Electricity Act, 2003 envisaged non-discriminatory Open access in transmission and distribution as a framework for encouraging competition in the electricity sector and enabling consumers to choose their suppliers. National Electricity Policy and Tariff Policy framed under the Act also laid emphasis on proper implementation of this framework. Central Electricity Regulatory Commission (CERC) framed regulations on Short-term Inter-State Open Access. State Electricity Regulatory Commissions (SERCs) also followed suit with similar regulations for intra state transmission and distribution. The regulations made provisions for allowing Short-Term Open Access (STOA) to intending users subject to availability of inherent design margins; the margins available due to variation in power flows; and Margins available due to in-built spare transmission capacity created to cater to future load growth or generation addition. These initiatives were intended to generate competition; induce improved services from the existing utilities; and creating a pan India market for generators as well as consumers of electricity.

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The essence of open access framework introduced in India was similar to that in the Federal Energy Regulatory Commission's (FERC) order 888 and 890.

Open Access regulations by FERC, USA

FERC Order No. 888, introduced in April 1996, directed all public utilities that own, operate or control interstate transmission to provide open access in transmission and file tariffs that offer others the same transmission services they provide themselves, under comparable terms and conditions. The second rule, Order No. 889, introduced in March 1997, is now known as the Open Access Same-time Information System rule or OASIS rule. It also covers Standards of Conduct. It works to ensure that transmission

Facilitating Open Access in transmission without compromising Grid security

An experience in Indian power system

owners and their affiliates do not have an unfair competitive advantage in using transmission to sell power. This rule requires public utilities to obtain information about their transmission system for their own wholesale power transactions, such as available capacity, in the same way their competitors do - via an OASIS on the Internet; and, completely separate their wholesale power marketing and transmission operation functions.

Open Access regulations by CERC

There is a fundamental difference in the situation prevailing in India vis-à-vis that prevailing in US. Our electricity law explicitly forbids a transmission licensee from engaging in trading of electricity. The Central Transmission Utility (CTU) operating the five Regional Load Despatch Centres (RLDCs) which administer the interstate open access cannot engage in generation or trading in electricity. There is thus absolutely no conflict of interest at the interstate level as far as implementation of open access is concerned. The STOA regulations in inter state transmission were introduced by CERC in May 2004 after extensive debate and discussions with the stakeholders. Several amendments and modifications were also brought about in due course to fine tune the regulations as per the needs of the electricity market and stakeholders' interest. The latest initiative in this regard has been the establishment of multiple Power Exchanges and regulations on Medium term Open Access. While there is a still lot to be done, the fast paced changes in the last five years have undoubtedly placed the Indian Electricity market on a trajectory of accelerated growth and momentum. In fact the freedom, choice, flexibility and potential available to the buyers and sellers of electricity in the Indian market are unparalleled in the world. There have been large numbers of transactions involving the generating companies, traders and distribution companies through open access in inter-State transmission. The margins inherent in design or those that arise due to variations in power flows and also due to in-built spare transmission capacity (created to cater to the future load growth or generation addition) began to be gainfully utilized through STOA. As a result the Indian market is now in the league of largest electricity markets in the world. The results of open access at the interstate level have been highly encouraging and satisfying. The model now needs to be scaled up with the help of Medium-term Open Access (MTOA) and aggressively adopted at the intra-state level.

> The transfer capability is determined by the System Operator to facilitate open access in a transparent and non-discriminatory manner without compromising the security of the grid.

Key Success Factors for Short-term Open Access

Success of Short term Open Access at the inter-State level could be attributed to several factors. The revolutionary legislation, the bold initiatives by CERC, the proactive support by the Regional / National Load Despatch Centres and the demanding stakeholders have been the drivers of this change. At the implementation level, the Forum of Regulators (FOR) in their November 2008 report titled 'Open Access - Theory and Practice' has recognized several factors for the success of inter-State Short term Open Access. Among those factors the transparent and non-discriminatory implementation of open access by Regional Load Despatch Centres (RLDCs) with complete information displayed on the RLDC website including the 52 week average transmission losses, Available Transfer Capability details, approved Open Access transactions details, schedules of each constituent, etc has been also stated as a Key Success Factor.

