Scottish honours in Electrical Engineering, having gained 2 class medals in maths, British Association scholarship, Duff and Garland Prize and the National IEE prize 2000. He also obtained a 1st class MSc and Diploma in Control from Imperial College, certificates in Management from LSE and after preparing the French classe preparatoire (Maths Sup-Spe) and succeeding in entrance exams (concours de l'X) he entered Ecole Polytechnique of Paris (promotion X99 de la 7eme Compangie), from where he obtained the "Majeures d'Ingenieur de l' Ecole Polytechnique" in applied mathematics and informatics, with mention “Honorable”. Currently he is a PhD candidate at Multimedia Technology Laboratory of NTUA. He has also worked for big multinational companies as an IT Consultant, Innovative Business Development Engineer and Project manager in big EU commercial and R&D projects. He is a member of the Technical Chamber of Greece, IEE, BCS, InstMC, SEE, French Mathematical Society, Mensa France, HI IQ Soc, IFAC, IEEE, SEPE, founding member of AFREL (Association Franco-Hellenique), member of the Greek-French Chamber of Commerce and holds two official patents. He is the founder of INTELEN R&D Group (http://www.intelen.gr) a strong research team that will lead and create advanced Energy Web Services for the Greek and European sector.

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