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# New Infratechnologies in the Deregulated Power Sector

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**Abstract**

*This paper discusses new infratechnologies in the deregulated power sector. Most measurement and standardization techniques can be viewed as infratechnology. Infratechnologies are technical tools, including the measurement of data, test methods, and practices and technique. Standardization requirements are related to the measurement requirement. Although the system operation and market transactions concern many import aspects, they are insupportable and often complementary. This distinction between the technical and market information is important because the characteristics of information needs and the impact on economic efficiency and clean power are generally different.*

*The present paper focuses on infratechnologies that can potentially increase the benefits or decrease the operational costs. Infratechnologies play an important role in several stages of the effective system operation.*

**Key Words:** *Infratechnology, Measurement, Deregulation, Power quality, Power system.*

## 1. Introduction

Deregulation of the electric power sector offers the possibility of improving the system operation efficiency. This efficiency requires the development of an infrastructure that can address the information needs of the sector in a less centralized and more organized sense. This infrastructure includes new and sophisticated measurement techniques and standards for tracking transactions in electricity markets and monitoring the performance of the electric power system.

The major dynamics for the deregulation of the electric power sector include the following:

The rate differences among the regions providing more efficient use of the existing generation resources by transmitting power over longer distances than was typical in the era of industry regulation [1]; the new, low-cost techniques for electricity generation; the complexity of establishing a regulated sector with the incentives of making socially efficient investment choices; the difficulty of building a responsive regulatory body that will adjust the rates and conditions of service with respect to the dynamically changing market conditions; the complexity of monitoring utilities, establishing cost-based rates for all customer classes that will promote economic efficiency, while at the same time addressing the equity concerns of regulatory commissions.

The main economical benefits expected from deregulation include improved quality of electricity service by allowing rates, that more closely track the true cost of service and by differentiating the product quality, for example, offering new products with different degrees of power reliability. The potential benefits associated with deregulation are significant because the system and hence the economic inefficiencies are large [2].

These benefits, however, are not free. Potential costs associated with deregulation include increased transaction costs for market transactions, increased bulk power transmission requirements, increased costs for the monitoring and control systems to enhance the system reliability and power quality and potential decreases in overall system reliability and power quality.

System reliability and power quality are important concerns associated with deregulation [3]. Reliable, high-quality electric power is one of the main objectives of the industry. In fact, poor reliability and power quality are the most important factors limiting growth in developing countries [4].

To study and identify the measurement and standards for the electric power sector, a data collection procedure with two stages was carried out. First, an extensive literature review was carried out and data were collected from various commercial publications, professional journals and statistical resources, and then extensive e-mail and telephone communications were carried out by various companies, such as SIEMENS; ABB; Corporate Research; Helsinki Energy, Finland; European Copper Institute, Brussels; Detroit Edison, Michigan; Public Service Electric & Gas Co., New Jersey; Electric Power Research Institute, California; Arizona Public Service Company, Arizona; Independent System Operator, California; Ontario Hydro, Toronto and Arizona State University, Arizona to investigate the evolving structure of the electric power sector and to identify the potential areas, where measurement and standards play important role. The identity of individual contacts has been kept undisclosed for confidentiality.

The following topics where discussed: system planning and operation (measurement and standards for planning, operation of power generation, transmission, and distribution systems); and market functions: measurement and standards for wholesale and retail services. The questionnaire form used in the studies is presented in Appendix A.

## 2. Information Flow in a Deregulated Sector

Technical and market information has historically been confined in each system with minimal exchange with the other systems. However, deregulation resulted in a wide range of information flow in terms of type and quantity among the systems [5]. This information is mainly used to support the physical operation and the economic efficiency of the system as well as power quality. To maintain system reliability, system coordinators monitor inflows and outflows from the grid, as well as other conditions, such as voltage profile, throughout the system. Operating conditions must be measured, transmitted, processed and monitored and the the necessary actions must all be dispatched in real time to maintain system security and stability. In the future, real-time state information on system operations may be used to support market functions such as estimating the cost of bulk power transactions on the transmission system. Some of the technical information flows for system operations are as follows:

- Generation monitoring and control (standards and communications protocols are needed),
- Transmission system real-time monitoring and control (measurements/standards for capacity utilization and dynamical system analysis are needed),
- Real-time communication links to end users to support demand-side management activities (standards and communications protocols are needed).

