IFAC

International Federation of Automatic Control

POWER PLANTS AND POWER SYSTEMS CONTROL 2000

A Proceedings volume from the IFAC Symposium
Brussels, Belgium, 26 - 29 April 2000

Edited by

J-P. WAHA

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Drève de Nivelles 58, Brussels, Belgium

Published for the

INTERNATIONAL FEDERATION OF AUTOMATIC CONTROL

by

PERGAMON
An Imprint of Elsevier Science

UK Elsevier Science Ltd, The Boulevard, Langford Lane, Kidlington, Oxford, OX5 1GB, UK
USA Elsevier Science Inc., 660 White Plains Road, Tarrytown, New York 10591-5153, USA
JAPAN Elsevier Science Japan, Tsunashima Building Annex, 3-20-12 Yushima, Bunkyo-ku, Tokyo 113, Japan

First edition 2000

Library of Congress Cataloging in Publication Data

A catalogue record for this book is available from the Library of Congress

British Library Cataloguing in Publication Data

A catalogue record for this book is available from the British Library

ISBN 0-08-043252 2

Printed in Great Britain

① Steam power plants — Congresses

② Electric power systems — Control — Congresses

IFAC SYMPOSIUM ON POWER PLANTS AND POWER SYSTEMS CONTROL 2000

Sponsored by
International Federation of Automatic Control (IFAC)
Technical Committee on Power Plants and Power Systems

Co-Sponsored by
CIGRE (TC's 37-38-39)

Organized by
IBRA–BIRA Federation

Continued from outside back cover

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POSTER PAPERS

SOME CONTROL ASPECTS OF POWER DELIVERY IN THE DEREGULATED ENVIRONMENT

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Abstract: Major restructuring of the electric utility industry driven by economics and open competition is in progress in various parts of the world. Although it is well advanced in a number of countries, it is relatively new in North America. Thus the experience from the North American perspective is limited. A brief review of the evolution of power systems, restructuring of electric supply industry in North America and some control aspects that might affect the reliability of electricity supply in a deregulated environment are given in this presentation. *Copyright © 2000 IFAC.*

Keywords: Control in deregulated environment, power system restructuring:

1. FOREWARD

Electricity supply is in the throes of significant change. Competition is the buzz word to-day accompanied with major changes that are taking place. For example, eighteen states with more than half of the total population of US have already committed to implement their version of customer choice (Anderson, 1999). In Canada, the province of Alberta is the most advanced with a power pool already operating for the past three years and the province of Ontario well on its way to deregulating its electric utility business.

Although each jurisdiction has its own approach to privatization and de-regulation, it would be fair to say that at present only the generation is de-regulated and privatized. Except for a few large industrial customers, at the distribution level individual customers, in general, still have no choice. The third element, transmission grid, is mostly still regulated because of the overwhelming reliability concerns.

Before going any further, it would be useful to first put the electric utility structure in perspective.

2. TRADITIONAL STRUCTURE

Due to political, territorial or geographical reasons, individual power systems evolved independently, but economic and technical reasons imposed the need for interconnections. As such they now constitute building blocks of interconnected power systems.

Although evolved primarily on the basis of need and good engineering practice, and not consciously designed using hierarchical system theory, vertically integrated utilities have developed into hierarchical systems. In a typical large interconnected power system, superpools, pools, areas, power stations, sub-stations and individual units can be identified as the individual levels of a typical hierarchical structure.

In such systems, policies are set at the executive level of the system management which may be called the self-organizing layer of control. This level involves a multi-disciplinary approach and is supremal to the other levels. A policy set at the executive level is translated into a set of goals and objectives to be achieved at the various structural levels of the power system. Achievement of these goals requires a well-defined strategy implemented in a set of controls corresponding to each structural layer of the power system.

In general, in interconnected power systems, generating units receive commands from area controllers which, in turn, may be controlled by pool computers (controllers) and so on. Controls are used to achieve collectively, as closely as possible, a predetermined performance from the integrated system. Thus, in parallel with the hierarchical structural levels of the power system, one can distinguish different control levels which can be broadly described as below:

- Generating unit controls which consist of prime mover control and excitation control with AVR and PSS.
- The regulator and governor set points are determined by the automatic generation controller, through system generation control which determines active power output such that the overall system generation meets the system load. It further controls the frequency and tie-line flows between different power system areas.
- The operation of the automatic generation controller is optimized by an economic load dispatch. Some of the constraints in an economic load dispatch study are determined by unit commitment decisions which in turn depend on the load forecast.
- System security states are defined according to the state of the system in relation to operating conditions following contingencies. Each of the system states requires a well-defined strategy to achieve its objectives and the strategy is implemented in a set of controls which could also be divided into hierarchical layers.

