IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE)
e-ISSN: 2278-1676,p-ISSN: 2320-3331, Volume 10, Issue 2 Ver. IV(Mar – Apr. 2015), PP 29-34
www.iosrjournals.org

‘Line-by-Line’ Embedded Transmission pricing methodologies

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Abstract: *The environment of the electric power industry in several countries around the world is changing from traditional regulated conventional set up to a deregulated one, to provide more effective generation of electric power. The movement of electricity industry environment in such a fashion resulted in the market forces to drive the electricity price and reduce the net cost through amplified competition. Provision of correct economic signals to the market participants in a deregulated electricity market is necessary to ensure reliable and secured operation of the overall power system. This paper introduces the concepts of deregulation of electric power industry and wheeling cost of electrical energy, exhibits different types of wheeling cost computation methodologies and presents in detail an embedded wheeling cost methodology namely “Power flow based Line-by-line methodology”. A software package in MATLAB is developed to compute the wheeling cost by different versions of the aforementioned methodology, applied on IEEE 30-bus system and the results obtained are presented for comparison.*

Keywords: *Deregulation, Embedded cost, Independent Power Producers, Wheeling cost, Incremental cost*

Nomenclature

Rs.	-	Rupees
BC	-	Book cost in Rs.
n	-	Year
p.u.	-	per unit
LIFE	-	Average service life in years
RC	-	Replacement Cost in Rs.
CoD	-	Cost of Depreciation in Rs.
SALVAGE	-	Salvage value in p.u.
DR	-	Depreciation Reserve in Rs.
NP	-	Net Plant cost in Rs.
AWC	-	Annual Wheeling Cost in Rs.
IPP	-	Independent Power Producer

I. Introduction

Regulated electric power industry is the one in which the three phases like generation, transmission and distribution of electric power are planned and operated by a single entity [1]. However, electrical energy is not a form of energy that can be stored and reused in large quantities. Also, it is difficult to meet the drastically increasing load demand as well as to maintain continuous supply at an economical cost. To overcome all these, electric power industry needs to be deregulated.

Deregulation is the concept where generation, transmission and distribution of power can be carried out by independent entities. Deregulation offers lower electricity price, provides better consumer service and maintains an improved and efficient system. The concept of deregulation has been introduced in many fields like automobiles, finance, communication, power industry etc. The present scenario of electric power industry in most of the countries around the world, starting from Chile in the early 1970’s, is undergoing the restructuring process [2]. Competition has been introduced in electric power industry around the world based on the promise that it will increase the efficiency of the industrial sector and reduce the cost of electrical energy.

Deregulated power industry allows many private companies called ‘IPPs’ in the power generation field to be connected across the power transmission system. This situation also welcomes recent and effective methods of power transmission in the electric power system [3].

II. Wheeling and Wheeling cost of Electrical Energy

2.1 Wheeling

Liberalization of the economic policies by the Indian government in 1990’s led the opening of power generation to private sector. Further, the amendment of Indian electricity act in 2003 resulted in separation of vertically integrated state electricity boards into three entities viz., GENeration COrporation (GENCO) for generation, TRANSmission COrporation (TRANSCO) for transmission and DIStribution COMpany (DISCOM) for distribution of power. However, the IPP's have to sell their generated electrical energy either to the government or to its buyer. In the second option, IPP's have to use the TRANSCO transmission network for delivering the electrical energy to the buyer. The job of TRANSCO is to "wheel" the electrical energy from a seller to a buyer. Thus, wheeling involves the transmission of electrical energy from a seller to a buyer through the transmission work owned by a third party [4].

2.2 Effects of wheeling

Wheeling affects the line loss, re-dispatch of generators, transmission line flow constraints, other power system security issues and recovery of embedded capital costs.

2.3 Wheeling cost

Usually seller and buyer reach an agreement on the rate of electrical energy based on the capital cost of the power plant, plant load factor etc. Wheeling cost or Transmission pricing is the cost paid by the seller of electrical energy to the transmission network holder for the use of transmission network to transmit power to the buyer of electricity [5]. Also the wheeling cost includes the cost for utilizing the assets and facilities of the transmission network. The wheeling company decides the wheeling cost of electrical energy.

III. Transmission Pricing Methodologies

3.1 Transmission pricing strategy

The rapidly changing business environment for electric power utilities all around the world has resulted in unbundling of services provided by these utilities. Wheeling of electrical energy (transmission services) is one of the more prevalent of such unbundled services. In fact, today there are enterprises whose main function is to provide only wheeling (transmission grid) services. National Grid Company in United Kingdom is the largest of such enterprises. Pricing of transmission services plays a crucial role in determining whether providing transmission services is economically beneficial to both the wheeling utility and the wheeling customers. However, it is important to realize that pricing of transmission services, although a technical issue is not an engineering problem [6]. Engineering analysis mainly deals in determining the feasibility and the cost of providing transmission services. It is not only one of many considerations in the overall process of pricing transmission services. Market and political considerations could also play major roles in determining transmission prices. Hence, it is extremely important to distinguish between transmission costs and prices.

