Review of Electricity Deregulation with Market Model and Renewable Energy

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Abstract- ***Countries worldwide, both developed and the developing ones have adopted electricity privatization, deregulation, and competition as the preferred model for the present and future grid interconnection transactions. This decision has changed the traditional operating, market and transaction models in power system and have also accommodated newer concepts such as competitive market model, and renewable energy integration into the grid. The worldwide review of the electricity deregulation across most countries were presented with the various electricity models and market models adopted by different countries. The renewable energy in deregulated environment with it associated impact on wholesale market clearing price and its contribution to negative wholesale power price were discussed. The way forward discussed lessons that can be learnt by the developing countries from the developed countries with long history of electricity deregulation. Also, the anticipated future post deregulation challenges for developing countries were discussed and suggestions proffered.***

Indexed Terms- ***Deregulation; Electric Power Sector Reform Act (EPSRA); Market; Nigeria***

I. INTRODUCTION

The U.S electricity market in the late 18th century was unregulated. The first regulatory framework was developed between the city of New York and Wisconsin in the early 19th century [2]. But, in 1920 the Federal Power Commission was created in the U.S with the responsibility to regulate wholesale electricity markets and interstate transmission network. In 1935, the Public Utility Holding Company Act (PUHCA) was passed, and this led to the emergence of vertically integrated utilities organized mostly on a state by state basis with final sales to customers controlled by state utility commissions. With the passage of the Public Utility Regulatory Policies Act (PURPA) in 1978, the participation of the independent power producers in the electricity market was made possible. The real phase of electricity market deregulation started in 1996 with the creation of the wholesale power competition throughout the U.S by the Federal Energy Regulatory Commission (FERC). FERC seeks to promote competition in the wholesale market through open access policy and nondiscriminatory transmission provision of public utilities. The wholesale electricity market is under the direct supervision of FERC in the U.S while the retail market is directly being controlled by each state regulatory commission. As a result, the power market deregulation differs in each state with each state having its own separate markets [5] [6].

The electricity market of PJM is one of the largest liberalized markets in the U.S with coordinating activities in several states. It acts as an impartial, independent party which controls a competitive wholesale electricity market and deals with the high-voltage electricity to ensure uninterrupted supply of several million people [7]. The California ISO (CAISO) is one of the leading electricity markets in U.S. Its activities cut across several states and supplies electricity to over 30 million people on its network. Apart from the initial hitches of blackouts and bankruptcy that characterize the market in 2001, as a result of transmission capacity inadequacy and the inability of the wholesale to meet their demands because of the low retail electricity price, the CAISO has been able to provide for electricity market trading, analysis of electricity bids, transmission capacity, and

reserves needed to keep the grid in balance. CAISO uses locational marginal pricing method that forms a very transparent system that bills, electricity, based on the costs of generation and delivery [8]. Other wholesale electricity markets in the U.S include NYISO, ERCOT, and MISO etc.

II. OVERVIEW OF WORDWIDE ELECTRICITY DEREGULATION

The pioneering deregulation of the electric power utilities started in Latin America in the early 1980s. Chile was the first country to privatize its electric power utilities in 1982. This was followed by Argentina, Peru, Bolivia and Colombia in 1992, 1993 and1994 respectively. The other countries were, however, hesitant about the deregulation process, but later embraced the process as a preferred alternative owing to the success recorded by Chile in its deregulation process. Generally, the deregulation of the electricity market in the Latin America essentially is the reason behind the improved power sector of these countries [9].

