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Deregulation of Power Systems in Asia: Special Consideration in Developing Countries

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Abstract — Power industry is undergoing restructuring throughout the world. The traditional vertically monopolistic structure has been deregulated and replaced by gencos, transcos and discos with competition introduced to gencos and discos in order to reach higher efficiency in electricity production and utilization. A lot of power markets have been established for the purpose. However for different countries, the principal objectives and considerations of power system deregulation are different. In this paper special considerations on power system deregulation of developing countries in Asia are discussed. Two regional power markets in China are used as examples. It is shown that for developing countries, the main objectives of power system deregulation are to attract various investments to power industry in order to meet the fast growth of electric demand caused by blooming economy and in the meantime to reduce government commitment and functions in power industry. Only this way, the power industry, as a significant infrastructure, can realize sustainable development at high efficiency. It is also shown that in the market environment, how to realize optimal system planning and reliable operation at acceptable electricity prices with qualifies service and how to transit to the market environment smoothly at lowest costs and lowest risks should be considered thoroughly.

Index Terms – Power System Deregulation, Power Markets.

I. INTRODUCTION

Power industry is undergoing restructuring throughout the world^[1-7]. The traditional vertically monopolistic structure has been deregulated and replaced by gencos, transcos and discos with competitions introduced to gencos and discos in order to reach higher efficiency in electricity production and utilization. A lot of R&D work has been conducted on power markets^[8-14]. However for different countries, the principal objectives and considerations of power system deregulation are different. In the developed countries, areas with higher electricity prices would like to introduce competitions so that electricity prices are able to reduce and social welfare can be maximized. In some countries, electric power supply sector is a regulated public utility, and the government

would like to privatize the electric power industry so as to reduce government commitment and functions. In this regard, gencos, transcos and discos are formed with competition introduced to gencos and discos to stimulate their incentives in efficiency improvement. When efficiency grows up and electricity price goes down, it can in turn promote GDP growth. In the developing countries, the power system deregulation and power markets are to establish fair competition among gencos so as to encourage investments to power industry from various resources, such as foreign investments, local investments and IPPs etc. The diversified resources attracted to power industry can well meet the requirement of fast growing electricity demand induced by blooming economy in the developing countries. This might be the main reason for Asian developing countries to promote deregulation in power systems.

Although power system deregulation is widely conducted in the world, it is not easy to successfully reach the initial targets set for the deregulation. Both experiences and lessons are obtained in practice. Considering that power industry is a significant infrastructure and in order to realize sustainable development of power systems at high efficiency, how to realize optimal system planning and reliable operation at acceptable electricity prices with qualifies service and how to transit to the market environment smoothly at lowest costs and lowest risks should be considered thoroughly in the market environment. This is actually an important task for the developing countries in Asia.

In this paper, special considerations on power system deregulation of developing countries in Asia are discussed in section II. Two regional power markets in China are used as examples and described in section III. Conclusions are drawn in section IV.

II. CONSIDERATIONS ON POWER SYSTEM DEREGULATION IN DEVELOPING COUNTRIES

A. Targets of deregulation

In Asian developing countries, power systems are usually owned by the state or provincial government before deregulation and operated as a vertical monopoly. Unified dispatch is applied to individual power grids with limited power exchange to external grids. Hence the interconnections among grids are relatively weak. Because of fast economic development, the electricity

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demand is growing rapidly and the power system expansion becomes a severe economic burden of the governments and a bottleneck of overall economy sustainable development. Investments from companies other than governments to power systems through approaches such as Build-Operation-Transfer (BOT) etc. are not so attractive. It is urgent to launch power system restructuring and deregulation and to establish power markets with fair competition so as to attract more investments from various resources to power industry. Moreover it is found that in some countries the monopolistic operation of power systems can also leads to low efficiency and even corruption for non-transparency and lack of surveillance in operation. It is clear that the power market is able to solve most of the problems appropriately.

Based on the facts mentioned above, the targets of power system deregulation and power market establishment in Asian developing countries can be outlined as follows with certain priority.

- * To attract various investments to power systems through open-access and fair competition so that power supply can meet the fast growth of demand in developing countries.