In general, strategic pricing of any service or product, without considering political impact seek to I) increase customer value by providing a wider variety of services and price options, II) promote economic efficiency by ensuring that the customer value and the cost of service are balanced and III) change customer consumption patterns wherever appropriate to improve the utilization of existing resources [7].

At present, pricing transmission services which account for all these considerations is not possible due to the following reasons:

- Regulatory oversight of electric utility pricing practices which constrains pricing methods to be cost based, simple and stable over long time periods.
- Limited experience of the utility industry with provision of transmission services at large scale.
- Difficulty in obtaining necessary tools and data for evaluating the economic impacts of providing transmission services. In fact evaluating transmission cost is even difficult task that requires complex analytical tools and extensive data. The problem becomes substantially more difficult and subjective when determining the value of transmission services to wheeling customers.

To deal with the above mentioned barriers to strategic transmission pricing, economists have advocated adherence to basic economic principles that would price transmission prices based on the incremental cost of providing transmission services. Two challenges under these circumstances are to be addressed. They are how to correctly calculate the incremental cost of providing transmission services and how much premium in excess of the incremental cost should be allowed in transmission pricing to provide wheeling utilities with an incentive to accommodate large number of transmission transactions [8]. Presently, the utility industry commonly uses cost based prices for transmission services.

For a technical review of cost based transmission pricing, the distinction between transmission prices and costs becomes very difficult and confusing particularly when the incremental transmission pricing methodologies are discussed. The emphasis on transmission costs is mainly to illustrate how these mitts are evaluated and translated to transmission prices [9].

3.2 Wheeling cost computation methodologies

Except for a methodology for transmission pricing based on a bidding process, practically all existing transmission pricing models are cost based with the goal to allocate and/or assign all or part of the existing cost and new cost of transmission system to wheeling customers [10]. Transmission pricing paradigm is the overall process of translating transmission costs into overall transmission charges.

The two methods to calculate wheeling cost are 'Embedded' and 'Incremental' wheeling cost computation methodologies. They are explained in detail in the following sections.

3.2.1 Embedded wheeling cost computation methodology

In this methodology, all existing transmission systems and the new costs of system operation and expansion, regardless of their cause, are summed up (rolled-in) into a single number [11]. Cost incurred during building the infrastructure and future investment, operation and maintenance costs are summed up and then the total cost is allocated to the customers. This cost is then allocated among various users of the transmission system, including the utility native customers, according to their extent of use of the transmission system. Various transmission pricing methodologies have been developed, each defining and evaluating this extent of use differently [12].

Various embedded wheeling cost computation methodologies include 'Postage stamp methodology' or 'Rolled-in methodology', 'Contract path methodology', 'Boundary flow methodology' and two 'MW-km' methodologies or 'Line-by-line' methodologies namely 'Distance based MW-km methodology' and 'Power flow based MW-km methodology' [13].

3.2.2 Incremental wheeling cost computation methodology

According to this methodology, only new transmission costs caused by the new transmission customers will be considered for evaluating transmission charges for these customers [14]. The existing system costs will remain allocated to utilities' present customers. Several methodologies are used along with this paradigm to calculate transmission prices for transmission customers. These methodologies include 'Short-Run Incremental Cost (SRIC) computation methodology', 'Long-Run Incremental Cost (LRIC) computation methodology', 'Short-Run Marginal Cost (SRMC) computation methodology' and 'Long-Run Marginal Cost (LRMC) computation methodology' [15].

IV. Line-by-line or MW-km Methodology

This methodology allocates the cost based on a computed set of parallel paths for a particular transaction [16]. The two versions of MW-km methodology are Distance based MW-km methodology and Power flow based MW-km methodology. In this paper, Power flow based MW-km methodology is used in determining the wheeling cost.

4.2.1 Distance based MW-km methodology

This methodology allocates the existing or rolled-in transmission charges to wheeling customers based on the magnitude of the transacted power and the geographical distance between the generator and load [17]. This is a non-power flow methodology and hence does not make use of any power flow simulation while calculating the wheeling cost. This methodology is simple, easy to apply and easy to calculate. However, the geographical distance does not indicate the actual transmission facilities involved in the transaction or the reinforcements required for accommodating the transaction and hence wheeling customers are likely to receive and act upon incorrect economic signals. Also due to the absence of fixed relationship between the geographical distance and the actual costs, the transmission users do not face their actual costs.

4.2.2 Power flow based MW-km methodology

The load flow based MW-km methodology reflects, to some extent, the actual usage of the power system. Transmission prices are determined in relation to the proportion of the transmission system used by individual transactions, as determined by load flow studies [18].

