Point of Connection Transmission Pricing in India

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Abstract— The National Electricity Policy (NEP) issued by the Government of India, mandates transmission prices to be distance and direction sensitive and capture utilization of the network by each network user. In line with the mandate, the Central Electricity Regulatory Commission (CERC) has issued Sharing of Interstate Transmission Charges and Losses Regulations, 2010; to introduce Point of Connection (PoC) based transmission pricing methodology in India. The methodology under the above regulations introduces one of the major reforms of its kind in the Indian power sector and seeks to share the total transmission charges in proportion to respective utilization of the transmission system by different entities. In this paper, the authors have enumerated their experience gained from the implementation of PoC based transmission pricing regime in India. Authors have also discussed various issues encountered in the process of implementation and the methodology adopted.

Keywords— Point of Connection (PoC), Transmission Pricing, Min-Max Fairness, Marginal Participation, Average Participation

I. INTRODUCTION

POWER Transmission is a public service because its benefits are reaped by all. A robust and well developed transmission system infrastructure is indispensable for optimal utilization of generation resources, development of power market in the country and to meet the ultimate objective of cost effective delivery of power. Transmission fosters competition between sellers and eventually leads to optimization in the power system. Insufficient capacity can cause constraints and local market power while adequate capacity can expand the size of the market and reduce market power.

India has a federal structure of governance in which “Electricity” is on concurrent list and both the Central as well as the State Governments have jurisdiction over the subject. Inter-state transmission systems are developed by the Central Transmission Utility and inter-state transmission licensees. On the other hand, intra-state transmission system is developed by State Transmission Utilities and intra-state transmission licensees. Tariff of inter-state transmission system is determined by the Central Electricity Regulatory Commission and the same is shared by users of the system.

Keeping pace with the high economic growth the Power Sector in India too is growing at a high rate – some states in India are exhibiting a double digit growth rate; for which a robust transmission system is a must. Need for adequate and timely development of transmission system has also been emphasized in the National Electricity Policy. The rapidly developing transmission system at the inter-state level has been a key factor in the evolution of power trading in the country since the Electricity Act, 2003 came into effect. More recently, operations of power exchanges have also been greatly facilitated by the increasing depth of the transmission network. In order to have cost effective transmission of power, a national transmission tariff framework needs to be in place.

II. DESIRABLE FEATURES OF PRICING FRAMEWORK

Transmission is a common carrier and its charges should be apportioned among the users in equitable way which at the same time provides correct, market based economic signal. Like any other commodity or service, transmission prices should reflect its marginal cost. Efficient transmission pricing is essential to facilitate economic dispatch of existing generation capacity and delivery of electricity to consumers at its minimum cost. If transmission prices do not accurately reflect the costs of transmission, including transmission constraints, participants in the market will not be able to correctly determine whether those constraints are best addressed through expansion of transmission capacity or the installation of new generation capacity closer to the load. Some of the desirable features of a transmission pricing framework are listed below:

i. Economic Efficiency through equitable sharing of the transmission charges between the transmission systems users, according to benefits derived.

ii. Ensure that the planned development / augmentation of the transmission system, which is otherwise beneficial, does not get inhibited.

iii. Non-Discriminatory between the customers buying or selling electricity at the same place and time.
iv. The scheme should not inhibit merit - order dispatch of generating stations.

v. Provide appropriate commercial signal for optimal location of new generating stations and loads.

vi. The owners of the transmission assets are fully compensated and the compensation should not depend on dispatch decisions and actual power flows. Sufficient incentives to transmission system owner to enhance availability of the transmission system.

vii. The transmission charges should be known ex-ante and no retrospective adjustment.

viii. Simple and Transparent.

ix. Dispute-free implementation on a sustainable basis.

III. EVOLUTION OF TRANSMISSION PRICING IN INDIA

Transmission Pricing has two distinct parts. First is the determination of the total charges that the transmission system owner would get and second is the sharing of these charges amongst the customers/beneficiaries of the transmission system. Transmission being a natural monopoly, the first part is regulated either by government or regulator. The second part i.e. mechanism for sharing of transmission charges has evolved over the last three decades in India. Initially, the implicit transmission pricing model was followed in which transmission charges were clubbed with the generation charges. Subsequently, with the unbundling of generation and transmission, the transmission pricing model was changed from implicit to explicit, wherein the charges were apportioned on the basis of net energy drawn. In this model, certain entities which were importing at one point of time and exporting at other, had to pay lesser transmission charges as the mechanism was based on net withdrawal over a month.

