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Simulation of the Multi-Node Open Access Same-Time Information System

Yong Tian
Univ. of Illinois at Urbana-Champaign
tian@uiuc.edu

George Gross
Univ. of Illinois at Urbana-Champaign
gros@staff.uiuc.edu

Abstract

This paper describes a Web-based simulator of the Federal Energy Regulatory Commission (FERC) mandated Open Access Same-Time Information System (OASIS) network. The purpose of the simulator is to provide a tool for study of the various aspects of an OASIS network and to gain a strong intuitive feel for its operations. For a specified simulation period, the OASIS*NET* simulator reproduces an OASIS network of multiple nodes using the same communications medium as the actual system, the Internet, and with multiple players using the simulator simultaneously. Salient features of the simulator are its modular architecture, the ability to simulate multi-node OASIS network operations and to accept simultaneous access from remote users through use of client/server technology. The simulation focuses on the dissemination and use of the available transmission capability information. Sample applications of the new simulator are discussed.

1. Introduction

To promote wholesale competition through non-discriminatory open access, Federal Energy Regulatory Commission (FERC) required each transmission owning public utility or its operator to create a real-time information network to disseminate information about the availability and price of transmission services. Open Access Same-Time Information System (OASIS) is the name given to the information system required by FERC. There is a tremendous amount of interest in OASIS recently as the system is completing design and is slated to be in service before the end of 1996. It is estimated that all the public transmission systems in the United States will be represented by 20-35 OASIS nodes [1]. The entire network will be connected through the Internet and will be heavily used by both transmission customers (TCs) and transmission providers (TPs) through their control center personnel in conducting wholesale transactions of electricity.

The development of a new system, the OASIS, and the entry into the electricity business of new players, such as marketers, brokers, scheduling coordinators and load aggregators constituting new TCs, have combined to create a need for a simulation tool for the following purposes:

- to provide operating personnel with a basic understanding of the OASIS operations and with a useable training tool.
- to allow personnel in marketing functions to understand the impacts of OASIS information on markets.
- to enable information system designers to study properties and effects of OASIS.
- to provide regulators with a tool to study the potential of violation of the recently promulgated rules of conduct [2].

The OASIS*NET* simulator makes detailed use of the advances in computing, simulation techniques and visualization technology in the construction of a user friendly tool for these diverse users. The simulator effectively represents the physical constraints and considerations in the interconnected power transmission system together with the impacts of the various transactions that are being contemplated or have already been committed. The focus of the simulation is on the available transfer capability (ATC) information [3].

The rapid advances in computer system have allowed power system simulation software to grow from simple text input/output to extensive graphic user interface (GUI) [4]. Even faster advances in the Internet and World Wide Web (WWW) have enabled multiple remote user access through standard tools such as the increasingly widely used web browser. The principal challenges in developing a simulator for OASIS include the calculation of ATC and total transmission capability (TTC) in a transmission network, evaluation of the impacts of load fluctuations and transactions on ATC, systematic record keeping of all transmission services, and incorporation of the effect of communications delay, both inter-OASIS nodes and between an OASIS node and its users. The OASIS*NET* simulator effectively addresses these challenges. For a specified simulation period, the OASIS*NET* simulator reproduces an OASIS network of multiple nodes using the same communications medium as the actual system, the

Internet, and with multiple players using the simulator simultaneously. Users can dynamically interact with the simulator through web browsers. Salient features of the simulator are its modular architecture, the ability to simulate multi-node OASIS network operations and to accept simultaneous access from remote users through use of client/server technology. This paper describes the major aspects of the OASIS*NET* and provides a sample of its displays.

In the next section we review the FERC requirements. The key concepts in ATC and TTC evaluation are summarized in section 3. We then describe the OASIS*NET* structure, and describe the application of the simulator and include some representative displays.

2. Overview of OASIS

OASIS is the culmination of FERC's vision of a uniform electronic bulletin board to make open access non-discriminatory transmission service a reality in most of the U.S. It represents effective use of available technology and is the vehicle that the FERC employed to bring about functional unbundling in the electric power industry. FERC's comparability requirements state that TCs must have access to the same information the TPs have *at the same time*. In the Order 889 [4], FERC outlines key information requirements for OASIS. These requirements may be grouped into four categories. These categories and the information contents are :

- *transmission system information* -- ATC, system reliability, response to system conditions, and date and time stamp for all the information.
- *transmission service information* -- complete tariff, service discounts, ancillary services, and current operating and economic conditions.