The electrical power utility deregulation in the Oceania is dated back as early as 1987 when the New Zealand government decided to reform its power sector by the setting of the Electricity Corporation of New Zealand (ECNZ) with the mandate to own and manage the facilities of the Ministry of Energy. The ECNZ in 1988 was able to establish the system operator named Transpower, and also successfully set up a wholesale market in New Zealand. The new electricity market in New Zealand has performed very well over the years and was rated among most of the successful electricity markets in the world. In 1990, Australia started the electricity sector deregulation as a result of the recommendation of the Industry Commission reforms that included the state-owned electricity industry. The state of Victoria and New South Wales established a pool market in 1994 and 1996 respectively. The National Electricity Market of Australia was formed in 1998 and it is the product of the two early markets. The Australia's electricity successfully implements the wholesale spot market. The formation of the national energy regulator was the next step of the reform, which replaces the earlier mixed federal and state regulators [10].

The Asian countries also participated in the reform process of their electricity market. Japan began the reform process of its electricity industry in 1995 by promoting the participation of independent power producers into the wholesale electricity market so as to foster competition [11]. These independent producers are ineligible to bid for services within their area but only those that are outside were allowed. The Japanese electricity reform has gone through several changes and modification since inception with the expansion of the retail competition to the residential sector in 2016 and provision for the future unbundling of the transmission and distribution sectors. The power industry in China has experienced a series of changes since 1985. Some of these changes include the end of the monopoly of exclusive participation in power generation investment policy. Between1985-1987, the Chinese government introduces policies to boost new investors to participate in power generation markets, but there were no changes as the vertically integrated remained government responsibilities [12].

III. DEREGULATION IN EUROPE

The deregulation of electricity started in England in 1989 when the parliament adopted the electricity act signifying the commencement of reform in the electricity sector. The pool, electricity market model was approved for the new electricity industry. But, not until 1998 when the full deregulation of the electricity market was achieved [13]. Although the pool market has performed well for the satisfaction of the majority, it was still heavily criticized for its susceptibility to market power by large generators and also its inability to execute bilateral contracts. As a result, the pool market was substituted by the new market called New Electricity Trading Arrangement (NETA) throughout England and Wales in 2001 [13] [14]. Under the new NETA market that emerged, electricity is treated like any other available commodity where bilateral contract amongst parties is allowed. Norway was second to England in Europe in the deregulation of its electricity market in 1990 by the adoption of the Energy Act. The Swedish electricity market was reformed in 1995, and in conjunction with the Norwegian electricity market established the Nord Pool that was launched in 1996. This is a power market, which includes both bilateral and voluntary pool modes. Thereby, it has avoided flexibility of

England's initial pool market. The Nord pool power market was specifically designed to accommodate both the bilateral and the pool modes. Finland became the third country to join the Nord pool in 1998 and Denmark became a member in 2000. The European Union also set a deadline of the year 2007 among member countries after many years of intense negotiation through the Electricity Directive 96/92/EC that all electricity market must be fully deregulated. Although the directive highlights some guidelines for the gradual opening of the power sector, it wasn't specific as to defining a common guideline for the electricity reform in the member state. As a result, the reform follows a different structure in all the member countries. In Germany, the Electrical Economy Right New Regulation was adopted in 1998 for the full deregulation of the power sector [15]. The electricity market was fully opened, and allowing the end users to make a choice of suppliers. Greece and Spain are also members of the European Union with fully deregulated electricity industry.

II. DEREGULATION IN SUBSAHARAN AFRICA

In Africa, most of the countries still operate the traditional vertically integrated electricity sector with the exception of Uganda and Nigeria which has deregulated its electricity industry. The electricity deregulation processes in Uganda began in 1999, with the unbundling of the Uganda Electricity Board (UEB) into three subsidiaries, independent companies, namely: The Uganda Electricity Generation Company Limited (UEGCL) that is saddled with the responsibility to provide electricity generation services. The Uganda Electricity Transmission Company Limited (UETCL) which is to provide the transmission services of electricity to the distributor, and the Uganda Electricity Distribution Company Limited (UEDCL) which distributes electricity to end consumers [16].