In 2002-03, the usage based sharing mechanism was replaced by access based method, in which charges were apportioned based on the quantum of transmission access. Transmission charges of interstate transmission system in a region (comprising of a few contiguous states) were pooled and shared by the beneficiaries, as per regional postage stamp method. Contract path method was used for the short term bilateral transactions. As this was not conducive to the operation of Power Exchanges, a methodology similar to ‘point-of-connection’ tariff had been adopted for Collective Transactions through Power Exchange, with uniform injection and withdrawal charges. Thus, prior to the implementation of PoC mechanism, ‘postage stamp’, ‘contract path’ and ‘point-of-connection’ pricing methodologies coexisted in the country for different types of transactions.

IV. DRIVERS FOR CHANGE

The postage stamp system for sharing of transmission charges was working well until the footprint was small and the system had a high degree of acceptability among the stakeholders. However, the policy mandate of distance and direction sensitive tariff was not getting captured. Over the time country has also seen an increase in the interregional flows which has further accentuated the problem of panckaking in the earlier method. Inefficiencies, rapid growth of electricity markets, changing structure of the network and increasing complexity including multiplicity of organizations, multiple licensees, large inter-regional energy transfers etc acted as drivers for change.

Competitive Bidding in generation and transmission has also been introduced recently. Under the previous methodology, generation bidding processes were severely distorted because of panckaking, and resulted in pit head / hydro plants not being competitive for inter-regional bids. Competitive bidding in transmission is leading to multiplicity of the transmission licensees which is making the existing method more complex. This further establishes the need of having a transmission cost sharing mechanism which fosters competition and works well in the imminent competitive environment.

The concept of regional postage stamp lost its relevance with the Ultra Mega Power Projects (UMPPs) and Independent Power Producers (IPPs) projects. In case of UMPPs the beneficiaries are spread in more than one region and all the constituents of a region are not beneficiaries. In case of IPPs most often the beneficiaries are not known at the time of transmission planning. IPPs may also sell part of their capacity in the market on short term basis to different beneficiaries at different times. This development resulted in a deadlock in building new transmission system and regional constituents did not agree for regional pooling of charges for such generation projects.
This led to delays in deciding the transmission system for few ultra mega power projects which had beneficiaries across regions.

Separate pools were created as a way forward to handle the disagreement between the beneficiaries in building a new transmission system. The charges of transmission elements in this separate pool were shared by the concerned entities for which the transmission system is developed which could be Discoms, Traders or IPPs. The creation of separate pools, in addition to the five regional transmission pools, for the purpose of sharing of inter-state transmission charges is likely to result in complications and more pan caking. As a result the postage stamp method might not work in a dispute free manner as was the case earlier with only five regional pools. In view of these developments it was imperative to change over to a national inter-state transmission tariff framework which should be distance and direction sensitive and centrally administered model to handle a multiple licensee organization scenario.

![Elegant Model for Transmission Pricing](image)

**Figure 2: Elegant Model for Transmission Pricing**

V. **POC MECHANISM**

An approach paper was floated by the regulator in May 2009 through industry-academia-regulatory collaboration. The paper discussed various feasible options for introducing point of connection (PoC) tariff. While many methods like contract path methodology, MW-mile methodology, short run marginal cost pricing, long run marginal cost pricing etc have been discussed in literature, considering the uniqueness of the Indian Power system, Average Participation (AP), Marginal Participation (MP), and Zone to Zone methods were considered suitable for further discussions.

After a nationwide consultation, CERC notified Sharing of Inter State Transmission Charges and Losses Regulations as PoC Mechanism in June 2010. A hybrid of average participation and marginal participation has been adopted to compute the PoC rates at each node. National Load Despatch Centre has been designated as the Implementing Agency (IA). A broad framework of PoC mechanism is described below:

A. **Preparation of Basic Network & Load Flow Studies**

Basic Network includes the power system of the country at voltage levels 132 kV and above and 110 kV where generators are connected, HVDC transmission network and all generator and loads connected to it. The basic network is prepared separately for NEW and SR grid based on the technical data such as network parameters, nodal injection and nodal withdrawal provided by the owners and users of the ISTS network.