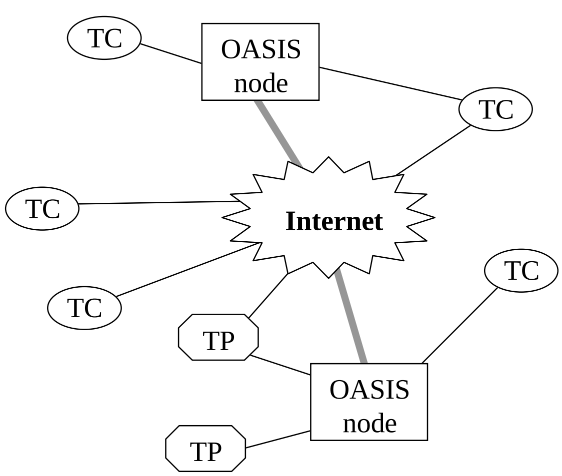

Figure 1. The OASIS network

- *transmission service request and response data* -- scheduling of power transfers, service interruptions and curtailments, service parties' identities, and audit log for discretionary actions.
- *general information* -- announcements and value-added services.

All transmission system operators are required by FERC to install and operate an OASIS node. FERC also requires that the Internet be used as the nationwide connection for all OASIS nodes and the OASIS nodes be accessible by authorized users through Internet, regardless of their physical location. Figure 1 illustrates the conceptual structure for the Internet-based OASIS network. The interconnection between OASIS nodes and users is clearly shown. In addition, all OASIS functions must support the use of WWW protocols, the Hypertext Transport Protocol (HTTP), and WWW tools, such as web browsers. Figure 2 shows the architecture of an OASIS node. The node is connected to the Internet through a firewall to ensure data security. Private Intranet and dial-up connections to users are also supported by the OASIS node. The database is used for storage of ATC and transaction data records, query searches of those records, as well as a backup in case of system malfunction. The connection to EMS is also provided to allow accurate real-time data for ATC calculations.

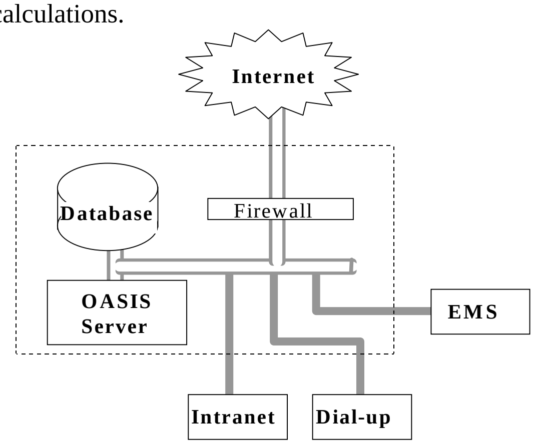

Figure 2. OASIS Node

3. Overview of ATC

The most basic type of system information required in OASIS is the transfer capabilities TTC and ATC. North American Electricity Reliability Council (NERC) conceptually defines TTC as the amount of power that may be transferred over the interconnected network reliably and ATC as a measure of the transfer capability remaining in the transmission network above a base case for commercial transactions. By their very nature, transfer capabilities are a function of the system-wide transmission network conditions. Two key properties of the transfer capability are implicitly stated in these definitions:

1. TTC and ATC are always defined between a two-area pair consisting of a power selling area and a power buying area.
2. TTC and ATC are time dependent quantities because the transmission system conditions vary over time.

The transfer capabilities are generally limited by three types of limits – thermal, voltage, and stability. Thermal limits constrain the amount of transfer that transmission network components can safely handle without being overloaded. Voltage limits are imposed so that the operating procedures in place can keep voltages across the transmission system within acceptable operating range. Stability limits constitute a general class of limits to ensure the survival of the interconnected transmission system in case of large disturbances. The TTC is determined by the most constraining one of these limits, and as system conditions vary, the limit type and quantity may change.