Market information primarily supports the pricing and billing activities for forecasting and dispatching generation and carrying out ancillary services [6]. It is key that information is recorded at regular intervals (for instance, hourly) and exchanged periodically (for instance, daily) with the other control centers. In addition, tariffs for energy and ancillary services must be provided to suppliers hourly (at least) in order to get their response. As the number of measurements is large, compatibility and operating costs are also important issues. In addition, these data are mostly commercial and proprietary (and valuable); thus, data security is an important issue. The Figure illustrates typical system and market operations.

## 3. Measurements for a Deregulated Sector

The need for a clear definition of the services and measurements arises for the following three reasons:

• Service agreements between the service suppliers and the system operator require clear definitions of the services to be provided,

• Unbundling of services to independent parts requires clear definitions of these services and the performance of the measuring equipment,

• The new market structure based on the principle of competition, rather than of regulated monopolies, requires clear definitions, of the services and the performance of the measuring equipment.

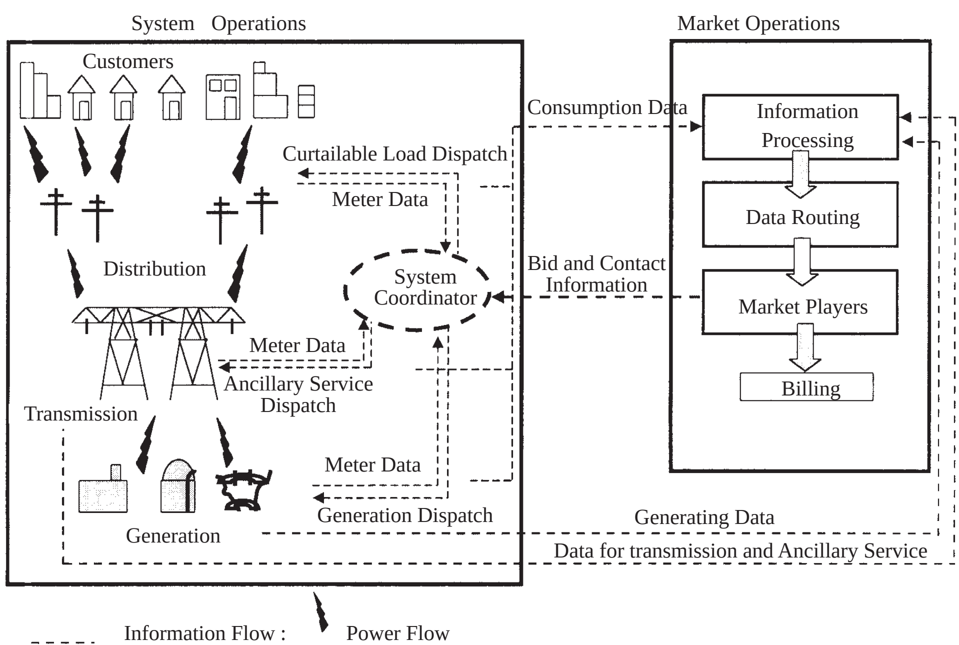


**Figure.** Information and power flow in a deregulated power system.

Deregulation has dramatically changed the characteristics, type and number of measurements to be made, although there is no physical change in the actual system. A large number of measurements are required at various locations of the system to carry out the specific contracted services. If these services are not properly monitored, less ethical competitors may win the next contract by lowering their service prices, even through the price does not actually cover the cost of delivery.

## 3.1. Measurements

Voltage and current are two fundamental variables to be measured [7]. Other variables, such as real and reactive power and energy, are calculated in terms of these measurements. Phase angle itself is not really a measurement, but is derived from the relation between voltage and current waveforms. Measuring harmonics involves measuring voltage and current over a period of time (the unique nature of power quality issues such as flicker, harmonics, sags and surges may warrant individually designed meters for each. Still, they are only measuring voltage and current) [8, 9].

Table 1 presents measurements needed for various services in a deregulated power sector. Note that although the time frames presented are typical, exact requirements may vary from location to location depending on the way each service is defined.

