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Review Article

Power Wheeling Pricing Considering Congestion in Power Network: A Review

Akangbe Samson Ayorinde[1, *], **Adepoju Gafari Abiola**[2], **Adebayo Isaiah**[2]

[1]Electrical and Electronic Engineering, Adeleke University, Ede, Nigeria
[2]Electrical and Electronic Engineering, Ladoke Akintola University of Technology, Ogbomoso, Nigeria

Abstract

Limited capacity of the power system infrastructure has a limiting effect on the quantity of electrical power that can be transmitted thereby resulting in the system been congested which also affects the quality of electrical energy supplied. Congestion is an undesired effect in power system with serious economic, reliability and security effect on power system infrastructure, which are yet to be adequately quantify in term of cost. Congestion occurrence and management on the power system network has been studied extensively, causes of congestion and various management techniques have been proposed which are at great financial consequences. While setting transmission wheeling prices, congestions are not adequately considered, nor are the management methods accurately financially compensated. Some wheeling pricing techniques however recognises the short coming and takes into consideration the financial cost of congestion and it's management methods when setting their transmission wheeling costs. This paper is a review of wheeling methods that takes into consideration the cost of congestion and the management techniques when setting wheeling prices and makes a recommendation using financial and economic implication of the occurrence of congestion and the management techniques adopted in reducing the impact when setting wheeling prices, in order to encourage investment into the transmissions system infrastructures.

Keywords

Infrastructure, Congestion, Wheeling, Restructure, Embedded, Management

1. Introduction

The main objective of any business is profit making, therefore restructuring of power system due to recent transformation by the unbundling of power system infrastructures aimed at increasing the capacity of the system and positioning the power sector for greater efficiency [1] will greatly be enhanced if it becomes a more profitable venture to invest. For greater efficiency and better performance, the power system was restructured into generation, transmission and distribution, therefore the pricing of electricity is becoming a more difficult task [23]. Power wheeling has a significant effect on power system infrastructure such as increased losses, transmission system congestion, and system security [2]. Electricity pricing is a significant aspect of electricity [26, 38, 40], although so many issues regard electricity pricing remains unresolved, price setting is the basis upon which the income of the electricity company depends. Price setting must take cognisance of the capital cost [37], operating and maintenance cost, power losses in the network and congestion.

[*]Corresponding author: akangbe.samson@adelekeuniversity.edu.ng (Akangbe Samson Ayorinde)

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The setting of the prices must bear in mind to create a fair competition among the power companies, it should be to encourage efficiency among participants companies, to recover the invested sum, the pricing procedure must be clear, easy to calculate and fair to all involved. The pricing should be non discriminatory but reflect accurate use of power infrastructure by each consumer [10, 15, 39].

2. Wheeling Methods

Traditional methods of pricing such as the embedded method which include postage stamp method, contract path and Megawatt-mile (MW-mile) method have been used over time. The Locational method such as zonal or nodal methods have also been used [8, 30], the forward looking methods such as incremental methods that include short run and long run incremental method and short and long run marginal method [10, 21].

These pricing methods have been explored severally with a view to getting maximum return on investment but that has not been possible because all of these methods have their strong and weak points.

In Embedded pricing method, prices are determined by the level to which the power infrastructure is being used. In the postage stamp pricing technique, each user of electricity is allocated a price based on the amount of load shared out of the total load [9, 14, 32, 36]. With this method, full recovery of investment cost is possible, the transmission pricing is easy and stable as each consumer can easily calculate his share, but as easy and convenient as this method is, the shortcoming of this type of pricing cannot be ignored because [12], it does not allow for each customer to pay for a share of infrastructure used [6], each of the network users pay the same price for different quantity of electricity used, thereby subsidizing high level user by low level users. It does not consider losses or congestion in the system [29].

The contact path sets a specific route between the point through which the power should be transferred between the seller and the user, a part of the asset cost and the cost for new infrastructure along the agreed route is added to the contract sum which is reflected in the pricing, with this pricing method, full recovery of the invested sum may be possible thereby encouraging investment, the pricing technique is also easy to determine. However, this method does not give the true path of power flow and therefore the effect of the contract on the infrastructure cannot be determine, it also does not reflect the true amount of infrastructure used for the transaction [13, 22]. It does not account for losses or congestion on the system as a result of the effect of the contract.

The MW-mile method seeks to overcome the above shortcomings, it is a load flow based method, It tends to consider the amount and level of power system infrastructures used for each transaction using load flow analysis [17]. The proportion of the load flow due to the transaction and the circuit capacity is determined with geographical distance, this proportion is multiplied by the cost of the circuit is used to derive pricing for each circuit. This kind of pricing is far, better and more efficient, but the method cannot account for the system losses and congestion due to transaction, there may likely to be system being under-utilized resulting in lower income for the system owners [6, 9, 10, 22, 24, 32, 36-38]. This method only considers the real power, the effect of reactive power is ignored on the system. A method that considers both real and reactive power has been researched and result compared, it shows an improvement but still not yet satisfactory, the direction of flow, and transmission conditions were ignored [34].

3. Wheeling Prices Reflecting Congestion Costs

Several researches have been carried out particularly with embedded cost method that seek to correct some or all of the shortcomings of these pricing techniques, but only few of them are able to consider congestion in power system pricing. This paper is seeks to review power system pricing techniques that considers power system congestion in electricity pricing.