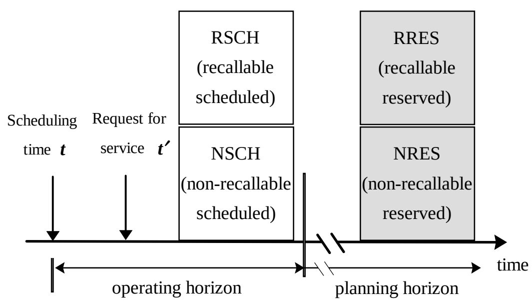

Figure 3. The four types of transmission services

There are four types of transmission services provided for commercial transactions, non-recallable scheduled (NSCH), recallable scheduled (RSCH), non-recallable reserved (NRES), and recallable reserved (RRES). They are differentiated by their recallability level and the date and time stamp of the request for service. Recallability is defined by NERC as the right of a TP to interrupt all or part of a transmission service for any reason, including economic, that is consistent with FERC policy and the TP's transmission service tariffs or contract provisions [5]. Figure 3 shows the transmission service type as a function of the time dimension. The scheduling time *t* is the reference point with respect to which the operating and planning horizons are defined. Operating horizon, typically a day, is a period over which the scheduled services are performed by the TP. The transmission services requested at a time $t' > t$ for a period inside the operating horizon are called scheduled services. Any period beyond that is considered to be in the planning horizon and only reservation can be made in the request for service.

The priority of services are illustrated in Figure 4. The shaded blocks represent reserve service requested at time $t'' < t$. The planning horizon at t'' covers the operating horizon for the scheduling time *t*. The white blocks represent additional services requested at time $t' > t$. Since t' falls within the operating horizon of *t*, these services are scheduled services. As shown, the non-recallable services generally have higher priority than recallable services. For the same recallability level services, date and time stamp of request determines the priority.

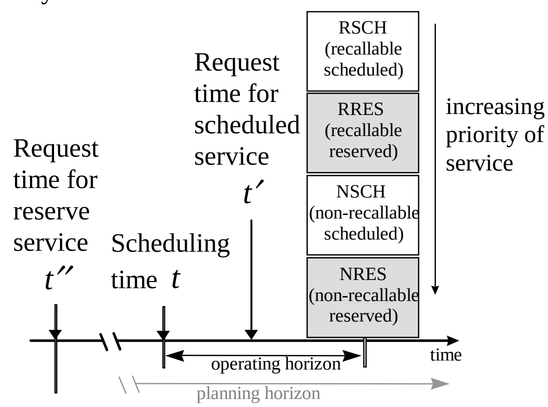

Figure 4. Priority of service

To make use of the ATC for actual transmission services in the real world, two more concrete and useable quantities called non-recallable ATC (NATC) and recallable ATC (RATC) are introduced. NERC defines *NATC* as follows:

$$NATC(t) = TTC(t) - TRM(t) - NSCH(t)$$

where *TRM* is the transmission reliability margin to account for uncertainties in calculation of TTC and ATC. For a specific period,

$$NATC[period] = \min \{NATC(t) : t \text{ is an hour in the period}\}$$

The *RATC* is defined as follows:

for operating horizon:

$$RATC(t) = TTC(t) - a \bullet TRM(t) - RSCH(t) - NSCH(t)$$

for planning horizon:

$$RATC(t) = TTC(t) - a \bullet TRM(t) - RRES(t) - NRES(t)$$

where $0 < a < 1$ is a value determined by individual TPs based on their reliability concerns. Figure 5 shows the relationship between TTC, ATC, and the scheduled and reserved transmission services.

In actual operations, NSCH services have the highest priority. NSCH services cannot be curtailed by the TP except in cases of emergency. *NATC* cannot include transfer capability that is currently held by NRES service because the reserve service would have priority over any new request for non-recallable service. However, *NATC* can include transfer capability that is currently used RSCH service because a non-recallable service has priority over recallable service. *RATC* has the lowest priority. It cannot include transfer capability currently used by RSCH service because the scheduled service would have priority over any new service.