- * To reduce government commitment to power industry, which is a severe burden to the governments of developing countries concerning huge amount of investment to the infrastructure construction; and to mitigate government functions in power industry so that the government can focus attention to significant issues of entire society.

- * To encourage efficient electricity production and utilization through competition and electricity pricing mechanism. The energy resources can be saved. The production costs can be reduced and hopefully the electricity price can decrease. It can in turn increase social welfare and benefit to national GDP growth. Thus sustainable development of power industry can be realized.

- * Through competition, the market clearing price (MCP) of electricity can provide clear economic information for future power system development use; power supply services can be improved; gencos' profits may increase through higher operation efficiency; and the government tax return from power industry can be raised.

However the realization of the targets are not easy because power system deregulation involves the benefits of various parties and each party will try hard to protect its own interests and add influence to the power market policies and rules. To keep a large genco can make it possess noticeable market power to get more profits. To define a MCP with or without congestion management consideration will lead to totally different profit distributions. To organize a small provincial market or a large regional power market may bring about significantly different social welfare. In order to construct power

markets with fairness, justice and transparency, thorough considerations should be made to various aspects, which will be discussed below.

B. Considerations on the scheme of power system deregulation

The overall power market scheme is usually considered by the government. It includes several aspects described below.

- * According to the targets set for deregulation, it is very important for the government to consider carefully at the beginning on: how many markets should be organized throughout the country; who should be responsible to organize the power markets, how to organize gencos, transcos and discos; what are their functions; who is responsible for market operation and/or system operation; how to develop market rules; who is responsible for market surveillance; how to transit from current regulated market to future competitive market; etc. A timetable should also be developed for execution. It is clear that a lot of negotiations and government decisions should be made at this level in order to make deregulation process successful. International consultant might be helpful, however for the different economic and technical backgrounds, it is more important to rely on own conditions and experts to make final decision.

- * After the fundamental decisions in launching the deregulation, the market rule development is a key step. A lot of lessons have been obtained in this aspect. For developing countries, copying power market rules of other countries or other markets such as natural gas etc. might lead to severe results. The market rules should be different from market to market with only principles unchanged. Therefore all market participants (suppliers, consumers, brokers, operators etc.) should have rights to join or examine rule development with consideration on all economic, technical and physical backgrounds, conditions and trends. The rule should try to be a perfect set on market organization, market functions, goods to be exchanged and services to be provided, sub-markets definition (futures, forward, option, day-ahead, and balancing markets for electricity as well as the markets for transmission service and ancillary service, etc.), pricing mechanism, participants and relevant regulation, market operation and system operation rules under normal and emergency cases, settlement, surveillance, etc. The rule should be revised from time to time to meet new requests and evolve gradually.

- * Another important task in power market operation is to develop a reliable computer supporting system to manage bilateral contract records, day-ahead market bidding and MCP - power selling/buying calculation, congestion management, and market information announcement etc.

It should be pointed out that different markets have different potential risks in operation, to which special

attentions should be paid. The issue is discussed below.

C. Consideration on risks and their mitigations

To realize successful running of the power markets, a significant issue is to examine carefully the potential risks existing in a specific power market. The risks include natural resource types, amount and relevant risks, economic development in the market area, gencos and consumers' features, grid characteristics, potential market power, risk in power markets of single-buyer mode, special reliability and security issues in power system operation, power system planning/expansion in market environment, possibility of power exchange with adjacent power markets and relevant issues, and possible local government interference, etc.

For a power market operating very well for years, we should not say the market is perfect until it operates very well under extremely severe market conditions and can also keep power system sustainable and efficient development for a relatively longer time horizon.

Some risks, which are often appeared in the developing countries, will be discussed in a little bit detail below.

Unbalanced economic development within the market area. When a power market covers both rural area and industrial area, the power generation in rural area usually has lower electricity price than that in industrial area if there is no power exchange between the two areas or if special price policy is applied to the rural consumers. When they are in the same market, discriminating price or proper measures should be taken to protect rural area consumers. Otherwise, industrial area users would like to sign bilateral contract with gencos in rural area at lower prices and the electricity price in that area will rise and have negative impacts to rural users.

