Electricity market simulator: adaptive for studies on different market behavior

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Abstract: A web-based electricity market simulator is designed and developed on .NET Framework, which simulates different operating conditions of power system. It employs ASP .NET 2.0 in user interface development, and uses C# as programming language and SQL Server 2000 as background database, which makes it possible to flexibly simulate and visually display different behaviors of the day-ahead and real-time electricity markets with pool-model and to calculate the market clearing prices and capacities. The advanced features of the B/S structure embedded in .NET Framework is adopted to realize the distributed web services based on open standards and heterogeneous platforms, which is suitable for information exchange among various market participants covering a wide geographical area, including market operators, generation companies and customers. A case study shows that, the simulator has good expandability and maintainability.

Key words: electricity market; simulator; .Net Framework; market clearing price
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0 Introduction

Over the past two decades, many countries around the world have restructured or are restructuring their power industries by making energy markets competitive, unbundling electricity services and opening access to electrical networks. This reform process resulting in a shift from tight regulation in vertically integrated monopolies to light regulation of functionally separated operational units is an ever challenging task to the power industry. As stated in the July 2001 issue of the Wired magazine, the current power infrastructure is as incompatible with the future as horse trails were to automobiles, However, with concerted effort of public/private coordination, the present power delivery system and market structure can be enhanced and augmented to meet the challenges it faces.

Electrical energy is a unique commodity in the sense that it needs to match supply with demand instantaneously and yet there is no cost-effective means of storage support. Therefore, ancillary services have to be provided in the energy market to ensure stable and reliable power systems be maintained. The recent blackouts in Europe and the United States remind us that stable supply of electricity is indeed essential to sustain well-being in every metropolitan city. A prime concern is to ensure continuous supply of electricity from the point of generation to the end-point of use via sophisticated power delivery function which is changing and growing more complex with the exciting requirements of the digital economy, the onset of competitive power markets, the implementation of modern and self-generation, and the saturation of existing transmission and distribution capacity. Without appropriate investment and careful policy setting, the vulnerabilities already present in today's power system will continue to degrade[1].

Simply stated, today's electricity infrastructure is inadequate to meet rising consumer needs and expectations. Specifying and creating new electricity market infrastructure governing the operation of the energy markets is a major challenge since these markets have exhibited wide variation in form and operational characteristics. Computer simulation has been recognized as a useful approach for examining the impact and behavior of different market structures. In recent years, sophisticated market simulation tools have become made available to the industry. Although these tools can provide many

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useful insights for the power system operators, they are limited in their ability to adequately analyze the intricate interactions among all the market participants prevalent in the deregulated power markets. Driven by these observations, this paper presents a simulator by taking advantages of the Internet for simulating all the trading processes in the power pool. The simulator is developed based on .Net platform, a distributed computing environment with excellent ability of scalability, high efficiency and performance for facilitating market participants to communicate easily with each others through graphical interface[2-4].

1 Needs for such type of simulator

Since electricity market involves participants located in wide geographically separated regions, its transactions right from placing bid from generators up to the final settlement stage have been handled as a form of E - Commerce with full support of interfacing commands over the Internet. Such system can enable seamless data exchange between control system operators (include independent system operators, regional transmission operators, transmission system operators) and control area operators already adopted as standard practice in the US and Canada and being partially implemented in Brazil, Thailand, China and part of the United Kingdom. The interfacing of real - time data and control commands require the use of a standard communication protocol, such as CIM (Common Information Models), GID (General Interface Definition), and the ICCP (Inter -control Center Communications Protocol). It prompts the needs to develop the simulator by conforming to the required standard of information systems and procedures to handle the data communication complexity underlying the power system operations. Many of these systems need continuous upgrading, matching with advancement of technologies, and revising the procedures where appropriate[1].

2 Capabilities of this type of simulator

The functionalities of the simulator are as follows:

a. Visualizing the power system in real time. Realizes real - time communication through an integrated electric and communication system architecture based on the Web. The data are required to be processed by fast computational engine and visualized in user - friendly formats for the system operators to respond and administer.

b. Increasing system capacity. The simulator can support more clients to participate in, making improvements on data infrastructure, upgrading the functions of each module, updating the database from online data and eliminating most of the bottlenecks that currently limit a truly functional wholesale market.

c. Enabling(Enhanced) connectivity to consumers through Web. Having defined the market model, connectivity among participants can be enhanced with improved communications. This enhancement will provide new areas of functionality: one relates directly to electricity services (e.g., billing information or real time pricing), and another one involves what are more generally thought of as communications services (e.g., data services)[1].