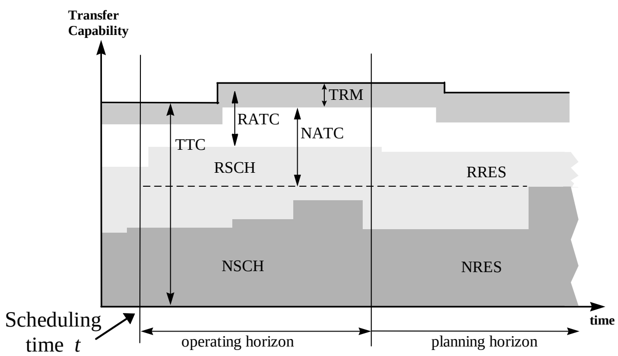

Figure 5. Transmission capability evaluation

The highly time and system condition dependent ATC is calculated by computer simulation based on forecast of conditions. Due to the large scale computation involved, it is impractical to update the ATC posting for all paths all the time. FERC has defined constrained path and unconstrained path and issued separate requirement for each to reduce the workload. "A constrained path is one for which ATC has been less than or equal to 25 percent of TTC for at least one of the last 168 hours or is calculated to 25 percent or less of its associated posted TTC during the next 7 days." [2] Any path that is not a constrained path is an unconstrained path. Table 1 lists the OASIS posting requirements for both types of path.

Table 1. TTC/ATC Posting Requirements of OASIS

ATC/TTC posting req.	unconstrained path	constrained path
next 168 hrs		X
next 7 days	X	
days 8-30		X
current month	X	
next12 months	X	X

4. OASIS*NET* Simulator

A separate copy of OASIS*NET* simulator is required for simulating each node in the actual OASIS network. For a specified simulation horizon, OASIS*NET* can simulate the operations of an actual OASIS node on a compressed time scale basis, with the smallest unit of time representing one hour of real time. The overall block diagram of the simulator is shown in Figure 6. The shaded blocks are components of OASIS*NET*, which consists of the *Module Interface* and the *TTC/ATC Calculation*, *Transaction Coordinator*, *Power System Simulation Engine*, and *Graphic User Interface (GUI)* modules. The direction of data flow is indicated by arrows. For the purposes of modularity, all data flow between the modules are either through common databases or external files. The Case Data block is a set of files describing the simulated system, and the Other Program block can be another copy of OASIS*NET* running to simulate another node or some future packages that will interact with the simulator. The modules inside the dotted box, *TTC/ATC Calculation*, *Transaction Coordinator*, *Power System Simulation Engine* are located on a central server computer, while the *GUI* module is WWW-based. Multiple copies of the GUI may run at remote locations simultaneously as shown. Using the networking client/server terminology,

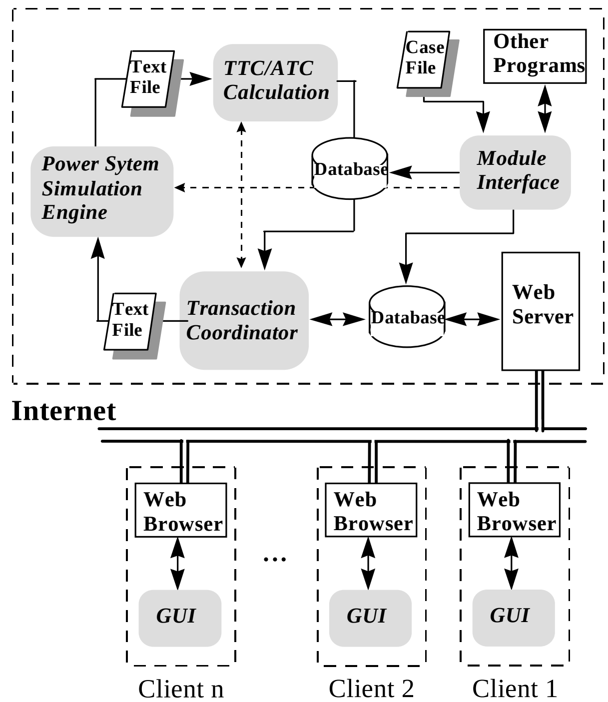

Figure 6. The OASIS*NET* simulator structure

each remote user is called a client. Each client computer accesses the web server through a web browser and runs a copy of the *GUI* module. The OASIS*NET* modules are distributed and connected by the Internet to emulate the actual OASIS operating conditions, including the impact of communications delay.

