Proceedings of the 5th WSEAS Int. Conf. on Power Systems and Electromagnetic Compatibility, Corfu, Greece, August 23-25, 2005 (pp466-471)

Reengineering of Systems Operation; A Solution to the Challenges in the Deregulated Market Environment – II

Dr. M. FAROOQ ASLAM
Professor
Dept. of Electrical. Engineering
University of Engineering &
Technology, Lahore,
PAKISTAN

TEHZEEBUL HASSAN
Associate Professor
Dept. of Electrical. Engineering
University of Engineering. &
Technology, Lahore,
PAKISTAN

Dr. TABREZ A. SHAMI
Professor
Dept. of Electrical. Engineering
University of Engineering. &
Technology, Lahore,
PAKISTAN

Abstract: - The absence of central coordination in deregulated electricity markets sets a new range of challenges to their organization and functioning. Although a lot of academic research has been done in the recent years on these topics, contributions and discussions tend to stay within a single field (economics, systems analysis, policy analysis...). This paper (presented in two parts) aims at providing a framework for researchers of different fields to focus on the crucial issues, in the coordination problem.

The fundamental factors in the operation of electrical power systems, at a macro level, are distribution of the operation parameters over vast areas, dominance of human factors and high dimensionality of the problem. Contemporary power system operation in vertically integrated utilities is based on the idea of a central dispatch office (CDO) relying heavily on SCADA for transportation of data to the CDO. The data arriving in the CDO is although useful for system stability, is of little value for the short term economic operation. Interconnection of units has increased the state space to the level of combinatorial explosiveness. Recent development of multiple fuel plants as well as deregulation of electricity market has added to the dominance of the human factor.

Looking at the roots, the problem of economic operation of power systems is primarily that of decision management. The deregulation of electric power industry since 1992 has rendered it just more complex. As the new market environment is still in its evolution process it is time to raise fundamental and radical steps to make the system operation more manageable. Emerging information technologies (IT) can help in addressing these issues more effectively. Preliminary research with encouraging results has already been presented in a doctoral thesis recently presented in the Department of Electrical Engineering. The Part – I of this paper elaborate on the fundamental concepts behind *reengineering* [9] and Part – II would provide the basis of a framework where the principal entities in the diverse fields of the system operation can share information to make the economic operation more manageable in the new market environment.

Key-Words: - Reengineering, Deregulated Market, Process Map, Distributed Economic Operation

1 Introduction

The growing pains of the electric energy industry restructuring are becoming quite visible to the general public now. These are reflected either through undesired service interruptions and/or through highly volatile electricity prices [1].

In Part-I of this paper, it has been mentioned that the problem of system operation is indeed a problem of management. Distribution of information and the human factors are directly related to the management of the system from economic point of view. Contemporary system operation is based around vertically integrated utilities. Operational data from all over the vast geographical area is brought to a central dispatch office (CDO). As a result the data arriving in the CDO is of such a huge amount that digging useful information from this pile is in itself a difficult problem [2, 3].

The system operation has two main aspects; economic and stability. These two are disjoint areas of system operation [4]. One less obvious impact of sending whole of the telemetry data to the CDO is that parameters required for stability and control of the system are easily sensed by the RTU and find their way easily to the control center whereas most of the parameters crucial for economic operation are not transmitted by SCADA and are dispatched through slow paper link [5].

Thus most of this data that is distributed in various parts of the system is lying dormant and do *not participate in any way whatsoever, in the economic operation. Before the present era of information technology, it was not even conceivable to find any suitable means for mobilizing this information* [5].

It is easy to visualize that the problem of power system operation is distributed in nature, where most of the problem-solving agents are hundreds of kilometers apart. Individually none of them can solve the entire problem and thus collaboration is necessary [6]. Distributed problem solving is said to occur when a number of independent problem-solving agents collaborate in solving a problem. Collaboration means the sharing of raw or processed data. Collaboration is necessary when no single agent can solve the entire problem [6].

Real retail electricity prices rose significantly during 1970s and early 1980s for the first time in the history of commercial electric power. Moreover, it became clear that there were significant variations in performance across utilities, but an industry structure which provided limited opportunities for more efficient suppliers to expand and to place pressure on less efficient suppliers to improve or contract [7]. Thus a prime motive behind the deregulation movement is to provide electricity to the general public at a cheaper rate.