It can be seen from the above broad description that in the vertically integrated utilities a cohesive structure exists within one organization to oversee and perform all control functions. Of-course, there is enough interaction with other surrounding utilities to which the particular utility is interconnected. Adjectives such as, regulated, monopolistic, inefficient, started to be attached to this traditional structure. However, whatever the objectives, one overriding consideration in the operation of such utilities was the reliability of electricity supply to its customers.

Power systems are subject to a broad class of disturbances ranging from switching surges to changes in policies. Changes in policies can affect the interconnected system operation on a long term basis. Earlier the policies were set at the executive level of the system management, but now many of these policies are being set in response to economic and political trends.

3. RESTRUCTURING

In the 1990s a major restructuring of the electric supply industry took hold in various parts of the world. The main incentive behind this move was the introduction of competition through privatization and the economic benefits that competition between the resulting companies will bring. The major step in this process is the devolution of the vertically integrated utilities into three independent components, i.e. generation, transmission and distribution companies. This is resulting in the introduction of competition in generation, permitting open access to the transmission and distribution grid, and the introduction of retail competition.

A great deal of attention is being devoted to the marketing aspects of the restructured electric supply industry. Words such as revolutionary, challenging, evolving, exciting, risky, etc. are being used to describe the electricity industry. Although the talk is of spot markets, forward contracts, direct sales agreements, power purchase agreements, contracts for differences, etc., very little attention is being paid to the effects such a change may have on the technical and operational aspects of electricity supply.

The three major components comprising the devolved power system are individually owned and operated by:

- the generator, existing utility generator or an independent power producer,
- transmission facility owners, and
- distribution system companies.

The function of the generator and distributor is quite obvious, i.e. to bid respectively for the supply and purchase of electric energy through some kind of a Power Exchange. Contracts for the supply and purchase of energy are fulfilled with the help of a transmission facility owner who is responsible for the operation and maintenance of the transmission system.

In addition, now there will be a separate structure to administer the marketing aspects. This will consist of:

- a system administrator (Independent System Operator, Power Pool Administrator) to administrator the electrical energy market, (Albuyeh and Alaywan, 1999; McMaster, 1999),
- system controller (scheduling coordinator) as the real-time manager of electrical energy network operation,
- a transmission administrator to ensure that all and sundry have open, non-discriminatory access to the grid. The transmission administrator also contracts the services of the transmission facility owner for the fulfillment of the energy supply purchase contracts.

As before, the ultimate aim is to ensure grid reliability. These various entities have to:

- schedule power flow over the grid,
- dispatch energy as per a pre-determined merit order,
- manage transmission congestion or any other constraints,
- manage market information flow to market participants,
- carry out financial settlements and account keeping,
- dispatch and manage support services.

Other marketing related functions include:

- contracts with transmission owners to provide services,
- tariff preparation,
- management of and payment for transmission losses, and operation related functions such as:
  -voltage and VAr dispatch,
  -establishment of standards for transmission system operation,
  -system security through network monitoring, and
  -directing system operation.

4. POWER SYSTEM MANAGEMENT AND CONTROL UNDER RESTRUCTURED SCENARIO

Under any scenario, whether the vertically integrated utilities interconnected through pools, or in the deregulated environment, power system still has to be managed properly. The primary functions of the power management system are the system dispatch functions and network security functions.

The dispatch functions include automatic generation control, AGC, generation schedule and dispatch with the desired merit order.

The network security functions include network topology processor, state estimation, security and stability validation, optimal power flow, dispatcher power flow and network security sensitivity calculations.

4.1 Automatic Generation Control

In some parts of the US, particularly California, power management is done through the existing area control centres. Even in the short time that the California system has been operational, two AGC systems have been tried (Albuyeh and Alaywan, 1999):

- first a hierarchical AGC scheme when the generator is dispatched on a system wide basis, area requirements are sent to the Area Control Centre that in turn performed LFC and sent dispatch signals to the generating units.
- in the second phase all AGC functions are performed on a system wide basis and dispatch functions are sent to the generating units via Area Control Centres thereby utilizing a centralized generation control. This centralized AGC process is the interface with the scheduling applications by which process the supplementary energy bids and auxiliary services in support of the AGC function can also be calculated.