Congestion is defined as a condition that can limit the transmission of high voltage, which can cause a significant increase in the cost of providing electricity. It occurs when the power flow exceeds the line capacity, it can lead to disconnection of generator or consumer [18, 42, 16] the occurrence of congestion also affects the security of the power network [19, 2, 27], it occurs when a particular network element reaches it limit and it is unable to transfer any more power. Congestion in a network indicates that the demand for electricity in a particular environment is equal to what the network is designed for, considering network security, therefore, an alternative supply path has to be provided which can affect the cost of supplying electricity. Thus, congestion leads to variation in the cost of electricity. For congestion issues to be resolved, costly actions are usually taking such as alteration of production schedule of some power plants which comes at a huge price for the company [27]. Some researchers have worked to proffer solutions to the issue of congestion in the power systems, the management of congestion has been classified as the free and costly one, the free one being measures taking by transmission company which include the modification of network topology by installation transformer taps, operation of conventional compensation devices like Flexible Alternating Current Transmission (FACT) devices. The cost method uses price control mechanism to solve congestion issues, indicating the issue of congestion comes at a huge cost for the power system operator [4, 27].

Amir et al. proposed determination of tariff for wheeling contracts considering fairness congestion cost allocation, the author divided transmission cost into two parts; the capacity cost and congestion cost [1]. The congestion cost was allocated to all users who contributed to congestion using distribution factor at different buses, the capacity factor was calculated using MW-mile method. When congestion occurred, each of the party that contributed to the congestion paid according to its contribution and when there was no congestion, the cost was low which was shared equally among users.

Amir B et al. proposed security base tariff for wheeling contracts considering fair congestion cost allocation, the author divided the transmission cost into three parts; capacity cost, congestion cost, and security cost. The transmission cost was calculated using distribution factor and MW-mile method and then with wheeling contract in the network, congestion cost and security cost related to wheeling contracts are allocated to the contract parties [2]. The security cost was determined by taking a random line outage, load interruption cost is calculated with and without wheeling contract. The load minimization cost was taking as objective function and A-factor calculated to determine the congested line. Applying the wheeling during the peak loads, the charges of congestion occurring is raised and congestion cost should be paid by the contract parties. The model was tested using IEEE 9-bus system with wheeling contract assumed between busses 6 and 8. Heavy congestion along line1-4 increased the cost paid by the parties involved in accordance to their contribution. It was concluded that congestion management guarantee the power system security.

A new wheeling price calculation method considering transmission line congestion and loss cost proposed by [3]. proposed a new wheeling method which included capacity cost, congestion cost and loss cost of transmission line [3]. Capacity cost was determined by Shapley value game theory, transmission loss by using loss calculation method and congestion was calculated using the proposed method. The proposed method was tested on one generator, one transmission line and one load. The result demonstrated that the wheeling price increases gradually with losses, and with congestion, there is extreme increase in price.

Power flow tracing based transmission congestion pricing in deregulated power market was researched by [7] the author calculated the cost of congestion using power flow tracing principle, Bialek's tracing principle to find power flow from generator to transmission line and load [35]. Using upstream and down stream algorithm, the power flow at congested line was obtained, the difference between the flow at base condition and congested condition is computed. The fixed cost of generation, fixed cost of load and fixed cost due to the occurrence of loss was determined from the difference in power flow at base case and congestion condition. The congestion cost was determined using locational marginal price (LMP) method. The result showed significant price difference with large scale power system.

Nilesh K. et al. [27] related the issue of congestion to voltage instability, the occurrence of congestion in the power system results in higher reactive power needed to sustain voltage at the appropriate level which cannot be supplied the generator due to armature and field heating limit, these extra reactive power is supplied using additional generator, distributed generation of capacitor bank. All these are extra cost to the transmission system owners.

An introduction to congestion in the [43] described congestion as a bottle neck that occurs when some elements in the network attain their maximum capacity to transfer electricity. To guarantee the security of supply, other paths to transfer electricity must be sought which affect electricity prices and cost paid by consumers. Congestion also affects system efficiency. Congestion might reflect change in pattern of generation or demand or change in transmission capabilities. The lower the likelihood of network congestion occurring, the lower the physical and financial trading risk of participants. Therefore, congestion can be eliminated when enough money is spent on the provision or expansion of transmission network infrastructure. It was concluded that congestion leads to higher prices increase, reduce system security and reliability with high trading and dispatch risk. Efforts at reducing the risk result in reduce system economic efficiency and weak economic signal that can aid investment decision into the system.

4. Congestion Management Techniques

Congestion in power system may be inevitable due to the limited capacity of the power system infrastructures, and rising power demand [23, 33], although it should be discouraged through whatever method possible to enhance security and reliability of the power system. Congestion management method has been divided into technical and non-technical methods [5, 25].

Expanding the existing power infrastructure to accommodate the rising demand in electricity has been suggested [18, 20, 31], the use of FACT devices to reduce congestion in transmission lines was also suggested [5, 14, 25, 28]. Generator and load scheduling and congestion price settings have been proposed as methods to overcoming congestion in power system. [41] used demand response programme and distributed generation to solve congestion issue.

It can be seen that congestion occurrence and management in power system are all at certain cost to the operator and power system managers [11, 27]. Therefore, wheeling should include congestion management cost and the occurrence of congestion be proportionately compensated.

5. Conclusion

Congestion occurs as a result of limited capacity of the existing power infrastructures, the impact of which might not be easy to adequately quantify, congestion is of great economic and financial risk on the power system because security and reliability is at stake. Although, congestion can be managed, but its impact on power system has not yet been adequately compensated. With adequate funding, congestion can be prevented or minimized leading increased system performance and enhanced security and system reliability. Consequently, congestion effect and management comes at a greater cost, therefore, managing congestion in power system should be adequately renumerated, and its occurrence be proportionately compensated.

Abbreviations

FACTS	Flexible Alternating Current Transmission
MW	Megawatt

Conflicts of Interest

The authors declare no conflicts of interest.

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