3 Feature highlights

Common type of market flaws originate from its structural design which can best be identified by means of a power market simulator. Different market rules and associated market - based mechanisms can be included in the simulator to reflect incentives of various market participants for finding ways that benefit stakeholders, facilitate efficient planning for expansion of the power delivery infrastructure, effectively allocate risk, and connect consumers to markets. For example, service providers need a new methodology for the design of retail service programs for electricity consumers. At the same time, consumers need help for devising means to optimizing their usage pattern and all market participants need to handle different sorts of risks. Since efficient operation of both wholesale and retail markets requires transparent and open system of data access, development of certain data and communications standards for emerging markets is necessary. Further, to test the viability of various wholesale and retail power market design options before they are put into practice, power market simulation tools should be able to help stakeholders establish equitable power markets.

4 Architecture and design

4.1 Market structure

Economic modeling is a process to capture economic behavior of a system with such an approach as much an art as science but avoiding complicated market rules so far if possible. Effect market simulator observes the economic characteristics of a market and helps avoid paying unnecessary high reform cost for settling up an optimal market structure. This paper illustrates the process of setting up a simple pool power market model as shown in figure 1[2,5-6].

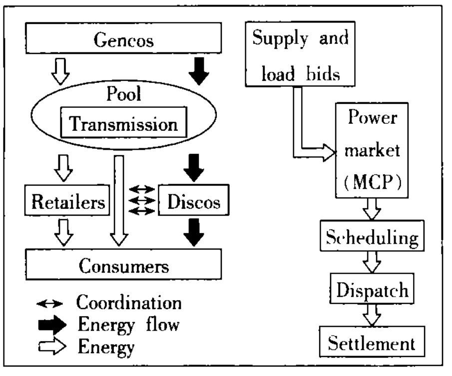

Fig.1 Market structure of the power market simulator

The electricity market participants include:

a. Gencos. All kinds of electricity provider to the network could be regarded as Gencos. Gencos could either bidding in the spot market of the Poolco mode or contract with customers in the bi/ multi-lateral market or both. A Genco's objective is to maximize its own profit by balancing the forward contracts, load and price forecasting, risk management, optimal unit commitment and bidding strategies.

b. Discos. All kinds of electricity consumers from the transmission network could be regarded as Discos, including distribution companies, large customers and retailers. Discos can either bidding in the spot market of the Poolco mode or participate in the bi / multi-lateral contract market or both. A Disco's objective is to minimize its cost by balancing the forward contracts load and price forecasting, risk management and bidding strategies.

c. PX. PX is usually designed to deal with all sorts of market trading, administer and clear the Pool. PX establishes an energy day-ahead market to match energy supply bids and demand offers, balances the market and dispatch the generators in real time, which acts as a pool administrator and establishes the MCP(Market Clearing Price) or SMP (System Mariginal Price). It is also responsible for exchange settlement and information publishing. And the PX broadcasts the long-term and short-term load forecasting, trading and dispatch information in an electronic bulletin board through the Web.

d. ISO. ISO is independent of all market participants. It is responsible for the technical aspects of system operation, control and management, including security and transmission switching, frequency and balancing power, voltage and reactive power, congestion management and emergency control, and maintenance scheduling.

e. SCs. SC brokers run a separated market from Pool for bi-lateral(multil-lateral contract). SCs could coordinate complicated transactions, offer futures and options contracts and provide attractive price deals.

These are generic constituents of any simulator model of which specific operation can be considered by interfacing among the generic units deemed appropriate to suit the market model under study[3,7-8].