The basic steps involved in the functioning of the OASIS*NET* simulator are shown in Figure 7 and explained below:

1. The simulation case is set up by the system administrator on the server using the *Module Interface*. At the start of simulation, the *Power System Simulation Engine* and *TTC/ATC Calculation* module are run on the base case to calculate ATC and TTC for the simulation horizon.
2. The users can connect to the server any time after the simulation starts via Internet and use their web browser to run the *GUI* module. They can view information and/or submit requests.
3. At every time step, the *Transaction Coordinator* module checks for overload conditions and curtails transmission services to alleviate overloads if any exists. The *Transaction Coordinator* module then processes transmission service requests by comparing them with ATC values.
4. The *Power System Simulation Engine* and the *TTC/ATC Calculation* module are run on the simulated system with all the newly scheduled transmission services taking into account the requests submitted to calculation a new set of TTC and ATC.
5. The simulator repeats steps 3 and 4 at every time step until end of the simulation horizon.

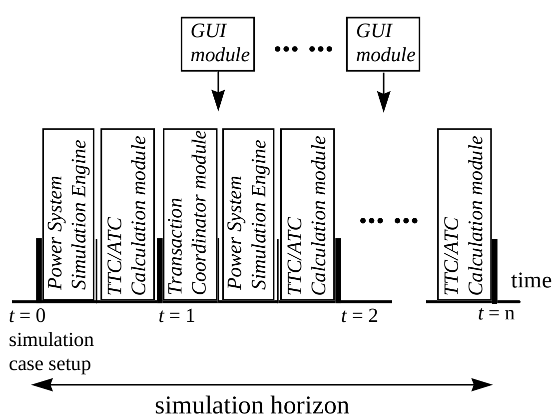

Figure 7. Basic steps in OASIS*NET* simulator

All the modules in the server are controlled by the *Module Interface*, which determines when to call each of the modules and handles inter-module communications.

The function of *Power System Simulation Engine* is to emulate the interconnected transmission network and EMS for calculating OASIS information by conducting off-line load flow studies. These load flow data are used by both the *TTC/ATC Calculation* module and the *Transaction Coordinator* module. Currently, we are using the POWERWORLD v3.0 [4] simulation package as the *Power System Simulation Engine* in OASIS*NET* simulator. However, due to the modular architecture of the simulator, the *Power System Simulation Engine* can be easily changed to other simulation packages or future version of POWERWORLD.

The *TTC/ATC Calculation* module is the most computationally intensive module of the simulator. It uses the load flow data to calculate the ATC and TTC values between each power selling and buying area pair by the Network Response Method [5]. From the TTC, *NATC* and *RATC* are derived based on their definition as discussed previously. The computational complexity is on the order of $O(\tau \bullet m \bullet n \bullet k)$, where τ is the amount of computation to find ATC between one area pair using the Network Response Method, m is the number of selling and buying area pairs in the transmission system, n is the total number of time steps in the simulation horizon, and k is the number of contingency cases considered.

The *Transaction Coordinator* module is the heart of OASIS*NET* simulator. It emulates the functions of an transmission system operator, who is responsible for maintaining safe and secure operations of the interconnected transmission network. The functions of *Transaction Coordinator* module include: checking and elimination of overload conditions in the transmission system, processing of transmission service requests, and the scheduling transmission services. The overload checking is done based on the load flow data from the *Power System Simulation Engine*. The processing of transmission requests are based on comparison of the requested capacities with their corresponding ATC value from the *TTC/ATC Calculation* module. A transmission service request is 'approved' if the requested service can be accommodated without violating ATC, and it is put into a database of scheduled services. The updated schedule then recorded in a file for the *Power System Simulation Engine*.

The *GUI* module provides a friendly interface for users to interact with OASIS*NET*. Essentially, it performs two functions, display of information and retrieval of user requests from individual clients to the server computer via Internet. The visual display consists a series of windows, The next section provides a sample of representative windows.

5. OASIS*NET* Applications

Typical applications of the OASIS*NET* include the illustration of the uses of ATC information by a broker for undertaking transactions and the study of effects of delay in information transmission. To illustrate the workings of the simulator, we walk through the results of the simulation a case designed to focus on the difference between recallable and non-recallable services requests.

All the OASIS*NET* displays consist of web pages displayed on web browsers. A simulation study starts with accessing the homepage of OASIS*NET*. The homepage provides pointers to other interface windows. These are the *area map, one-line diagram, system information, transaction processing, service information,* and *general information*. The first two windows show topological information of the simulated system. The other four windows provide the OASIS data in the four classes of information described in section 2. The display of a*rea map* bring up a graphic showing a map of the areas of the system. For the case system under discussion, a 23 bus, 3 area system, the map is shown in Figure 8.