4.2 Voltage Control

In the deregulated environment power is traded through an open commodity market known as the pool, and the generators have no obligation to supply. At the same time they have to compete for business and have no assurance of market share. Thus the generators may come and go. From the system perspective this results in a continuously changing profile of power generation and reactive power support. This could adversely affect voltage at critical points within the system.

In the regulated industry, the utilities were obliged to maintain power system operation both in respect of meeting the load requirements and voltage profile. Any potential security problems could be identified well ahead of time and measures taken to obviate these problems. Automatically controlling the transmission network voltage is more effective than controlling the generator terminal voltage. Thus a utility could provide voltage support along transmission paths to improve synchronous stability.

Under the new structure, the ISO does not control generation nor can it install reactive power equipment at appropriate locations so quickly. Such a situation will require ingenious solutions, e.g. relocatable VAr sources, etc. (Luckett, 1999).

4.3. Transmission Congestion

Transmission plays a key role in opening markets to competition. It provides the means to broaden and strengthen competitive generation markets. No amount of competition in generation will bring to the consumer the benefits of privatization unless a robust transmission system exists that can allow distant generators to enter the high priced market and add to the market power of local generating incumbents (Hyman, 1999).

Transmission can function as a pipeline or as a bottleneck. The transmission operator, too, plays a vital role in maintaining grid reliability. Current operating practices are based on reliability criteria that were established in response to certain events in the 1960s. For example, one commonly accepted safety criterion is the (N-1) criterion which requires that the system continue to run even if one major part such as a critical transmission line or the largest generator is lost. This may require re-examination or the operator may achieve reliability by adopting other strategies to run the network more effectively.

Unless something is done to reduce congestion or increase transmission capacity, there is always the possibility of more blackouts like the two Pacific Coast blackouts of 1996 (Taylor, 1999) and the June 1998 price hikes. Transmission congestion management is becoming a major problem in system operation in the deregulated environment. Most solutions proposed in the literature to alleviate this problem seem to concentrate on rescheduling the power flow using some kind of economic incentives or economic penalty approaches. For an example of approaches proposed in the literature, see (Gribik, *et al*, 1999; Fang and David, 1999; Rau, 1999). Those who believe that network congestion will be relieved through economics instead of command and control are either oblivious of or ignore the alternative that control can play a very important role in increasing the capacity of the transmission grid and reduce transmission congestion.

One key point will be to enable the system to operate closer to the limit. This requires system monitoring and development of appropriate controls. Power carrying capacity of individual transmission lines can be increased by installing FACTS devices, a family of electronic controllers. They offer the added advantage of improving overall system reliability by reacting almost instantaneously to disturbances. Using FACTS devices, system operator will be able to dispatch transmission capacity and facilitate open access.

5. PROBLEMS AND CONCERNS

In an article titled "Keeping the lights ON", the authors state that "maintaining reliable grids in a deregulated power industry will get harder, as temptations to cut corners multiply" (Mountford and Austria, 1999). They further describe the paramount concerns within the industry as:

- "Market economics would define the optimal cost/benefit tradeoff that determines how system reliability is maintained and provided.
- Voluntary cooperation between utilities and integrated planning would disappear.
- Voluntary compliance with reliability issues would be lacking to the detriment of the global network.
- Open access would lead to multiple transactions, system overloads and operational difficulties".

5.1 Transmission Capacity

Technical problem arising from deregulation are chiefly related to transmission reliability in complex networks. Transmission capacity, already squeezed due to various factors, must now meet the new demands created by open access and deregulation. These demands consist of power flows for which transmission systems were not designed, arising from both open access and siting of new generation with little concern for transmission requirements (Baker, 1999).

Linked to this are the unit commitment and dispatch that are normally based on a computer model that minimizes production cost assuming that bids represent cost. The dispatch may be further modified on account of transmission constraints.