For economic operation of the system, the fuel cost characteristic are modeled for each unit in the system as a quadratic and are shown in (1) below.

$$F(P_i) = \alpha + \beta P_i + \gamma P_i^2 \qquad (1)$$

Where *F(P_i)* is the cost of fuel incurred per hour. The determination of the parameters α, β and γ requires the availability of data relating the cost $F(P_i)$ to the generation level P_i considering the operation of *m* thermal generating units on the same bus [8]. Assuming that the variation of the fuel cost (F_i) of each generator with the active power output (P_i) is given by a polynomial similar to (1) above, the total fuel cost of the plant can be given as the sum of the individual unit cost converted to \$/h [8].

$$F = \sum_{i=1}^{m} \alpha_i + \beta_i P_i + \gamma_i P_i^2 \qquad (2)$$

For the system operation to be optimally economic, all the units participating in the operation at a certain time should operate at equal incremental fuel costs [8]. *Therefore as a necessary condition for optimal economic operation, it is enough to make sure that the committed units are indeed operating at equal incremental fuel costs* [8].

Once an economic dispatch has been established then increasing the power level of a thermal unit with the intention to sell extra power capability to a demanding potential buyer would only increase the system cost causing a fuel loss at the national level.

In such an instance a fresh economic dispatch as well as unit commitment has to be initiated in real time to determine the sellable power capability of a unit complying with all the constraints imposed by economic dispatch formulation, which is definitely a combinatorially explosive problem.

Reliability in continuity of service as seen by the customer is another crucial issue of grave concern because of major changes in fundamental principals underlying reliable electric energy service as the industry restructures [9].

1.1 The Restructuring Exercise

Replacing the hierarchical governance arrangements with well functioning decentralized market mechanisms is a very significant technical challenge, about which even the best experts have disagreements. As a result the restructuring and competition initiatives got off on the wrong foot at least in part because policymakers and many of their advisers underestimated the nature and magnitude of the technical and institutional challenges associated with successfully introducing competitive wholesale and retail markets and the uncertainties associated with how best to respond to these challenges [7].

To some extent the underestimation of the magnitude and extent of the challenge was strategic, reflecting efforts by some participants in the process to feather their own nests. However, it also reflected a combination of ignorance, political barriers, and true uncertainty about how best to restructure to support competition and how to design effective wholesale and retail market, transmission, and system operations institutions. The experts did not, and in many areas still do not, agree on exactly how best to proceed with these structural and institutional reforms [7]. This in turn resulted in numerous political compromises over restructuring and market design issues and the mixing and matching of pieces of alternative restructuring models that did not fit very well together [7].

As a conclusion to the above discussion as well as that given in Part-I, it is suggested in this paper to reorganize the restructuring effort according to the reengineering principles.