The electricity reform bill of the government of Nigeria was passed into law in 2005 thereby paving way for the full deregulation of the country's power sector. Soon after, the state-owned National Electric Power Authority (NEPA) was unbundled into eighteen successor companies with the formation of a holding company known as Power Holding Company of Nigeria (PHCN) and the regulator called the Nigerian Electricity Regulatory Council (NERC). The government of Nigeria has embarked on the most comprehensive power sector reform in the African continent [17].

Nigeria remains the only country in Africa that has fully deregulated its electricity industry. Most other African countries electric utilities are still vertically integrated in nature, but many plans to reform their energy sector in the future for greater efficiency and increase participation.

Electricity generation in Nigeria began as early as 1896 with the installation of the first generating station in Lagos by the British Colonial Government [18]. Ever since then, the electric power sector has evolved through so many stages covering a long period of time of more than a century. The Electricity Corporation of Nigeria (ECN) established in 1962 to oversee the generation, distribution, and retail of electricity while the establishment of the Niger Dam Authority (NDA) was solely for hydroelectric power development in the country. These two institutions were merged together in 1972 to form a new organization known as National Electric Power Authority (NEPA) [19]. NEPA, from inception, was a public utility organization and have the monopoly of electricity generation, transmission, and distribution within and outside the country. With the increase in economic activities over the years as a result of industrial growth, population increase and improve lifestyle; energy demand has been increasing steadily without a corresponding increase in generation. Electricity demand in the country far exceeds the supply from NEPA and this shortfall causes recurrent outages and unreliable power supply to the customers [20]. Nigeria presently has a total installed capacity of 7876.4 MW with only less than 4000 MW available capacities for a population of 180 million people. Poor maintenance of the generators, inadequate transmission and distribution networks are some of the factors responsible for the discrepancies in the installed and the available capacity in the country. The transmission network consists of almost 5000km of 330kV lines and 6300km of 132kV lines with 6098MWA transformer capacity for the 330/132Kv network and 8090MWA transformer capacity for the 132/33 kV network. The transmission

network coverage is very poor with most parts of the country, not covered; the current maximum wheeling capacity is 4000MW. The Nigerian distribution network is equally characterized by weak and inadequate network coverage, overloading of the transformer and obsolete equipment. The Federal Government of Nigeria had embarked on a comprehensive power sector reform to solve the energy crisis in the country. The reform is expected to proffer solution to the energy crisis, and also, act as the roadmap for the full deregulation of the power sector. The electric power sector reform act 2005 (EPSR) is the statutory document that laid out the model and framework for deregulating the electricity industry. The reform has two main components: which are restructuring and privatization.

The implementation of the reform started with the creation of an initial holding company called the Power Holding Company of Nigeria (PHCN) in 2005. Although the processes were characterized by delays and postponements several times, it eventually started with a tentative timetable for the implementation schedule to follow. The Bureau of Public Enterprise (BPE) was established to carry out the deregulation and privatization of publicly owned establishment for the Federal Government of Nigeria [21]. Power Holding Company of Nigeria is made up of eighteen successor companies which include: six generation companies (GENCOs), one transmission company (TCN) and eleven distribution companies (DISCOs). The generation sector was deregulated through core investor sale and concession. The generating companies (GENCOs) will be responsible for operating the existing generating stations, and also, making the necessary investment to improve generation. The six-generation companies are made up of both thermal and hydropower stations. More new Independent Power Producers will be licensed in addition to the ongoing National Integrated Power Project (NIPP) to participate in the generation of electricity in the country. It is expected that in line with the deregulation objectives, more participants in the generation sector will bring about the desired competition in the electricity market and improve electricity generation in the country.