5.2 Coordination

One significant lesson that came out of the two major blackouts of July and August 1996 in the Pacific Northwest was the need, in the event of a disturbance, for a close coordination between the utilities, energy traders, generation operators and transmission operators. It is coming out that such coordination may be limited under the regulations set by the government legislation. Because of the lack of such coordination, controls for load shedding, etc. could not be implemented properly thereby resulting in the uncontrolled splitting of the entire interconnected system into four islands on August 10, 1996 and interruption of service to 7.5 million customers for periods ranging from several minutes to nearly six hours. Frequency in certain islands dropped to below 59.0 Hz for 20 minutes and below 60 Hz for over an hour. Such coordination is essential for the coordination of under frequency load shedding, load restoration, controlled islanding and establishment of criteria for multiple contingencies and relay failures.

5.3 Dispersed Generation

In the past utilities typically developed large central generating stations. Evolution of the grid under the restructured deregulated environment is resulting in the tying to the grid a large number of independent generators. The pattern is not a totally uniform dispersion. Safety and reliability issues will go up as more of these come on line. There is also the problem of getting the power to go where and when it is required. Unscheduled power flows include loop flow on neighbouring transmission systems and inadvertent interchange between neighbouring systems. This will of-course require certain performance requirements from excitation and governor systems.

6. CONCLUDING REMARKS

Restructuring of electric utility industry is being considered by a number of jurisdictions in North America. However, it is still relatively new with limited experience to date. Generation only is de-regulated initially. Since it is a common carrier of electric energy, a number of schemes for transmission system, like the distribution system, remaining in the regulated mode are being considered.

At present the major focus is to operate the system from an economic perspective and solve the various problems by economic disincentives or economic penalties. Very little attention has been paid to use control to remedy the problems encountered. Some recent incidents have demonstrated that there is a need to develop new ways to increase system reliability. Some actions aimed at increasing the reliability include:

- better communication and coordination among generators and the system controllers,
- creation of new markets which provide incentives to industrial customers for dropping loads.

Reliability issues in a competitive market can be mind boggling. Introduction of a competitive market is synonymous with buying and selling electricity and services. Reliability issues can be handled better by integrating the buying and selling with the physics of the network.

There is a scope for development of control techniques using new technologies to solve problems that may develop as deregulation spreads and electricity markets mature.

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Unbundling and Safe Operation of Power Systems Solutions for the Practice

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Abstract: *Starting from the continuously grown tasks and the strategy for the reliable operation of the interconnected European power system during the decades of regulated energy market, the cooperation between the new companies resulted by the unbundling process is pointed out; this means the cooperation between the power generation companies and the marketing companies - responsible for trade and supply - on the one hand and the now trade-independent system operators on the other hand.*
Based on these considerations, changes required in system operation when turning over to the open electricity market are stated as well as measures, which will - from the present technical and organizing standpoint - already be necessary for retaining a reliable interconnected system operation furtheron. These statements will be underlined by practical examples.

Keywords: *open electricity market, power-system operation, power-system control, power-plant scheduling.*

1. INTRODUCTION

In spite of the fact that the „guidance for the transit of electricity through transmission grids" has already been published by the council of the European Community /1/ at 29.10.1990, the transfer from the hitherto existing regulated electricity market to the open electricity market had not been performed – if at all up to now – smoothly within the single countries belonging to the Trans European Synchronously Interconnected System TESIS. Thus in Germany still not before the new law for the energy market /2/ was enacted at 29.04.1998. The following shock-affected transition led e.g. in Germany to sustainable structural changes inside the single utilities as well as between different utilities.

Besides others the main reason of these hectic and vehement reactions is the different standard of living in the varied UCTE-countries (Union for the Coordination of Transmission of Electricity). Due to this, in UCTE-countries with low wage rates electric power can be generated cheaper and consequently offered at lower prices. To retain the competitiveness within the open market the partner countries with high wage rates - and thus the german utilities too – have the only possibility to rationalize by all means, and this not only concerning maintenance and service but especially by reducing wage costs. As a stepshaped reduction of the wage level seems not to be realizable within the near future, there remains the only way of extreme man power reduction.

The second reason is that partner countries - with more central orientated power economy and corresponding subsidized Investments in the past - have often available higher amounts of cheap power generation units than other partner countries.

Another reason is rooted in the so far federal power economic structure of single partner countries, and this especially in Germany, where first utilities have opened themselves rather early for catching economic advantages, what other national utilities forced to do the same.

Such open market behaviour is in contrast to the restrictive behaviour of other more centralized organized UCTE-countries, where the power economy