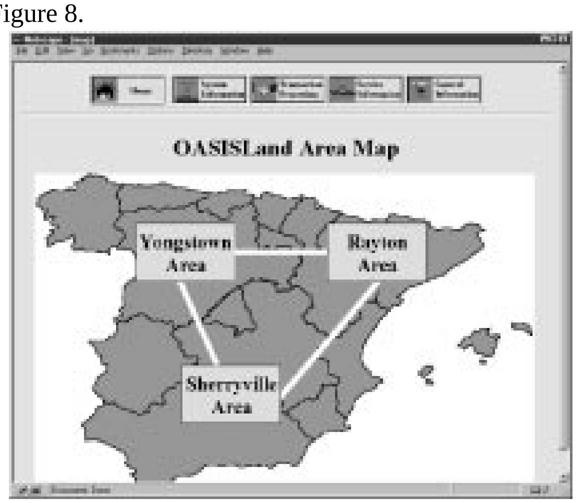

Figure 8. The *area map* window

The *system information* window is shown in Figure 9. The buttons at the top of this window can be used to move to the other windows or the OASIS*NET* homepage. The clock to the right of the buttons shows the current simulation time. All the OASIS*NET* windows have a uniform section at the top so as to give the users easy access to the information. In the middle of the window is the ATC table, showing both *NATC* and *RATC* for the transmission paths on an hourly basis. Since values change on an hourly basis, the simulator *GUI* module reloads to update the values at specified interval. The ATC for both the constrained and unconstrained paths are listed.

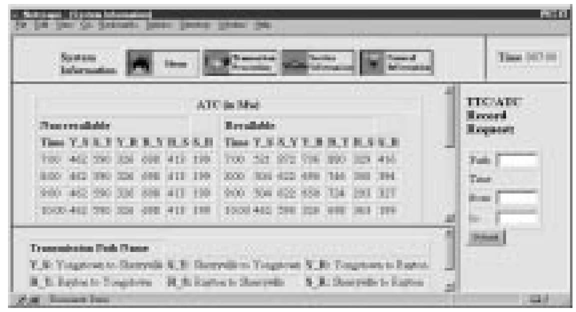

Figure 9. The *system information* window

Let us next discuss how requests for services are displayed, the *transaction processing* window is shown in Figure 10. The window lists all current and scheduled transmission services. In addition, for each user request its status is shown. For example, as shown in Figure 10, the request *uiuc001*, made in the previous hour (hour 6:00), has been approved. This request is for non-recallable capacity of 200 MW on path S_Y form hour 8:00 to hour 12:00. The *NATC*[8:00 to 12:00] is 590 MW for that path, which clearly can accommodate the requested service. A second request, *berk001*, for recallable capacity of 100 MW on path R_Y from hour 8:00 to hour 13:00, is also approved. The display in *system information* window of Figure 9 is for the ATC values at hour 7:00. Note that the *RATC* for paths S_Y and R_Y are reduced to account for these two approved transmission services, while the *NATC* values show no reduction on the path R_Y, on which the recallable service of *berk001* is scheduled. Another request for service, *uiuc002*, is made at hour 10:00, which is for non-recallable capacity of 650 MW on path R_Y from hour 11:00 to hour 15:00. The request is also approved. However, this is done at the cost of curtailing another transmission service (not shown). The *NATC*(11:00) on path R_Y is 698 MW and the *RATC*(11:00) is 567 MW, 83 MW deficient to accommodate the non-recallable 650 MW service requested in *uiuc002*. The priority of service kicks in and results in the curtailment of the lower priority recallable *berk001* request by 83 MW. This example then, illustrates how services with different recallability levels are treated.

For each window, requests for historical data can be made and obtained. This feature provides the capability to conduct audit trails on the way transmission requests were received and handled.

Figure 10. The *transaction processing* window

6. Conclusion

This paper presented a web-based simulator of multi-node OASIS network. Our OASISNET simulator is capable of demonstrating the workings of the OASIS as envisioned by FERC in its Order 889. The simulation discussed here focused on ATC calculations. However, the modular structure of the OASISNET architecture allows expansion to include other features as the need arises. Future developments include the simulation of the role of transmission pricing in undertaking transactions and the functioning of secondary markets in transmission services.

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