**Table 1: Basic Network Statistics for First Half of 2012-2013**

<table>
<thead>
<tr>
<th>Buses</th>
<th>5227</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generating Stations</td>
<td>657</td>
</tr>
<tr>
<td>Generating Units</td>
<td>1257</td>
</tr>
<tr>
<td>Transformers</td>
<td>2262</td>
</tr>
<tr>
<td>Loads</td>
<td>3128</td>
</tr>
<tr>
<td>DC Lines</td>
<td>7</td>
</tr>
<tr>
<td>765 kV</td>
<td>10</td>
</tr>
<tr>
<td>400 kV</td>
<td>853</td>
</tr>
<tr>
<td>220 kV</td>
<td>3190</td>
</tr>
<tr>
<td>132 kV</td>
<td>5288</td>
</tr>
<tr>
<td>Total</td>
<td>9348</td>
</tr>
</tbody>
</table>

B. **Network Truncation**

Most of the Inter State Transmission System is at 400 kV in all regions except North Eastern Region where it is at 132 kV level. Therefore, the basic network is truncated at 400 kV in all regions except North Eastern Region where the network is truncated at 132 kV. Truncation helps relate local demands with local generation. All injection from the lower voltage system into 400 kV (in the case of NEW grid except NER and SR grid) and 132 kV in the case of NER grid is treated as a generator and vice-versa in the case of net withdrawal, the system below each node is replaced by a net load.

AC load flow is performed on the truncated network and the truncation is accepted only when the

I. Slack bus generation &,
II. Voltage angles at generation and demand buses closely match with the AC load flow on the full network.

The reduced network is used for computation of Marginal Participation Factor.

C. **Average Monthly Transmission Charges**

Yearly Transmission Charges (YTC) applicable for the next application period are provided by the owners of Inter State Transmission System (ISTS) to the IA. The total YTC is apportioned to each line based on the average monthly transmission charges (MTC) for each conductor type and voltage level. Average MTC is computed based on the total circuit
length and indicative cost level of each conductor type at each voltage level.

\[
\sum a_n \cdot l_n = T \tag{1}
\]

\[
a_i/a_n = k_n
\]

\[
k_n = c_n / c_i \tag{2}
\]

\[
T = \text{Total MTC of a synchronous grid}
\]

\[
a_n = \text{Average MTC of } n^{th} \text{ conductor type}
\]

\[
l_n = \text{Total circuit length of } n^{th} \text{ conductor type}
\]

\[
c_n = \text{Indicative Cost Level of } n^{th} \text{ conductor type}
\]

Indicative cost level indicates the total cost of constructing a transmission line with a particular type of conductor and at a particular voltage level.

D. Computation of Nodal PoC Rates

The truncated network and transmission charges of each line forms the basis for computation of nodal PoC rates using Hybrid Method. The method is a hybrid of average and marginal participation wherein average participation is used to identify the slack buses for each generator and load bus and marginal participation identifies the utilization of the ISTS network by each agent. The algorithm is performed using a software which is developed by academia-industry collaboration and available through web based delivery.

The average participation method traces the source and sinks of each agent in the network by tracking the influence in the network of a transit between each node and several ending nodes. The output of this method is the slack buses and their participation factor for each node. The slack bus participation factor for each node is calculated by distributing the inflow to a bus proportionally between the outflows. The method works as follows:

i. **Generator Tracing**: For every individual generator a number of physical paths are constructed, starting from the injection node, following through the lines as the power moves through the network, and finally reaching several of the loads in the system.

ii. **Load Tracing**: For every individual load, upstream tracing from the demand bus is done until some generators are reached.

Marginal participation analyzes the changes in flows in the grid when minor changes are introduced in the production or consumption of any agent and it assumes that the relationship of the flow through line \( j \) with the behaviour of the agent \( i \) can be considered to be linear. The output of this method is the utilization factor of each line by different nodes. The charges of each line are apportioned to each agent based on the utilization factor. The method works as follows:

i. **Marginal Participation sensitivities** \( A_{ij} \) are obtained that represent the changes in flow of any line \( j \) when the injection / withdrawal in any bus \( i \) is increased by 1 MW. The increase in 1 MW is compensated by a corresponding increase in load or generation at some other bus or buses – called the slack bus(es) which is computed through average participation as discussed above. Only positive participation in the direction of the power flow in the base case are considered which implies that increments which reduce burden on lines are neither given any credit nor charged for use of the system.

\[
A_{ij} = \left| F_j \right| \cdot \left| F_i \right| \tag{4}
\]

ii. **Total participations for each agent** are calculated as a product of its net injection by its marginal participation.

\[
U_{c/l} = \left( \left| F_j \right| - \left| F_i \right| \right) \cdot P_i \tag{5}
\]

\[
U_{c/l} = \text{Usage Index in line } l \text{ due to injection / withdrawal at node } i
\]

\[
P_i = \text{Power diapatch at bus } I \text{ under base case}
\]

iii. **The cost of each line is allocated pro-rata to the different agents** according to their total participation in the corresponding line.

\[
\text{Cost Allocated} = U_{c/l} \cdot C_i \tag{6}
\]

HVDC line flow is regulated by power order and remains constant for marginal change in load or generation. Hence, marginal participation of HVDC line is zero which means that MP method cannot directly recover its charges. A ‘with and without HVDC’ method is adopted to evaluate the utilization of a HVDC line in a synchronous system. The difference between the nodal charges in with HVDC and without HVDC scenario is termed as the benefit derived from HVDC. Positive benefit is scaled to recover total charges and added to the total charges of respective nodes. Negative benefit is collared to zero.