The transmission sector remains regulated and managed by the Independent System Operator (ISO). ISO's responsibility includes overseeing the market operations that involve the trading of the wholesale energy amongst market participants. The newly emerged transmission company from the unbundling of the PHCN is called the Transmission Company of Nigeria (TCN). TCN is responsible for guaranteeing the technical security and reliability of the interconnected power system, achieving the technical quality of the electrical power supply, and also, providing non-discriminatory access to the transmission system as stated in the electric EPSRA 2005. The competition level in the electricity markets is highly dependent upon the transmission system robustness, therefore, the government enters into a management contract agreement with an international electricity company to manage the Transmission Company of Nigeria on its behalf for an agreed period of time through a Memorandum of Understanding (MOU). There is also a core investors' sale (sale of equity) agreements between the Federal Government and the new distribution companies that provide for the DISCOs to manage the existing distribution network in the country. The eleven distribution companies are restricted to operate within specific geographical areas in the country. The distribution companies distribute electrical power to the consumers in their various operating areas.

The Nigerian Electricity Regulatory Commission (NERC) was inaugurated in 2005. Its establishment forms an integral part of the reform process. The responsibilities of NERC include: to regulate electricity tariffs and the quality of service rendered, to effectively oversee the power sector [22], and to monitor and discourage anti-competitive behavior among various participants, including mergers and acquisition which involves licensed electricity companies. NERC is also responsible for issuing licenses to the generating companies, transmission services, distribution companies, system operators, and trading companies as part of its many functions.

The national integrated power projects (NIPP) are gas turbine power stations located mostly in the southern parts of the country to harness the abundant natural gas in those areas. Owing to the relatively short duration of construction and installation of the equipment of the gas turbine power station (between 18-24 months) it is expected that approximately 5000 MW of electricity

will be injected into the National grid to boost electricity generation and improve electricity supply to both domestic and industrial consumers [23]. This short-term solution is expected to meet the shortfall in supply, pending the completion of other medium and long-term power projects. The Nigerian Bulk Electricity Trading is a public liability company owned by the Federal Government of Nigeria. NBET (Bulk Trader) was established in 2010, in line with the "Roadmap for Power Sector Reform" for trading licenses, holding a bulk purchase and resale license, to engage in the purchase and resale of electrical power and ancillary services from independent power producers and from the successor generation companies [24]

III. DEREGULATED ELECTRICITY MODEL

The analysis of deregulated electricity markets globally shows that the method of reform differs in all the various countries that were studied. The varied market structure adopted by most of the countries is largely due to both economic and political reasons coupled with the prevailing domestic conditions. But, it can be observed that they all bear similarities of competitive electricity markets. The first among these similarities is the unbundling of the former electric utility company into generation, transmission and distribution services which are now managed and run by different companies thereby resulting in a deregulated electricity market. Also, the regulatory authority supervises and enforces strict regulation on market guidelines and operations. The regulator is empowered by law to impose sanctions and penalties on any erring participants and also settle all forms of dispute that may arise. Under the deregulated electricity market structure, the generation and distribution are competitive while the transmission remains monopoly but with an open access and non-discriminatory policy. The monopoly of the transmission is not unconnected with the associated huge cost of investment, and also due to both environmental and ecological factors. This means that all participants need to have equal and non-discriminatory network access without prejudice. In achieving the fairness of non-discriminatory network access to all market players, an Independent System Operator (ISO) is assigned with the responsibility of managing the grid. Some parts of the responsibilities entail: balancing the bids/offers submitted through an increase/decrease, calculating the available transfer capability (ATC) of the network, dispatch/re-dispatch and providing ancillary services for system balancing, etc. Another similarity in some of the developed deregulated electricity market is the issue of hedging the risk of contracts thereby causing electricity prices to fluctuate. The market participants can either directly obtain the contracts from ISO, or the regulator or participate in the trading of these contracts like any other commodity in a secondary market. The two basic forms of the market upon which others are developed from are the pool market and bilateral contract market. The bilateral market offers the producers and consumers the opportunity for direct negotiation of the quantity of energy trading and the price. All the participants' schedule will be submitted to the ISO requesting for approval to undertake a transaction, the ISO then carries out some network analysis in line with the volume of transaction submitted and if the network is considered suitable to accommodate the transaction without the network balance being threatened after which the ISO can now accept this schedule. Once the ISO now accepts the transaction, the ISO then requires the participants to share in the cost of network losses either by providing the necessary power or through payment. Also, the participants are billed by the ISO for using the network to carry out transactions. The pool market does not provide a direct link between the seller and the buyer, the ISO operates a day ahead bids/offers arrangements for the market participants where the generators and loads are economically dispatched so as to minimize cost. Most of the deregulated electricity markets always include both market in its daily operations [25]. In Figure 2.1 the deregulated electricity market is illustrated in its general form.