Ever since the implementation of short term opens access in interstate transmission, there are now forty (40) licensed traders and two Power Exchanges (PX) operating in the market. The trading margin for bilateral open access is 4 paise/ Wh as notified by CERC. There are many months in a year when the short term surpluses are insignificant and the size of pie (read short term market) shrinks. The transmission network is not stretched much under these conditions. On other occasions when the power surplus goes up it often goes up in certain pockets only and the demand rises in far off pockets. It is here that the transmission network gets stretched and the network capability as assessed by the RLDCs comes into question. The market players already overcome by issues such as more number of players competing for a share of the shrinking pie, trading margin restriction, inter play with the imbalance or Unscheduled Interchange (UI) market get a feeling of being further constrained by the network capability restricting further transactions. Transfer capability in the interconnected system therefore arouses a great deal of curiosity amidst stakeholders and therefore it has been elaborated further in the following paragraphs.

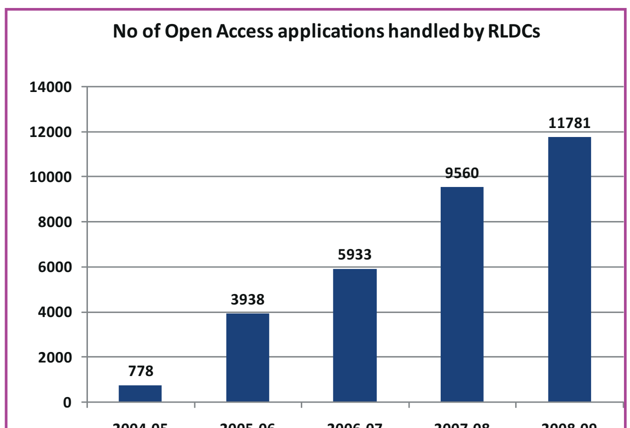

Fig. 1: Inter-State Short-term Open Access applications approved

Transfer Capability in interconnected network

'Transfer Capability' is the measure of the ability of interconnected electric systems to reliably move power from one area to another over all transmission lines (or paths) between those areas under specified system conditions. It is directional in nature and is highly dependent upon the generation, customer demand and transmission system conditions assumed during the time period analyzed. Transfer Capability may be limited by the physical and electrical characteristics of the systems. The limiting condition on some portions of the transmission network can shift among thermal, voltage and stability limits as the network operating conditions change over time.

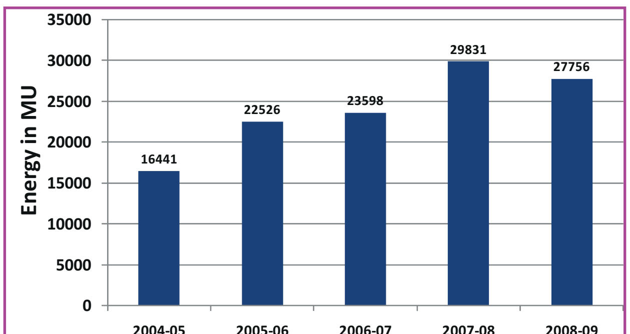

Fig. 2: Energy approved under inter-state Short-term Open Access

Sl No	Transmission Capacity	Transfer Capability
1	Is a physical property in isolation	Is a collective behaviour of a system
2	Depends on design only	Depends on design, topology, system conditions, accuracy of assumptions
3	Deterministic	Probabilistic
4	Constant under a set of conditions	Always varying
5	Time independent	Time dependent
6	Non-directional	Directional
7	Determined directly by design	Estimated indirectly through simulation studies
8	Declared by designer/ manufacturer	Declared by the System Operator
9	Scalar in nature	Vector in nature
10	Considered unambiguous & sacrosanct	Subject to close scrutiny by all Stakeholders

Table 1: Transmission Capacity vis-a-vis Transfer Capability

Transfer capability is determined by System Operators across the world. In the International Conference on Open Access in the Deregulated Regime organized at Institute of Technology - Banaras Hindu University in August 2007, POWERGRID had published an approach paper for assessment of transfer capability of the bulk electric power supply system in the Indian context. The paper highlighted that 'Transfer Capability' is different from 'Transmission Capacity', which usually refers to the thermal limit or rating of a particular transmission element or component. The individual transmission line capacities or ratings cannot be arithmetically added to determine the transfer capability of a transmission path or interface. In fact the actual transfer capability of the network is often less than the aggregated transmission capacity of the individual circuits of a specific transmission interface between two areas of the network. CIGRE Working Group 5.04, Technical Brochure 301 also recognizes that the cross border capacity available for commercial trade would be less or at most equal to the sum of capacities of cross border lines individually. The distinguishing features of transmission capacity and transfer capability are shown in Table 1.