**Table 1.** Measurements.

| Service | Measured variables | Measurement period | Deployment period | Reporting period |
|---|---|---|---|---|
| Harmonics | V and I | $< 1$ s | | periodic measurement when problems are reported |
| Voltage, flicker, sags | V | - 1 s | | |
| Voltage regulation | W | -1 min | -1 min | Periodic |
| Voltage stability | Watt and/or vars | $< 1$ s | $< 1$ s | Periodic |

The wide range of voltages involved in the system introduces practical complications into the measurement task. Transmission voltages and currents are too high for direct measurement. Hence, particular devices are needed to reduce the sampled signals to a measurable level. Voltage transformers, which are referred to as PTs (potential transformers), are used for this task. Similarly, current transformers (CTs) are used to scale the currents down to a measurable level and to extract the electric current signal at a voltage much closer to zero than line potential. PTs and CTs are generally expensive devices, and careful attention must be paid in choosing their ratings in order to avoid saturation and distortion.

## 3.2. Synchronization of measurements

Synchronization is very important for the accuracy and correctness of measurements. System control and data acquisition (SCADA) systems collect data sequentially by polling the measurement points every few seconds. Measurements obtained from these points polled in the early cycles may not be in synchronism with obtained in the later cycles. This is especially true when a switching event occurs within a cycle in which the system operator (or automatic control equipment) is trying to analyze the system [10]. In this case, power flows at the ends of the line may be completely different because the line has been tripped as a result of a fault or one of the measurements was obtained before the generator has been tripped out and then the other one was obtained after the generator has been tripped out. The problem becomes more complicated as additional commercial entities get involved with the same data and as the measurements and equipment of multiple vendors are used. Hence, in order to avoid such problems, a time-stamping convention must be developed and these time stamps must be sent along with the measured data.

## 3.3. Additional measurements

A number of other parameters are measured in order to evaluate the present status of the transmission system. The power carrying capacity of most electrical equipment is inherently temperature-limited. The heat generated due to excessive power transfer may shorten the life of the equipment or may even cause the destruction of the equipment [11]. Measuring the temperature of a piece of equipment is often difficult, since the determination of the exact equipment subject to overloading is problematic and obtaining measurement on energized equipments is rather difficult. For example, determining the section of a transmission line limiting the power carrying capacity may change with the environmental conditions. The environmental conditions influence the temperature inside the cable, and the determination and transmittal of that information to the system operator may sometimes be difficult. Transmission lines are thermally limited, since heat allows the conductor to expand. If the conductor reaches a high temperature, the line may permanently weaken or fail. The power carrying capacity of transmission lines generally determined by the sag of the line, rather than by their thermal limits. These limits are determined with respect to the sag of the line calculated in terms of the ambient temperature and wind. These limits could also be based on direct temperature measurements instead of loading the line up to its physical limit. Alternatively, the line sag can be measured directly, in terms of the tension at the ends [12]. Status measurements obtained from circuit breakers throughout the power system indicating whether the lines are open or closed are also required. In order to determine the system status, all breaker and switch positions, and the generation status must be known. System operators require regular reports concerning the generator capacities either from the plant operators or by measurements obtained directly at the generator terminals in order to update the information concerning capability.

## 3.4. Transmission

Public reactions to new transmission line projects make it difficult to increase the transmission capacity of the system. Deregulation procedures introduce further complications by making it more difficult to argue that the transmission system is built exclusively for reliability purposes and then to use the power of eminent domain to obtain right-of-way. In a deregulated energy sector, the main reason for expanding the transmission system is operational economy, rather than security in other words, to provide a more economical alternative to installing a new generation plant closer to the load. The shift from system security to operational economy for the justification of new transmission projects increases the difficulty in convincing the public before building new transmission lines [13]. In a deregulated energy sector, not only the measurement system but also the operational principles on how to deal with customers is changing. Because customers that use similar transmission services may require different ancillary services, bundling these services with the basic transmission service would result in some customers having to pay different amounts for ancillary services [14, 15]. Unbundling the transmission and generation activities also makes the solution of the transmission problems (line and transformer overloadings and congestions) by using the traditional generation dispatch techniques more difficult [16]. Transmission system overloading and congestion problems can now be solved within the these principles by redispatching the generations with all the customers paying the increased costs associated with off-economic dispatch, through slightly higher average rates.

## 4. Standardization for Deregulation

Standardization is directly related to the measurements. Utility-oriented standards are continuously being developed [17-23]. Transactions for system operation and market activities differ in many aspects they are insupportable and often complementary. Hence standardization is needed for establishing a minimum set of activities. Establishing these standards will improve competition and lower the limits for entering the market. Standardization is also needed to obtain proper pricing information for the transmission services. For example, new tools/procedures are needed to determine the market values for bulk power at transmission interfaces in real time. These tools/procedures include the new measurement and reporting techniques to collect and distribute information obtained from these interfaces.