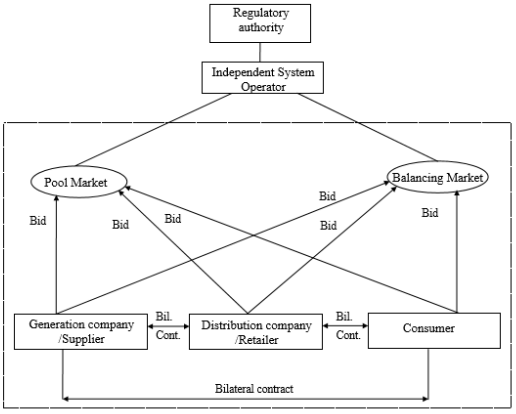

Figure 2.1: Deregulated Electricity Model [26]

IV. OVERVIEW OF ELECTRICITY MARKET MODEL

Economic efficiency is the major stated reason why governments have chosen to restructure and deregulate generation markets [27]. Electricity markets were developed as a way of enabling competition in electricity generation where competition had previously been seen as impossible. Electricity cannot be stored economically in large quantity and demand and supply must be matched at all parts of the system in real time. It had generally been accepted that a centrally planned and managed system was necessary to do this, but market mechanisms were developed in the 1980s, which promised significant improvements in the way electricity was generated and sold. It was shown at the time that such markets could achieve much higher levels of economic efficiency than the vertically integrated monopolies they replaced. Economic efficiency here refers to both short-term (static) and long-term (dynamic) efficiency. Short-term efficiency is maximized when at any time the system is using the lowest cost combination of plants to meet system demand and the lowest cost reserve is available to the system in the case of outages or changes in demand. Electricity markets provide this when they operate a transparent real-time auction, accepting generation offers from lowest to highest price until demand is met. Most buyers and sellers in electricity markets also seek the certainty and risk management benefits of electricity contracts across the market. But a transparent real-time market is essential to allow competition, transparent price setting and the basis for contract prices. During the day-ahead market, suppliers offer generation services, buyers submit bids for energy, and ISO procures ancillary services on behalf of buyers. These markets are then cleared through security constrained unit commitment auction, the resulting clearing prices are used for financial settlement [27] [28].

Long-term efficiency relates to the way in which the market develops over time. This includes providing timing signals for investment to enter the size and type of plant that the market requires and for the exit of older or higher cost plant that cannot compete with new and more efficient technology. Previously, the vertically integrated and centrally planned systems increased their capacity as they saw fit and passed on these costs to customers via regulated tariffs. The risk of the investment was passed on to customers rather than borne by the investor. Questions that are pertinent include: Do we have a transparent market that results in the economic (least cost) dispatch of the plant to meet demand at any time? Is the market price a good guide for long-term contract prices? Does the market encourage appropriate entry and exit of the plant? Who bears the risk of new entry?

To ensure power system security and reliability, ancillary services are needed, including frequency and voltage control and black-start capability. ISOs or their equivalent organizations purchase ancillary services from service providers. Frequency control ancillary services are commonly traded on a market that has marked similarities to the electricity market.

V. COMPETITIVE MARKET

Market trading of electricity as a commodity can have significant consequences for customers. With open access, suppliers will target those customers with the most attractive load and profit profiles. It will, therefore, follow that market trading will lead to load disaggregation and potentially higher supply costs for residual customers. Market trading has also led to greater price volatility and an increased premium for risk. Therefore, a competitive market is a market whereby there are a number of producers and consumers with the ability to freely choose which producers they want to acquire services from. In the case of competitive electricity markets, generators

(renewable and conventional), are producing electricity and consumers both large and small can freely choose their electricity service, provider.