4.2 The structure of the simulator

It is commonly found that simulator in the market is built by using JAVA / MAS-based components, CORBA (Common Object Request Broker Architecture) technology and even integrated software platforms. Also, object oriented structure is popular which has its advantages in distributed design for aspects on safety, robustness, scalability and flexibility. But this tool can support limited clients and has very long development span. The COBRA technology can be regarded as an object oriented tool which can provide a support platform to integrate various software and hardware materials. Owing to that the COBRA technology has serious shortcomings in cross-platform and Internet programming application, the power market simulator in this paper advocates on using .NET Framework based on the B/S(Browser/Server) structure for its excellent flexibility in Internet application[4].

In Internet applications, the B / S structure is widely used to publish huge volume of information on the Web or to provide dynamic information searching functions to client. This structure is compatible with traditional browser such as IE or Netscap. In the client side, their requests can be submitted as database by using the CGI (Common Gateway Interface) drivers on the Web server. In comparison with that developed based on the C / S (Client / Server) principle, the B / S structure has greater flexibility and can support more number of clients. Moreover, all it needs is linking up the client through the Web and subsequent maintenance or update of the system are very easy and flexible. Figure 2 shows a typical layout of the B / S structure[9-11].

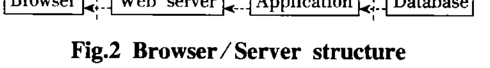

Fig.2 Browser/Server structure

4.3 Three-layer software architecture of the power market simulator

The simulator is designed with flexibility for establishing an electricity marketplace for one or more of the above three structures with five participants. Trading rules can be specified to suit various market architecture designs to cover a number of crucial issues such as:

a. Accurately evaluate the impact of different market structures and rules on the performance of the market and on the operation of the power system.

b. Analyze the market the operation based on a double-side auction scheme.

c. Determine the MCP and correspondingly the total CP(Cleared Power) for each generation company.

d. Simulate the settlement process.

e. Realize and mitigate market power if any and impose penalties as required.

f. Specify long-term, day-ahead, or real-time operational frames.

g. Central exchange or tightly controlled dispatch, and so on.

With support of the Internet advancement, the Web service system based on the layer architectures has proven advantages of high application compatibility and readiness of development tools. Figure 3 shows the three-layer framework for developing the basic architecture of the simulator.

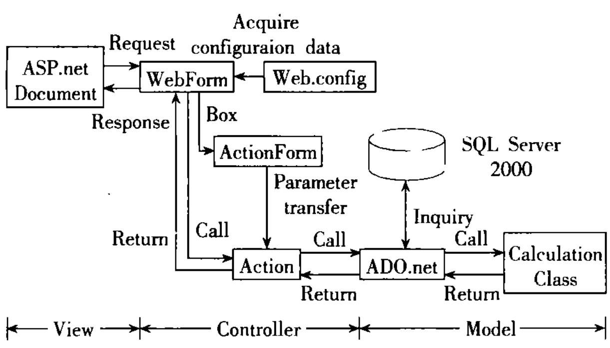

Fig.3 Three-layer software architecture of power market simulator

The special feature of this distributed module structure is that the configuration can easily be expanded, re-designed, maintained or operated in different platforms in case that the electricity market structures and rules are required to be changed. The functions of each layer are shown as follows:

a. View layer includes various soft components, programs and browser in the client side, which can provide plentiful and flexible interactive user interfaces to display and collect data, and fulfill the requests raised by the client according to the function modules provided in the controller layer.

b. Controller layer is the core of the distributed application system. It is responsible to process all the client requests from the view layer by applying the interfaces in the model layer and return the results to the view layer afterward. The controller layer also has to provide the rules for handling the services and function adjustments according to the clients' requirement.

c. Model layer fulfills the definitions, maintenances, access and update of data. The model layer accesses the database in the Microsoft .Net Framework with ADO.NET technology to manage and response the data request from the controller layer.

The design is particularly suitable for developing the graphic user interfaces required to separate the layers between database and display functions. Hence, the developer can modify each layer separately and reduce ambiguity. The structure of the power market simulator based on the .NET Framework can support multi-layer distributed process and make the data passing more readily[9-13].