E. Zoning

The PoC Mechanism is based on the locational nodal charges for each grid connected entity.
However, the implementation of nodal PoC charges is cumbersome considering the large size of the Indian Power System. Further, the existing mechanisms such as scheduling, metering and settlement, contracts, access etc are based on the control area concept instead of nodal. It was imperative to align the PoC mechanism with the existing structure and move towards zonal pricing. Nodes are clubbed into zones based on the following criteria:

I. Each state control area is considered as a separate generation and demand zone.

II. Each ISGS connected at 400 kV is considered as a separate generation zone.

F. Computation of Zonal PoC Rates

The total zonal transmission charges are divided by the total long term access of a zone to arrive at the zonal PoC rate. The zonal PoC rates are scaled to ensure that the total transmission charges are recovered fully. In order to ensure gradual transition to the new transmission pricing mechanism, 50% of charges are required through Uniform Charging method.

\[
\text{Uniform Rate} = \frac{\text{Total Transmission Charges}}{\text{Approved Injection} + \text{Approved Withdrawal}}
\]

The final PoC rate is computed as the summation of 50% PoC Rate and 50% Uniform Rate.

Accounting of transmission charges is the responsibility of Regional Power Committees (RPC). The first and second part of the bills are raised based on the Regional Transmission Account (RTA), whereas fourth bill is raised as per the Regional Transmission Deviation Account (RTDA). The third bill is raised based on the statements issued by the CTU.

The total collected charges are disbursed to the transmission licensees whose assets have been considered in computation of PoC rates in the ratio of total YTC. Any under recovery or over recovery is adjusted at the end of the year through a supplementary bill.

VII. IMPLEMENTATION & RELATED ISSUES

The transition process should be smooth and phased such that it is widely acceptable at all points of the implementation process. Implementation of the PoC Mechanism in the country was an intensive exercise spanning over a period of one year. An implementation committee was formed for the purpose of facilitating seamless implementation of PoC mechanism, which had representation from all the stakeholders including regulator, planner, system operator, central transmission utility and states. A large scale capacity building was done pan India for a uniform understanding. A number of issues raised, were discussed and sorted during the implementation phase. Some of the major issues are discussed below:

i. Difficulties in Submission of Data

The mechanism is dependent upon the forecast data provided by the DICs for computation of PoC...
charges separately for five seasons, and for peak and other than peak scenarios. Stakeholders have expressed difficulty in submitting node-wise forecast data for different scenarios, one year in advance. In view of the difficulties, past 3 year data was considered to forecast the generation and demand of each entity until the time stakeholders are ready for forecasting their demand and generation for different scenarios, a year ahead.

ii. Usage vs Access

The recovery of transmission charges may be done based on actual usage, Long Term Contracts or Long Term Access. Long Term Contracts are commercial instruments for participating in the electricity market which may vary dynamically depending upon the business strategy of the entities. Recovery based on actual usage would not give a signal for correct identification of transmission requirements which is essential for planning a robust and reliable transmission network. Transmission is sunk investment and thus to be recovered as per approved Transmission Access which is the most sacrosanct figure for transmission planning. The usage factor is being captured while computing the PoC rate of each node. The analogy of the same can be drawn from the hospitality sector wherein the charging is based on the access that anyone has taken i.e. number of days no matter even if the room is used for two hour a day or twenty four hour a day. However, the normal usage of the rooms is being considered while fixing the tariff.

iii. Volatility of PoC Rates

It was observed that the POC rates obtained were volatile ranging from 5 paisa/unit to over 25 paisa/unit between zones. This volatility was even more between different scenarios, peak and other than peak conditions. In the initial phase, such variations would have been difficult to comprehend by stakeholders. A single average scenario was opted to start with. Further, slab rates were introduced to smoothen transition process and reduce heartburn. It is a variant of max-min fairness mechanism wherein the maximum rates obtained are clamped. Further, ‘slab’ rates are also used in most walks of life wherein large numbers of people or applications are involved as these slabs are easy to comprehend and implement. Fixation of slab rate is an optimization problem with an objective to minimize the standard deviation of PoC slab rates from original PoC rates such that neither they cause large over-recovery nor any under-recovery. Three slab rates have been approved by the regulator for the initial years.