The components of the typical competitive market are shown in Figure 2.2. It comprises of the generating companies (Genco), the independent power producers (IPP), the wholesale market, the retailer, and consumers.

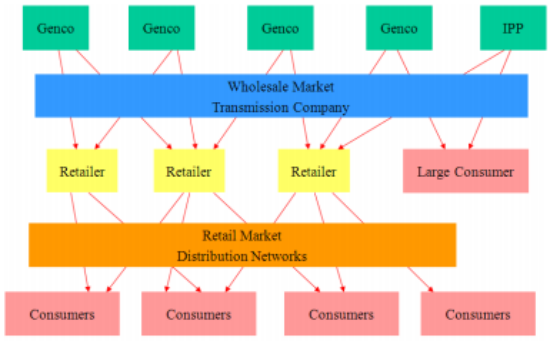

Figure 2.2: Competitive Electricity Model [29]

VI. RENEWABLE ENERGY IN DEREGULATED MARKET: EXPERIENCE OF OTHER COUNTRIES

Many countries, such as Germany, Spain, France, UK, and the US have a significant proportion of renewable energy mix. Although the level of integration of renewable energy varies from one country to another, most of the experience of such integration in the individual deregulated electricity market is almost similar.

a. Impact of Wind Integration on Wholesale Market Clearing Price

It was found that the wholesale electricity spot prices in the UK would be significantly affected by the amount of wind generation in every hour, more especially if it relies significantly on the wind generators to meet a large share of its renewable energy target [30]. Mostly, an increase in the availability of wind generation usually results in a decrease in the wholesale market clearing prices mainly because the availability of the wind generation reduces the demand for thermal generation output [31] [32]. This is mostly because market clearing prices are proportional to the marginal costs of generation, with conventional generators having higher marginal costs compared to wind generators.

A lower market clearing price will reduce power prices for all consumers; therefore, additional wind power can reduce the cost of electricity to a wide range of consumers. However, according to [33], it can be deduced that the federal tax credits and state renewable portfolio standard policies result in lower market clearing prices, it distorts wholesale power markets, displace generation from the base load power facilities, and unfairly impact the compensation received from existing generation assets.

Figure 2.3 illustrates how additional wind power within a competitive market might theoretically impact the electricity clearing for all generators.

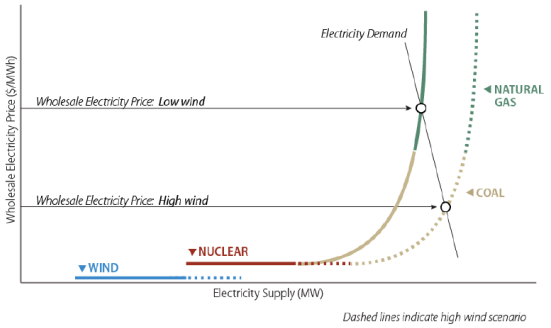

Figure 2.3: Illustration of Potential Wind Power Effects on Wholesale Electricity Prices [34]

Figure 2.3 shows two different scenarios of low and high wind availability. During the period of high wind, the wholesale electricity price curve shift to the right, thereby reducing the wholesale electricity price paid to both conventional and wind generators as against the price paid during the period of low wind availability.

b. Wind Power Contribution to Negative Wholesale Power Price

The negative pricing phenomenon occurs when the supply of electricity exceeds the demand. When this happened, the base load generators, like coal, prefer to stay running and pay to put their electricity on the grid by placing negative auctions, bids rather than take their generators offline and incur high ramping costs when demand goes back up. The cost of paying end

users to consume their electricity is less than the ramping cost of restarting their turbines. But, considering the role of wind generation in the occurrence of negative prices, during the period of high wind power in-feed and low demand, the market reacts with bids underneath variable costs in order to avoid ramping-down base-load power plants, which are expensive to restart. Thus the likely impact of negative pricing on resource adequacy remains one of the most persistent issues related to variable renewable energy sources and competitive market design. Negative wholesale power prices serve as a market indicator for extra requirements that target system flexibility.