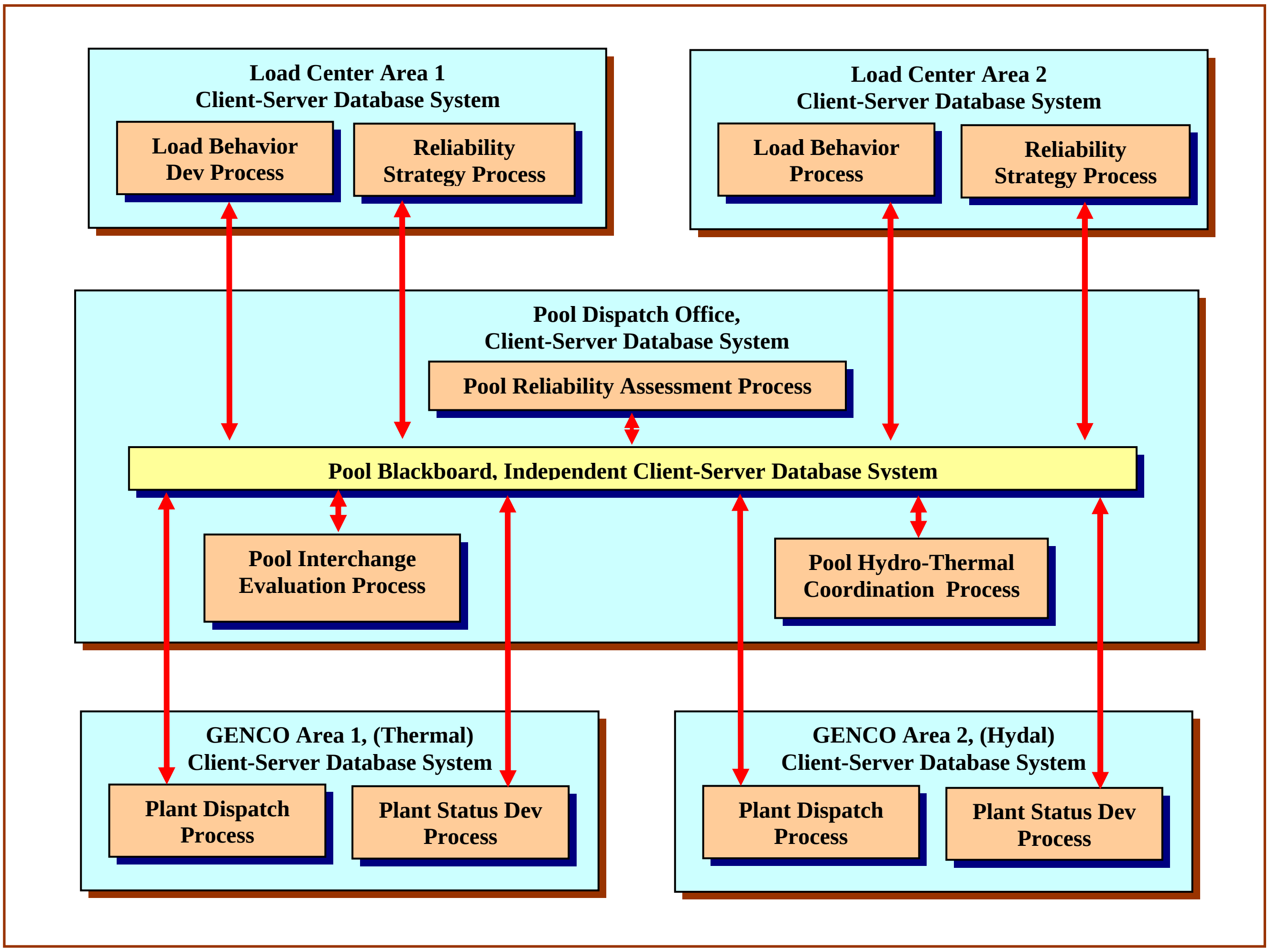

Fig. 1: A Typical Process Map for the Operation of a Power System

2 Previous Work

The previous work cited in the literature broadly concentrates on the procedural optimization of the individual tasks, such as economic dispatch and optimal power flow [8]. Work has also been cited that utilizes AI techniques and considers the distributed nature of the problem but only to some extent [6, 12]. The economics of the system as regards to the policy analysis has been seriously undertaken only by the economists in the context of present restructuring paradigm [7, 9, and 10]. The problem has been first envisioned by the present authors as a management problem and a possible solution based on the concepts of reengineering have been proposed.

3 Reengineering the Operation

Processes, not organizations, are the object of reengineering. Companies don't reengineer their manufacturing or other departments; they reengineer the work that people in those departments do [11].

3.1 System Operation Task List

The principal goal in the operation of an electrical power system is to supply electricity to the general public at a minimum the cost. A review of the whole scenario seems worthwhile for identification of the main processes.

- The electricity is generated in thermal as well as hydro power stations located at far off distances from each other.
- The thermal units are built with different technologies, different minimum and maximum capacities and thus have different input-output characteristics.
- The fuels used for running these thermal units have different calorific values, different

transportation as well as storage charges and also different federal and provincial taxes.

- The cost of generation depends not only on the input-output characteristics, but also on the calorific value, as well as its cost, including all taxes and transportation charges for the fuel that is in current use.
- The selection of a particular fuel for a particular thermal unit is the responsibility of the plant engineers, in the thermal power stations.
- All thermal units are not always available. Some fail during operation while others are put OFF LINE for maintenance purposes. Scheduling of units to make them *available* is the responsibility of plant engineers.
- Some units are given the *must run* status because of *reliability* requirements.
- *Must run status* is sometimes assigned temporarily because of certain restrictions due to startup and shut down constraints. Sometimes this status is permanent for a longer term because of agreements with external power companies.
- The overall cost of generation is minimized when all the units that are, COMMITTED, operate at *equal incremental fuel cost*.
- A subset of AVAILABLE units may be COMMITTED to meet a given load. However there may be many such subsets, which can meet a given load.
- All such subsets, although operated on equal incremental fuel cost, won't operate at minimum overall cost. Which of the subsets operate at minimum overall cost is the subject of *Unit Commitment*.
- Coordination with external power companies is to be considered at this stage and their place in the commitment order has to be determined.
- The overall cost of operation also includes the transmission losses. Thus minimizing the overall cost of operation also means minimization of transmission losses.
- The Optimal Power Flow Analysis is an important part for generation planning as well as for estimating the transmission losses.
- To accurately account for the transmission losses, apparently it seems logical to be able to anticipate the magnitude of load at each power plant.
- This necessitates the requirement of finding the *short-term load forecast* at each main load center.
- Short term load forecasting can be done, by an hourly log of load variation kept in a client-server database system at each load center.
- Hydro resources also form a good proportion of a large electrical power system. Therefore the amount of energy available during the next dispatch period has to be anticipated, before going through the above mentioned event cycle.
- For this purpose, hydrology data has to be made available for all hydro power stations.
- Unless this hydrology data is made available ONLINE, it seems impractical to bring coordination between Hydro and Thermal generation.
- After computing the share of energy from hydro resources, an economic dispatch may also be initiated for hydro units.