5 Implementation and analysis

5.1 The development tool of the simulator

The power market simulator makes use of the advanced features of the B/S structure embedded inside the .NET Framework, which has been accepted as a new technology for realizing the distributed Web services based on open standards and heterogeneous platforms. The structure of the .NET Framework is shown in figure 4 with discussion provided in the following context:

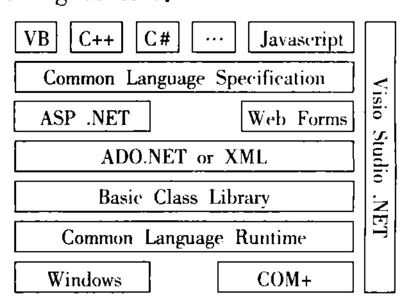

Fig.4 Structure of .NET Framework

a. The program codes are separated from the client UI (User Interfacing) codes. The developer can easily modify the object-oriented and modular based components. After setting the parameters and the rules, these components can be utilized and called upon repeatedly. As a result, it saves a lot of programming time and enhances its efficiency.

b. .NET platform is easier to use Internet based development system which out-performs any other similar tools such as DCOM and CORBA. It provides distributed function components on different computer platforms and loosely integrate the system and the Internet.

c. It works with an efficient database that ensures integrity of the system for easy maintenance.

d. Its object oriented features, such as scalability and class inheritance, make it adaptive for supporting 10 times more users than J2EE and inter-operation of multiple programming languages.

e. It can recompile the program into a DLL document while modifying the program, which can realize the secrecy of the program itself and secure the safety of the market data.

5.2 Key technologies

5.2.1 CLR(Common Language Runtime)

The source programs developed by Common Language Specification can be compiled into the same MSIL (MicroSoft Intermediate Language) and be called by each others on the .NET platform. Whatever programs the system adopts, they will be decoded into MSIL format codes and transplanted on the .NET platform. In operation, the MSIL format codes would be loaded and translated into binary codes in the local computer by its CLR compiler.

5.2.2 Database accessing technology: ADO.NET

ADO.NET is the best database accessing technology based on Internet application program, which can support various databases with OLEDB data source, such as SQL Server2000, Oracle and Sybase etc.. It boxes most of the database operations into a set of objects, which are ready to be called by other program for execution. Moreover, it is an excellent database accessing technology in the server side for it needs to handle less number of layers between the front end application program and the data source for normal operation. Also, it needs less memory and disc storage to manipulate the data, even without knowing its source. By comparing with other database technology such as CGI, ADO.NET is well established for its flexible operations and multithreading.

5.3 Design of the system

The ASP .NET 2.0 is employed for developing the interface of the display layer with C# as the program language and SQL Server2000 as the database. The flowchart of the simulator is shown in Figure 5.

In its operation the server-side technology is fully utilized to create the Web pages by converting the algorithm into appropriate classes and then complied it into DLL files. Hence, the database operations which are embedded into the classes are manipulated to generate the I/O as required. By so doing, the structural platform can easily be used to call the instance of the classes to run the market clearing algorithm[12-14].

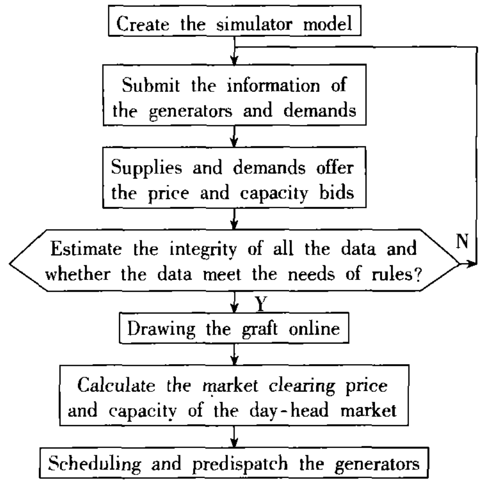

Fig.5 Simulator flowchart

5.4 A pool-model market simulation results

To test the features and performance of the simulator, the example in reference[7] is employed. In this example, there are five generators and single demand bidding over four time intervals. The algorithm for determining market clearing price is embedded into the class, which is called by graph forming module. The graph function module could easily get the results by calculating the sum of the supply and demand incremental curves' areas. In Tab.1, the dispatched power of each generator is listed. A case referring to the 2nd time interval of the example in reference[7] is shown in figure 6.

Both the Gencos and Discos can submit their offers through the bidding interface and get the trading results through the information publishing module. The administrator runs the calculating engine and dispatches the roles and rights of all participants, through which different participants can act on their own strategic bids and get corresponding private and public information based on their rights.