Hydraulic resource and hydrothermal dispatch in market environment. When a certain area has a higher hydraulic capacity ratio and/or the hydraulic resources should also be used for navigation, irrigation and flood control purposes controlled by the government agent, the risk of hydraulic power generation may occur. Basically there are several ways to dispatch hydropower: central dispatch with priority for hydropower taking care of peak load to maximize social welfare, thus all hydro power can get maximum benefits. However this might have negative impacts on thermal power generation profits especially when water resource is rich in certain years. However if hydraulic power plants bid in the same way as thermal power plants, the hydraulic resources might not be used efficiently. Besides some compensation should be provided to hydraulic power plants for their loss caused by diversified usages of water resources. Therefore certain rules should be developed to manage the case to make both thermal and hydraulic power companies have proper profits with incentives to make further investment to the power markets when load grows.

Market power. When a market has few power

generation companies, the company with large market share is able to control the price and get high profits from it. Such market power is harmful to consumers and may reduce social welfare noticeably. Therefore market share and/or capacity limits should be applied to any gencos. Grid congestion is another source of market power. Improperly defined transmission rights or congestion management rules can be utilized by market participants and strengthen the locational market power. In peak load condition or when large units are under maintenance, some machines become 'must-run', the market power can be severe. In addition to well-defined market rules to manage congestion and mitigate market power, market power existence and severity should be supervised constantly. Market surveillance and certain penalty should be applied to solve the issue.

Reliable and secure power system operation under market environment. This is the most significant issue in deregulation. The power system deregulation should not sacrifice the system operation reliability and security. However the risk does exist. Lots of reasons can cause the issue, such as lack of reserve capacity, lack of reactive power supply and voltage control, poor organization of real-time power balancing market, poor emergency control and restorative control, wrong load forecasting and/or poor generation and transmission expansion planning which in turn leads to inadequacy of capacity, etc. In developing country, the grid construction may lag behind the generator installation and the resultant stressed network may cause severe problems under large and small disturbances.

Centralized dispatch is highly recommended in such case to make full use of system-wide resources to avoid system instability and collapse. In principle, the economic issue such as various transactions should be determined by market rules before real time operation. Even if the resource/service is used/provided in real-time, it should be scheduled beforehand regarding to time, price, quantity, and the way to use/provide. However secure and reliable system operation should be realized in real-time absolutely through central dispatch and control and the system operator should have the authority to make decision according to load demand, power quality and security requests etc. under normal and emergency conditions. The difference of system operation with or without power market existence is that in power markets the operator should dispatch/use the available resource according to bilateral contracts, day-ahead market, ancillary service market outcomes determined beforehand.

Considering former monopolistic operation condition, existing EMS and operation experience, it is recommended to have two computer systems for market operation and system operation respectively but with real-time link to each other for information exchange, software/database sharing and necessary mutual support. The same institute will manage both computer systems to realize cost-effective operation and well coordination. A

system operator should get some training on market operation and vice versa so that he/she can understand the impacts of market environment on system operation very well.

Electricity pricing and demand elasticity. Pricing is a core issue in power markets. Bidding strategies are worked out base on pricing mechanism. For most power markets, MCP is used to determine day-ahead market price and electricity production amounts, which are then revised according to congestions if any. If the pay-as-bid principle is used in spot pricing, the ISO of a single buyer market can get significant benefits.

A disco, who buys electricity from the market and sell it to the end users, may suffer from fixed electricity price for end users. The load elasticity is very important in power markets. Market failure might happen when the energy supply price is extremely high while end user can't see it.

Other merchandises in power markets should have their prices well defined as well. However at the beginning stage, the market rules should be simple and practical. Some services, such as reactive power supply and voltage control, reserve capacity, AGC etc. can be considered as a whole by the ISO and then distribute the cost to users as a lumped 'uplift'. The users' bill will not show the price for each service. This can be improved gradually when the technology is mature.

Smooth transition to the market environment. This is also an important point in deregulation. A violent transition should be avoided. Usually when a market has adequate generation capacity and the supply is a little greater than demand, it is a good time to start power markets. The price will be smooth in transition and market rules can be tested under normal conditions first. Operators can practise in the real market environment. In this case, reliable and secure system operation can usually be ensured. Otherwise risk will appear in the test operation of power markets.