Many of the processes that exist in present day system operation, such as economic dispatch, unit commitment, load flow analysis, reservoir analysis, are broken in nature and cannot be considered as complete processes unless they are redesigned so as to play a more useful role for the benefit of a larger objective.

3.2 Development of Processes & Process Map

Traditional process analysis takes the process inputs and outputs as given and looks purely inside the process to measure and examine what goes on. *In contrast to that, part of reengineering a process is, to look at it from the outside to find what the process's customer (the user) does with that output.* Therefore the better place to begin to understand a process is on the user end. The following questions must be answered.

- Who is the user of this process?
- What are the user's real requirements?
- What do they say they want, and what do they really need, if the two are different?
- What problems they have?
- What processes do they perform with the output?

Since the eventual goal of redesigning a process is to create one that better meets user's needs, it is crucial that the team truly understands these needs. *Understanding means considering the customer's underlying goals and problems, not just the mechanics of the process that links the two organizations together* [11].

3.3 A Process Map of the System Operation

Just as companies have organization charts, they can have *Process Maps* that give a picture of how work flows through the company. A process map also creates a vocabulary to help discuss reengineering. As has been already explained, "Processes are a collection of activities that takes one or more kinds of inputs and creates an output that is of value to a user. One way to identify processes that make up an organization is to give them names that express their *beginning and end states*. This implies all the work that gets done between their start and finish. Just like organization charts, a process map can be prepared that gives a picture of how work flows through the company [11].

A typical process map developed by the authors is shown in Fig. 1 above. This process map shows how work flows in the operation of an electrical power system. *It can be clearly seen from this Process Map that the components of the system operation should be decentralized.* This would help in arriving at better decisions in a timely and more efficient manner. The presence of high speed networks has made it possible to employ knowledge-based excess of distributed databases.

3.4 A Few Reengineered Processes

Keeping in view the basic requirements, some processes involved in operation of electrical power systems, have been reengineered and a few have been implemented with encouraging results.

3.4.1 Thermal Plant Status Development Process

This process would take in, fuel consumption data, maintenance and forced outages data, startup and shut down information and would identify the units available and their fuel cost characteristics (FCC) as well as minimum and maximum plant capability, for next 24 hours. It would also identify those units that have a MUST RUN status. *The process runs an algorithm that computes the fresh FCC from the measured data and hands it over to the CDO upon request* [4].

- The process owner is each thermal plant.
- The customer of this process is central dispatch office.

3.4.2 Hydal Plant Status Development Process

This process takes in, hydrology data, scheduled and forced outages data, reliability reserve, identifies the available units and prepares their water consumption characteristics (WCC) as well as minimum and maximum plant capability, for next 24 hours.

- The process owner is each hydal plant.
- The customer of this process is central dispatch office.

3.4.3 Load Behavior Development Process

This process would be initiated at the load centers, and it would log the MW and MVAR outputs that are fed into each category of the feeders and prepare a load curve. The process would also identify cyclic variations in the load curve, such as daily, weekly and seasonal variations. It may also identify the effects of weather variations.

- The process owner is each load center.
- The customer of this process is the central dispatch office.

3.4.4 Pool Interchange Evaluation Process

This process uses the output of Hydal Plants Status Development Process, Thermal Plants Status Development Process and Load Behavior Development Process as its input for next 24 hours, as well as most recent transmission constraints, and identifies the units to be committed and optimal share of load for each GENCO. This is a shared process that requires multiple hops between GENCOS and central dispatch office, for its completion.