Some of the key areas where standards may be helpful in system operation are as follows:

- Standardization of information will be an important factor for competition. At present, some purchasers may have certain operational advantages in competition, because the asymmetrical information flow may be in their favor,
- Measurement and transmission of the operational data concerning the dynamic system performance (e.g. the transient performance of the system, and monitoring of the voltages) to the system operators,
- More frequent measurement and data transmission from the generating plants to system operators. For example, standards are needed to increase the amount of information received from the generating plants. In addition system operators need more accurate and correct information concerning load characteristics,
- Measurement and data transmission services provided to system operators for ancillary services concerning generations and loads,
- Requirements for maintaining system security, stability and integrity as the market opens up and grows,

and

- Design and development of real-time software with a proper help system to assist the system operators manage the incoming data display information in a form so as to avoid information overloading on system operators and facilitate decisions.

The main contribution of standardization for market transactions will be:

- To assure compatibility among equipment in different systems and to provide reliable and accurate information for contracts (e.g., billing, performance evaluation and verification) and to resolve disputes,
- To develop pricing systems that reflect proper incentives and to support the development and enforcement of non-compliance penalties.

Technological areas where new standards may improve wholesale and retail activities include the following:

- Development of a data exchange system (EDI) among metering, communication software and equipment, so that the retail market players (e.g., generation suppliers, distribution utilities and sales companies) can easily obtain and exchange data needed for their activities,

- Tracking of generations; whether they are supplied as agreed in contracts,
- Tracking of loads shed by retail customers and power marketers/brokers,
- Tracking of actions on power marketers/brokers whether they apply load relief by providing ancillary services as agreed in contracts,
- Tracking of power flows to assign responsibilities on the cost concerning cognition on lines that exhibit overloading or congestion. More accurate measurement of standard billing parameters for contracts that were neither previously needed nor explicit,

and

- More precise measurement of power quality, especially harmonics, voltage flicker, sags and surges for contracts that were neither previously needed nor explicit.

# 5. Economic Impacts of Measurement Standardization

Measurement standardization for the electric power sector will have a significant impact on the sector, as presented in Table 2. In fact, reliable, low-cost power is one of the main objectives in every sector of the economy. Power reliability and power quality are related to factors that affect customers. Power quality requirements affect customers by encouraging them to be sensitive to changes in system reliability and to install backup system equipment and protective devices.

**Table 2.** Impact areas associated with deregulation.

| Concerns associated with deregulation | Potential economic impact | Importance of measurement standardization |
|---|---|---|
| Power quality after deregulation | *High* | *High* |
| Diagnostic tool from the monitoring system conditions and identifying problems | *High* | *Medium* |
| Cost, complexity and vendor diversity of metering equipment for market transactions | *High* | *Medium* |
| Development of power markets at different levels of quality | *Medium* | *Medium* |

## 5.1. Power quality after deregulation

*Potential Economic Impact (High).* The importance of power quality will increase with the number of pieces of consumer equipment sensitive to power quality. The cost of low power quality will be paid by the failure of consumer equipment and lost productivity, labor and capital. An estimate of the annual loss to U.S. industry arising from power quality problems in term of loss of productivity or equipment damage is about $ 26 billion/year. A single shutdown in the electric power system costs as much as $ 500,000/hour, which is why U.S. companies impose conditions concerning power quality in their contracts. The present estimate of the loss due to power quality problems in European industry about 10 billion euros/year. In 2000, 50% of electricity customers in the information technology sector in Germany were found to suffer from data loss due to equipment and computer lockup [24].

*Importance of Measurement Standardization (High).* Harmonics and flickers increase with the use of power electronic devices in the system and create problems for loads susceptible to power quality problems. Standards for power quality and measurements to locate the source of problems are needed to maintain power quality.

## 5.2. Diagnostic tools for monitoring system conditions and identifying problems

*Potential Economic Impact (High).* The reliable operation of a power system spread over a large geographical area requires a high degree of observability by the system operators. The number of measurements to be installed in such a widespread system is generally large and this number increases with system size.

*Importance of Measurement Standardization (Medium).* Complicated instrumentation is required to process measurements and to yield results from these data. Measurement standardization will increase the speed of communication and decrease errors in data transfer, as well as help to coordinate different systems and lower the costs involved in the development of conversion and interface devices and software.