<table>
<thead>
<tr>
<th></th>
<th>NEW Grid</th>
<th>SR Grid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tier I</td>
<td>80000</td>
<td>70000</td>
</tr>
<tr>
<td>Tier II</td>
<td>95000</td>
<td>85000</td>
</tr>
<tr>
<td>Tier III</td>
<td>110000</td>
<td>100000</td>
</tr>
</tbody>
</table>

A series of orders on removal of difficulties have been passed by the regulator for facilitating the implementation of PoC Mechanism followed by amendments in the regulations. Finally, the PoC mechanism was implemented w.e.f. 1st July 2011 in all horizons i.e. Long Term, Medium Term and Short Term Open Access.

VIII. BENEFITS

Fulfills Policy Mandate: The Point of Connection (PoC) transmission pricing mechanism is aligned with the requirements of the Tariff Policy, National Electricity Policy and acts as a facilitator of a competitive market. The National Electricity Policy requires the transmission charges to reflect network utilization. The Point of Connection tariffs are based on load flow analysis and capture utilization of each network element by the customers.

Distance Sensitivity: Electricity is a fungible commodity and flows by the law of displacement. The power generated at a location would not physically travel as per the contracted distance and may get consumed nearby. The PoC rates are independent of the geographic distance and capture the electrical distance.

Entry and Exit Rates (Direction Sensitivity): PoC Rates are computed separately for all entry (injection) and exit (withdrawal) points of the network. The rates at the entry and exit points are independent of the contracted sink and the source. Relevant nodes are grouped into zones for which entry and exit rates are computed as the weighted average of nodal rates. Different rates for entry and exit provides direction sensitivity to this mechanism. A zone with low entry rate and high exit rate provides a signal for investment in generation in that zone and vice versa. Both generators and loads are liable to pay transmission charges, unlike the present ‘Postage Stamp Method’ where only loads had to bear the transmission cost.

Promote Competition: The mechanism would facilitate integration of electricity markets and enhance open access and competition by avoiding pancaking of transmission charges. This will further facilitate fair and transparent competition for case-1 competitive bidding.

Planning Efficiency: Prior agreement among the stakeholders is not a precondition for development of any transmission scheme in PoC regime. This
will facilitate planners to plan the system efficiently based on the system requirements. **Declaration of Transmission Requirement:** The mechanism provides for submission of node wise demand and generation forecast by all DICs. The forecast would help the planner to identify the transmission requirements of each DIC and plan the system accordingly. **Encourages Solar Generation:** The mechanism facilitates solar based generation by allowing zero transmission access charge for use of ISTS and allocating no transmission loss to solar based generation. Solar power generators shall be benefited in event of use of the ISTS. Since such generation would normally be connected at 33 kV, the power generated by such generators would most likely be absorbed locally. This would cause no / minimal use of 400 kV ISTS network and might also lead to reduction of losses in the 400 kV network by obviating the need for power from distant generators.

IX. FUTURE SCOPE

Implementation of POC mechanism is a giant step in ensuring efficient planning and development of transmission and reliability of the electricity grids in the country. However, coordinated development of transmission system and avoidance of pancaking would only be there if a similar mechanism is replicated at intra state level. The importance of implementing POC based transmission pricing mechanism for facilitating development of a robust and a well developed transmission system has been recognized in the amendment to the Tariff Policy (dated 8th July 2011). As per Section 7.1(7) of the amended Policy:

"After coming into effect of the CERC Regulation on the framework for inter-State transmission, a similar approach should be implemented by the SERCs in next two years for the intra-State transmission, duly considering factors like voltage, distance, direction and quantum of flow."

The present system of transmission planning is based on the requisition given by different entities as per requirement which may not be economically efficient for all cases. The new pricing framework obviates the necessity of prior approval of the stakeholders for planning a new system. Under such scenario the planning objective should be to minimize the impact of new transmission system on the PoC rate.

X. CONCLUSION

Implementation of PoC Mechanism is the second big ticket reform in India after the Availability Based Tariff (ABT) mechanism. PoC method would ensure that transmission schemes at the inter-state level are planned and constructed in an optimal fashion. POC philosophy would also help in the competitive bidding as the POC charges and losses can now be used for bid evaluation. However, the subject is still in the nascent stage of development in India. Finding a perfect model is difficult; it has to be tailor made as per requirement. The methodology adopted would undergo refinement based on the experience gathered during the initial years of implementation.

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