6 Findings and comments

It has been shown that the Web-based power market simulator is operationg in modular format and adaptive for use by different market participants, ISOs, market administrators (e.g., PXs) and interested parties within the market covering a wide geographical area. It serves various purposes including developing market rules and trading strategies, operation and resources planning, etc..

Tab.1 Dispatched power of each generator

Interval	Date	A corporation	Generator ID	Dispatched capacity/MW	Total/MW
	8/24/2006	1	1	0	
	8/24/2006	1	2	40.0	
1st interval	8/24/2006	1	4	19.0	245.0
	8/24/2006	1	5	113.0	
	8/24/2006	2	3	73.0	
	8/24/2006	1	1	5.4	
	8/24/2006	1	2	101.9	
2nd interval	8/24/2006	1	4	34.5	545.0
	8/24/2006	1	5	260.6	
	8/24/2006	2	3	142.6	
	8/24/2006	1	1	76.9	
	8/24/2006	1	2	149.8	
3rd interval	8/24/2006	1	4	55.3	735.0
	8/24/2006	1	5	290.0	
	8/24/2006	2	3	163.0	
	8/24/2006	1	1	106.4	
	8/24/2006	1	2	188.4	
4th interval	8/24/2006	1	4	67.3	815.1
	8/24/2006	1	5	290.0	
	8/24/2006	2	3	163.0	

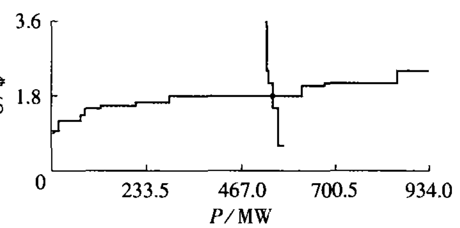

Fig.6 Graph forming for the 2nd interval

The market simulator has also been proven to be a useful tool for developing market functional modules by making different Web - based, object - oriented and distributed network technologies. It allows market functions be provided through the grid and adaptive for heterogeneous platforms.

7 Conclusion

In this paper, the electricity market simulator designed to be adaptive for studies on different market behavior has been presented and demonstrated in operation on pool - model power markets. The simulator system is developed based on the B/S structure taking advantage of the Internet and .NET platform with good flexibility and extensibility. It has also been shown that the modular features make it adaptive for used by different market participants including the market operators.

Implementation of the market simulator is demonstrated on the pool - model market operations including day-ahead and real-time markets; it showed the various features of the simulator assuring potential of application in the power industry.

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Rotator temperature on - line monitoring based on short message service(Ⅱ): data communication and communication protocol

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Abstract: The data communication platform of on - line rotator temperature monitoring system consists of wireless modem,public mobile communication network and wireless mobile communication modules. The commands and data are transmitted by SMS(Short Message Service),in either multi - master or master - slave communication mode. A relatively sophisticated communication protocol is adopted to improve communication reliability and security,including frame head flag, communication password,communication address of temperature measuring unit,command or data information,check sum and frame end flag. Test results show that,its working performance is stable and the data transmission is secure and reliable.

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Key words: on - line monitoring; mobile communication; short message; AT command; communication protocol

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适用于不同电力市场行为的电力市场仿真器

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摘要:设计并开发了一个基于网络结构,能够模拟电力运行方式的电力市场仿真器,并在.NET Framework上开发了此电力市场仿真系统。该仿真器采用了ASP .NET 2.0开发用户界面,C#作为编程语言以及采用SQL Server 2000作为后台数据库,这样的结构可以灵活地仿真及图形化显示电力库架构下的日前及实时市场运行行为,计算出市场结清价及结清容量。该电力市场仿真器利用了内嵌于.NET Framework的浏览器/服务器结构的卓越特性,这种结构可以实现基于开放标准和异构平台的分布式网络服务请求。并且,这种基于.NET平台构架的结构很适合用于地理位置相隔甚远的市场参与者(诸如市场运营商、发电商、用户等)进行信息传递。仿真实例显示,该仿真器具有很好的可扩展性和维护性。

关键词:电力市场;仿真器;.NET Framework;市场出清价

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