## 5.3. Cost of metering equipment for market transactions

*Potential Economic Impact (High).* The development of a widespread metering system will yield benefits beyond simply supporting the market transactions. System reliability and commercial activities will both be enhanced when numerous small power sources participate in the market in real time. For example, on the supply side, in terms of operational reliability, it is better to have a number of contingency reserves located at various parts in the system, rather than to rely on a single large generator. This is because there is always a risk that a single generator will fail to meet the demand. On the load side, increasing the number of measurements will provide the benefit of balancing the load demand in terms of both load diversity and demand elasticity. The benefits of enabling a customer as a resource are potentially very large and some respondents to the survey questionnaire characterized them as “hard to underestimate”.

*Importance of Measurement Standardization (High).* Measurement standardization will help to reduce the metering and communication equipment cost for small generators. In order to obtain reliability and commercial benefits, metering costs must be reduced to a level so that smaller generators will install these meters. Fortunately, the volume of investment involved in measurement increases with system size and hence the benefits of mass power generation may be exploited once the “technical specifications” for market participation are specified, and then customer confidence in marketplace offering is gained by these specifications.

## 5.4. Development of power markets at different quality levels

*Potential Economic Impact (Medium).* “Power quality” is an attribute that can only be achieved by paying the cost to be incurred. This cost may sometimes reach a high level that an industrial customer cannot tolerate. To overcome this difficulty and to provide power to customers at reasonable prices generation spectrum with different quality levels may be offered. The market could address the demands of individual customers concerning power quality, where customers who prefer “cheapness” against “quality” pay for the resulting problems (e.g., harmonics or flickers).

*Importance of Measurement Standardization (Medium).* There is an increasing need for detecting power quality problems through measurements and to define acceptable performance in terms of standards. Standards are important improving power quality from the sources at the generation level to the system level (e.g., if a set of conditions concerning power flows are satisfied at key points in the system), and to the customer level (e.g., at the terminals of customer appliances). Standards will also help define, match and satisfy users with different demand characteristics for power quality to suppliers that supply power with different levels of quality.

## 6. Conclusions

Deregulation in the electric power sector is far from reaching its final stage. It is likely that regional differences will arise in terms of objectives, applications and instrumentation. Several trends appear to be established:

- Development of a wide variety of commercial services requires increased measurements, communications, and control technology and equipment,
- Individual transactions for small power entities (both loads and generators) will be possible and important, and metering systems must accommodate these transactions.

Many real-time services will be unbundled, each to be charged independently to the side that benefits from the services. It will be possible to calculate the revenue at a faster rate in terms of the transactions and compare the requested and realized responses. A faster response will be required from the transmission system, and the technological achievements that will increase the speed of this response will valuable.

The study of measurement requirements and the needs for standardization is underway in several areas to assess the benefits that are potentially available in a deregulated electric power sector. A decision on whether to pursue standards in an area requires a prospective assessment of the benefits and costs of standards for that area. A retrospective assessment of these benefits is also valuable, not so much to affirm or withdraw the original decision, but to help refine the techniques and areas of investigation in future assessments.

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## APPENDIX A

The following survey questionnaire was used for the primary data collection activities:

1. Will the unbundling influence the availability of supply of certain ancillary services?
2. How do you regard the additional costs that somewhat offset the economic benefits?

3. Can measurement and standards play a role in enhancing system efficiency? If so, how?

4. What are the other areas where measurement and standards will lead to enhancements in reducing costs due to restructuring?

5. What are the major difficulties in system planning and operation associated with restructuring the power industry?

6. Will the increased number of power generation and ancillary service providers affect the power quality and reliability of system?

7. What role can measurement and standards play in maintaining system reliability? Will the increased number of power generation and ancillary service providers influence power quality?

8. What are the major technological issues that need to be addressed to implement wholesale and retail markets for electric power?

9. What measurements and standards are needed for the efficient pricing of bulk power transmission? In which areas will these measurements and standards have the greatest potential impact?

10. What measurement and standards are needed to assess the value of the service provided by the generator and ancillary service providers? In which areas will these measurements and standards have the greatest potential impact?

11. What measurements and standards are needed for metering and billing activities in retail services? In which areas will these measurements and standards have the greatest potential impact?

12. What measurements and standards are needed associated with system planning and operations? and

13. What measurements and standards are needed with wholesale market transactions?