Power system planning in market environment. Under market environments, generation and transmission network expansion are vital to power industry sustainable development. Accurate load and fuel price forecasting and correct estimation of profits are very important. Government policy and market rules in power system planning also play an important role in system expansion. In order to attract enough generation investments, a key point to developing countries, some rules with bias to gencos have to be applied. A typical price policy is two-part electricity price including capacity price and energy price, which can greatly reduce gencos' risks in capital return and encourage generation investments effectively. This price policy is now used in NE China regional power market. In the meantime, to let grid company (which may also be the operator of both power market and power system) have enough income as transmission network capital return and for future

development, transmission service price can be set at a relatively higher level.

In power system planning, it is important to have an authorized institute to make centralized optimal planning with participation of market participants based on the information of economic development, load forecasting, energy resources available etc. Interested companies can then bid for power plant expansion and construction. However the transmission network expansion is a problem since it is difficult to get investment back in a short period through transmission service charge. The incentives to invest transmission line construction are therefore unclear. And the stressed network may lead to system instability under disturbances and even blackout under cascaded faults. Special measures and policies should be applied to solve the problem.

D. Other considerations

To ensure fairness, justice and transparency in market competition, government should have minimum interference to the markets. But special purpose committees can be organized to manage the overall power industry policy, energy planning and investment consideration, market surveillance, etc.

The market rules should also define duties, rights and benefits of individual market participants; include extraordinary operations of markets such as emergency stop, termination and re-start conditions and procedures.

In order to promote power exchange and obtain more economic benefits and social welfare, transaction between markets are highly encouraged which include hydrothermal coordination across the markets, emergency support to reduce reserve capacity cost, and peak-load-time-difference utilization, etc.

In certain area, special policies on electricity tariff are applied to special users, such as compensation to rural area users and special local industry, etc. These policy may exist at the beginning stage of power markets. It will be reduced and eliminated gradually when market is mature.

In general power system deregulation is a kind of 'system engineering', which is relevant to various aspects including economy, politics, society, engineering and technology. The success of power system deregulation will have great impacts on overall society and national economic development.

III. POWER MARKETS IN NE AND NW CHINA

China is a developing country in Asia with fast economic development in recent years. By the end of 2004, the total generation capacity reaches 447 GW, ranking at No. 2 in the world. Its electricity is still in short for the fast blooming economy.

Huge population, fast economic development and electricity demand growth cause severe burden of the government under traditional vertically monopolistic operation mode, in which the government is responsible for the investment of main power plants and transmission grids. In order to attract diversified resources to invest power industry, power system deregulation and power market establishment to ensure fair competition is the best and sustainable way to solve the problem.

The main steps in power system deregulation in China are as follows^[15-18]. In Dec. 1998, the State Council of China announced to launch power industry reform in China. In the first stage, the restructuring was focus on forming independent power companies and grid companies. Five provincial power markets and Shanghai power market were built up and tested as pioneers. Competition was introduced to gencos and the markets were in the single buyer mode. However the provincial power markets only covered small areas, which strongly limited the power exchange across the provinces and the goal of optimal use of resources over a wide region could not be realized. In Feb. 2002, the State Council of China announced a new document of 'The Scheme of Power System Reform'. In this document, it is declared that to form regional power markets will be the future direction of power industry restructuring in China. In Dec. 2002, two independent grid companies were formed. They are S. China Grid Company and the State Grid Company. The latter includes 5 regional grid companies. They are Northeast, Northwest, N. China, E. China and Central China Grid Companies. The traditional government owned power plants were reformed into five generation-group companies with their individual shares in each regional power market less than 20%. In Mar. 2003, the State Power Market Surveillance Commission (SPSC) started to work. Under the leadership of SPSC, Northeast and East China regional power markets were built up and committed to test operation in Jan. and May of 2004 respectively. In the meantime all original provincial power markets were asked to stop operation. Other regional grid companies are actively making R&D to ensure well design and optimal operation of future regional power market and avoid any potential risks.

The power market in NE China and R&D work in NW China will be discussed below.