VII. THE REFORM AND THE WAY FORWARD

A number of studies have examined the effect of reform on economic performance in the developing countries, and conclude that ownership alone does not generate economic gains, and that competition is associated with lower costs, lower price and high productive efficiency, and that success or failure of deregulation depend on the post-deregulation regulatory framework (Ying-Fung, 2008). Congestion poses a great threat to the success of deregulation in the electricity sector. Transmission congestion simply means the inability of the network to accommodate all of its desired transaction due to one or more constraints [8]. It distorts the market and causes electricity price increase in some area. The Transmission networks represent undoubtedly the infrastructure that enables the power market, but it does not sufficiently support the competition of generator, causing congestion of lines. Since the transmission system is limited by operational and reliability constraints, the market participants face significant congestion cost. Transmission congestion inhibits market competition and it is capable of jeopardizing the whole deregulation process if not properly managed. Therefore, as a post-deregulation measure, proper congestion management techniques should be applied to reduce the effect of congestion and allow for competition among the various market participants. Undue political interference that characterized developing nations' politics should be discouraged in the deregulated electricity sector and consistency in policy formulation and implementation by successive administration to sustain the achievements recorded in the reforms should be encouraged. A policy on integration of renewable energy sources of electricity generation for effective energy mix and for climate change purposes must be formulated. Since electricity industry is highly capital intensive, government should encourage investment in this sector through provision of enabling environment for the investors to earn from their investment so as to further re-invest into the sector to improve the generation, transmission and distribution's infrastructures in the country.

CONCLUSION

With over 600 million people not having access to electricity in Sub-Saharan Africa, it becomes imperative that radical change is necessary to bridge the gap between demand and supply so as to unlock economic growth and development. Deregulated electricity industry is expected to bring about competitiveness and inject efficiency into most of the state run utilities in Africa for improved performance. It is also expected to open up the space for private sector participation in form of independent power producers (IPPs) for increase electricity generation and distribution through either or both conventional and renewable sources to meet the growing demand for the purpose of increasing access to electricity for both unserved and underserved. Deregulation remains a viable alternative to improve electricity supply among most African countries after several years of non-performing utilities. Post-deregulation management of the power utilities company remain very crucial and will required careful and consistent regulatory frameworks to achieving the desired result.

Congestion management would be critical in the management of the post deregulation challenges as the transmission network remains the back bone of the electricity deregulation, providing open and non-discriminatory access to all the participants. Congestion occurrence can be experienced in various forms and can be caused by transmission line outages, changes in demand and uncoordinated transactions. The need for congestion management to achieve the objectives of deregulation without compromising the security of the transmission network, and at minimal cost for social welfare reason cannot be overemphasized. Post-deregulation congestion

management is more complex as generation, transmission and distribution companies are unbundled. Therefore, congestion management is very important in emerging deregulated environment like sub-Saharan Africa and the system operators need efficient non- discriminatory mechanism to solve congestion problems.

The primary economic rationale for restructuring of the electricity industry has been the promise of lower prices and more efficient power generation through market competition, but electricity market gamming by participants could prevent this objective from being realized and subject customers to high electricity price. Electricity market gaming distorts market and gives undue advantages to some generation companies or IPPs. It is a major barrier to fair competitive trading in a post-deregulation era and must therefore be discouraged by the system operator.

Many uncertainties exist in electric power system, electricity market parameters such as demand fuel cost and availability and equipment availability are stochastic in nature. Therefore, issues relating to decision making under uncertainties are relevant to deregulated electricity market.

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