This methodology takes into account the quantity of transacted power and the electrical distance between the generators and loads. This methodology allocates the charges for each transmission facility to transmission transactions based on the extent of use of that facility by these transactions. The allocated charges are then added up over all transmission facilities to evaluate the total price for usage of transmission system. For this reason, this methodology is also called 'Facility-by-facility methodology'.

A power flow model is used to calculate the flow caused by the transaction on each circuit of the transmission system. The ratio of the power flow due to the transaction and the circuit capacity is then determined. This ratio is multiplied by the circuit cost to obtain a cost for the transaction on each circuit. The share of the total system costs for the transaction is the sum of the costs for each circuit. The relatively simple and clear calculation of transmission charges using this methodology increases the degree of transparency of charges [19]. In addition, the problems of prices not being cost-reflective which is common to distance-based methodology is reduced by making users face prices that are more closely related to their use of the network. Consequently, these results show that there is a decreased discrimination between users and an increased allocative efficiency.

However, the load flow based MW-km approach still fails to signal the costs of future investment caused by individual users' decisions, as it is on the recovery of historic costs. Additionally it is expected that the total power flows are less than the circuit capacity, hence not all the transmission system capital cost may be recovered [20]. If congestion occurs due to the transactions this will be observed from the results of the load flow and a methodology to address congestion can be considered.

Different types of MW-km Methodology include Net difference based Line-by-Line methodology, Vector difference based one and Positive difference based one.

To yield ΔMW-kms, the net difference based line-by-line methodology involves subtraction of absolute values of base case power flows from those of transaction case power flows and vector difference based line-by-line methodology uses absolute values of difference of base case power flows and transaction case power flows, while determining wheeling cost [21]. However, the positive difference based line-by-line methodology considers absolute values of difference of base case power flows and transaction case power flows under the condition of transaction case power flow greater in magnitude than base case power flow, in computing the wheeling cost [22].

The stepwise procedure for computation of wheeling cost by MW-km methodology is as follows.

1. Select the study year.
2. Develop Book cost, Cost of Depreciation, Depreciation reserve and Net plant cost for each line using the following equations numbered (1) to (4).

$$BC_n = BC_{n-1} - \left(\frac{BC_{n-1}}{LIFE}\right) + \left(\frac{RC}{LIFE}\right) - \left(\left(\frac{RC}{LIFE}\right) * Study\ year * 0.05\right) \tag{1}$$

$$CoD_n = \left(\frac{1 - SALVAGE}{LIFE}\right) * BC_n \tag{2}$$

$$DR_n = DR_n + CoD_n - \left(\frac{BC_{n-1}}{LIFE}\right) + \frac{SALVAGE * BC_{n-1}}{LIFE} \tag{3}$$

$$NP = BC - DR \tag{4}$$

3. Sum the cost data available in the appendix along with gross cost of depreciation and express the result based on the total net plant cost, to obtain Annual Fixed Charge Rate (AFCR) in p.u.
4. Determine the annual wheeling cost using the equation-(5).

$$AWC = AFCR * \frac{\sum_i NP_i}{\sum_i MWkm_i} * \Delta MWkm \qquad i = Transmission\ line \tag{5}$$

V. Case Study

IEEE 30-bus system is considered for the determination of wheeling cost by the three versions of Power flow based MW-km methodology, with a buyer at bus-12 demanding 100 MW of active power from a seller available at bus-2. The cost data and technical data of the considered bus system are presented in appendix.

Table 1 compares the annual wheeling costs obtained by different versions of Power flow based MW-km methodology.

Table 1: Annual Wheeling Cost

Study year	Annual wheeling cost (Rs.)		
	Net difference methodology	Vector difference methodology	Positive difference methodology
1	18.07 Crores	34.63 Crores	1,457.80 Crores
2	19.49 Crores	37.36 Crores	1,572.94 Crores
3	20.76 Crores	39.79 Crores	1,675.15 Crores

VI. Conclusion

Consideration of active line power flow in any one direction in every branch of the bus system or assumption of both line power flows acting only in one direction in every branch of the bus system may over rate or under rate the wheeling service. Thus it can be stated that the net difference based line-by-line methodology and vector difference based line-by-line methodology gives inaccurate results. However, as the inclusion of Independent Power Producer leads to extra line power flows in the network thereby leading to the occurrence of extra power losses, the positive difference based line-by-line methodology is found to give correct economic signals in the wheeling cost calculation.

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APPENDIX

Cost data and Technical data

Capital cost per unit line length	Rs. 1 Crore
Capitalization breakdown per annum	5 %
Administrative and general Expenses per annum	2 %
Operation and maintenance per annum	2 %
Working capital provision per annum	5 %
Taxes per annum	5 %
Insurance per annum	1.5 %
Study period	3 years
Transmission line maximum capacity	100 MW
Transmission line average service life	30 years

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