- The process owner is power control center.
- The customers of this process are each GENCO.

3.4.5 Thermal Plants Economic Dispatch Process

This process utilizes the output of above processes and produces optimal share of load for each of its ONLINE units. The process owner is each thermal plant. This process also requires a few hops between central dispatch office and thermal plants for its completion. Its output would be the economic dispatch plan for each unit in the plant. An Intelligent Agent inside this process keeps all the units always optimally dispatched through local SCADA lines.

- The owner of this process is the PE in each thermal GENCO.
- The customers of this process are unit operators.

4 Conclusions

Part-I of this paper elaborates on the necessary ground work and Part-II (this paper) gives some of the implementation details for the reengineering of system operations. It is hoped that once this distributed system is fully developed, would be able to cope with the challenges faced by present day restructured market.

Thermal Plants Status Development Process and Thermal Plants Economic Dispatch Process has been developed for Guddu, Gas Thermal Power Station in Pakistan. This is a multiple fuel plant where natural gas is brought from four different fields. The natural gas from all the four fields has different calorific value as well as different transportation charges and taxes. Anytime when pressure on any of the gas lines drops due to some reason, the units are shifted to the other gas lines by the plant engineers. It has been established that the relationship between calorific value and load share of each thermal unit is non-linear [4]. *Therefore computation of fresh FCC is a mandatory requirement subsequent to every fuel change*.

The process has been simulated with a thermal database developed using Visual FoxPro. Three thermal units were dispatched for a 24 hour load profile furnishing about 22,800.00 MWh of energy and displayed a saving of about Rs.0.5 Million to Rs.6.5 Million, per day. (1 US $ = 65 Rs. approx)

5 Acknowledgement

The authors are grateful to the University of Engineering & Technology, Lahore and Higher Education Commission of Pakistan for providing the necessary funding for this research.

The authors are also grateful to the management of Gas Thermal Power Station Guddu, for providing the necessary technical data.

References:

[1] S. Stoft, *PJM's Capacity Market in a Price-Spike World*, University of California, Energy Institute, May 2000.

[2] Pinheiro Raul, Zita A. Vale, Electrical Distribution Network Measurement Data Pre-Processing for Knowledge Discovery: Preliminary Results, *Proc. of IASTED International Conference on Power & Energy System*, EuroPES-03, Marbella, Spain, Sep 03-05, 2003.

[3] Miao S., S. Wang, P. Liu, S. Cheng, *The Design and Implementation of the GPS based Real-time Monitoring System for the State of Power Network,* International Journal of Power and Energy Systems, Vol.21, No.3, 2001.

[4] Aslam, M. F., *An Expert System for Optimal Economic Operation of Mixed Hydro-Thermal Power Systems*, Ph.D. Dissertation, University of Engineering and Technology, Lahore, 2004.

[5] Aslam M. F. and T. A. Shami, Power System Operation in Information Technology Era, *Proc. of the 2nd International Electrical Engineering Congress, Lahore, Pakistan, Feb. 2001.*

[6] Talukdar, S. N. and Cardozo, E., Leao, L., Banares R., and Joobbani R., A System for Distributed Problem Solving, *Workshop on Coupling Symbolic and Numerical Computing in Expert Systems, Bellevue, Washington, 27 – 29 August 1985*

[7] Joskow, P. L. The Difficult Transition to Competitive Electricity Markets in the U.S. *Conference on "Electricity Deregulation: Where From Here?"*, Bush Presidential Conference Center. Texas A&M University, April 4, 2003.

[8] M. E. El-Hawary, *Electrical Power Systems Design and Analysis,* Virginia, Reston, 1983, pp. 701-716

[9] José R. Arce, Marija D. Ilić, Francisco F. Garcés, Managing Short Term Reliability Related Risks, *IEEE Transactions on Power Systems*, Vol. 9, No. 1, 2001

[10] Joskow, P. L. Restructuring, Competition and Regulatory Reform in the U.S. Electricity Sector, *Journal of Economic Perspectives*, 11(3), Summer 1997, pp. 119-138.

[11] Hammer, M. and Champy, J., *Reengineering the Corporation, A Manifesto for Business Revolution*, New York: HarperCollins, 1993.

[12] Talukdar, S. N. and Cardozo, E., Artificial Intelligence Techniques for Power System Operations – Some Demonstrations and an assessment of Opportunities, *EPRI Report for Project No. 1999-7*, August 1985