A. Northeast Regional Power Market in China

The Northeast region covers three provinces (Hei-long-jiang, Ji-lin and Liao-ning) of NE China and East of Inner-Mongolia with the population of 100M and generation capacity of 41GW (85% thermal power and 15% hydropower) at the end of 2003. The rich coalmines in the north and heavy load in the south cause a long transmission corridor from N. to S. of the region. In addition, a short power transmission corridor exists in mid-region from west (thermal power) and east (hydraulic

power) to central part. The NE has been interconnected to N. China to sell their electricity.

From the Northeast Regional Power Market, we can see some rules which are typically defined based on developing country conditions and significant to secure operation and sustainable development.

- * The NE Grid Company owns the regional transmission network and runs the regional power market and power system in parallel. It is also responsible for organizing generation planning and transmission planning according to the load forecasting although the Grid Company is not responsible for the construction of power plants.

- * The NE Grid Company keeps main hydraulic power plants in hand (10% in capacity) for frequency control and peak load dispatch to avoid sky-high prices under heavily loading conditions.

- * Two-part electricity pricing is used, in which capacity price and energy price are separate. The capacity price is defined by the State Tariff Department, while energy price is generated through competition. This is good to encourage future investment in power generation and solve sunk-cost issue.

- * The market in its first stage adopts single buyer mode. For long-term contract, pay-as-bid rule is applied for settlement, which can protect the benefits of the grid company and consumers. For day-ahead spot market, MCP is used. In general major energy transactions are through forward contract (round 80-90% of total power exchange); only a small amount is exchanged through spot market. Besides the generation option market is under organization to reduce gencos' risks.

- * All transmission and ancillary services are centrally dispatched and the cost is distributed to consumers as a 'transmission cost' in average cost nature, which is also examined by the state Tariff Department. In order to avoid high service price, each power plant should provide certain reactive power and reserve power and join voltage and frequency regulation without payment. Later on a compensation method will be worked out.

- * Bilateral transaction is limited to large consumers and power plants as test right now. It will be gradually increase. Currently only machines at or above 200MW are in the market. Later on it can be generators at or above 100MW.

- * Ancillary service market is under consideration. Competition among discos and the transition of the market from single buyer to wholesale mode are also under consideration. But these will commit only when the current market operates well and experiences have been cumulated enough.

B. R&D for future Northwest Regional Power Market

The Northwest Grid covers four provinces or autonomous region. They are Shan-xi, Gan-su, Ning-xia

and Qing-hai. Its area is about one seventh of China. By the end of 2003, the total generation capacity is 20GW with 65% thermal and 35% hydraulic power. However the economic development is quite unbalanced in the region, relatively rich in Shan-xi and poor in Qing-hai. Hence the electricity prices are quite different in the two areas. The upper Yellow river provides rich hydraulic resources. However the request of nevegation, irrigation and floor protection, which is controlled by certain official organization, may significantly reduce the profits of hydraulic power plants and bring about difficulties in day-to-day dispatch. Another issue is caused by larger area and lower population density, which means more transmission system investment. The western area hydraulic power and eastern area thermal power can be dispatched properly to yield most economic benefits. The peak load time difference between western and eastern areas also asks for large amount of power transfer between east and west parts. However currently relative weak network may lead to severe congestion and relevant market power if power market is committed. The region is going to interconnect to N. China and Central China Grids to sell electricity to the two regions.

Based on the facts mentioned above, NW Grid Company is actively conducting R&D towards future power market operation. Three R&D projects have been implemented with the help of universities. The three projects covered the following three aspects respectively (i) overall market structure, market operation mode and market rule etc.; (ii) pricing mechanism and grid average transmission cost estimation; and (iii) Potential risks and their mitigations in the NW Regional Power Market. The last project was jointly implemented by the University of Hong Kong and NW Power Grid Company.

All the R&D projects examined the characteristics of the Grid thoroughly and made valuable qualitative and quantitative suggestions on future power market operation. Experiences and lessons from world power market practices are also considered in-depth, which laid a solid foundation for future successful operation of the power market and secure and reliable operation of the power system.

IV. CONCLUSION

In this paper, special considerations on power system deregulation in the developing countries in Asia are discussed. Northeast and Northwest Grids of China are used as examples to show the applications of such considerations in real power markets.

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VI. BIOGRAPHIES

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