The transfer capability of the network is heavily dependent on the network response to the various transactions between control areas in the system. The sharing of power by each element in the corridor (also known as distribution factor) is not equal. This implies that the transfer capability of a corridor cannot be determined by arithmetic sum of individual transmission capacities of all parallel transmission lines in that corridor. As the power transfer across the section is increased one or more elements could hit the limiting value before the others. The total power transfer across the section would therefore have to be restricted to the value at which the first element reaches the limiting value. If the loading on each parallel element is balanced with the help of series compensation the transfer capability could be enhanced. However it would be seen that the transfer capability would vary depending upon whether the series compensation is in service or out of service during the period for which the transfer capability assessment is being carried out. The network limitations are also not constant and are time dependent.

For instance we might have an eight-lane expressway between Delhi and Jaipur and a Ferrari driven by a Formula-I racer. Each may have the capacity to operate at a speed of 300 km/hour. Still it would not be possible to cover the 265 km distance between Delhi and Jaipur in less than one hour due to various bottlenecks, road intersections disturbances on the way. In fact it could take as high as three hours giving an average speed of 88 km/hr (the system capability), which is only 30% of the design capacity.

Relevance of transfer capability assessment for Open Access

The report 'Open Access Theory and Practice' by the Forum of Regulators states that for successful implementation of OA, the assessment of available transfer capability (ATC) is very important. A pessimistic approach in assessing the ATC will lead to under utilization of the transmission system. Similarly, over assessment of ATC will place the grid security in danger.

CIGRE Working Group 5.04, Technical Brochure 304 states 'in order to prevent the violation of security limits, System Operator SO must define the limits on commercially available transfer capacity between zones.' It has also been accepted as an integral part of congestion management.

"System Operators try to avoid such unforeseen congestion by carefully assessing the commercially available capacities and reliability margins." Thus determination of the Available Transfer Capability of the interconnected network is essential for two reasons -

- To determine the secure operating limits of the interconnected system
- To establish the baseline for scheduling of open access transactions.

Approach adopted by European Network of Transmission System Operator for Electricity (ENTSOE)

European Transmission System Operators define Total Transfer Capacity (TTC) as a maximum possible power transfer between two adjacent areas. In order to find the TTC, the power exchange between areas is increased until there is a breach of security constraints, being it internal or cross-border congestion. This is done by increasing generation in one area and lowering it in the other. Using load flow calculations and detailed topology data, feasibility of such border exchanges is tested. The same procedure holds in both the directions. TTC in either direction is generally different. After assessing the TTC a part of cross border capacity is withdrawn from the market to account for the random threats to the security of the interconnected grid, such as to cope with loss of a generating unit. This capacity is called as Transmission Reliability Margin (TRM). TRM for a given control area is calculated based on the size of the biggest unit in the synchronous area and the domestic generation peak of a control area. Thus the Net Transfer Capacity (NTC) is the maximum exchange program between two areas compatible with security standards, taking into account the technical uncertainties on future network conditions.

Net Transfer Capacity = Total Transfer Capacity – Reliability Margin

NTCs are calculated for each border independently by both System Operators involved, and the lower of the two is made publicly available. NTCs are published twice a year (winter and summer) and serve as the cross-border indexes, sending a signal to market participants concerning the physical limitations of the grid.

Approach adopted by North American Electric Reliability Corporation (NERC)

NERC defines Total Transfer Capability as the amount of electric power that can be transferred over the interconnected transmission network in a reliable manner based on all of the following conditions

- All facility loadings in pre-contingency are within normal ratings and all voltages are within normal limits.
- Systems stable and capable of absorbing the dynamic power swings
- Before any post-contingency operator-initiated system adjustments are implemented, all transmission facility loadings are within emergency ratings and all voltages are within emergency limits

The commercial capacity available for market players is calculated by deducting Transmission Reliability Margin (TRM) and Capacity Benefit Margin (CBM). TRM is set aside to ensure secure operation of the interconnected transmission network to accommodate uncertainties in system operations while CBM is set aside to ensure access to generation from interconnected systems to meet generation reliability requirements.

Available Transfer Capability = Total Transfer Capability – Reliability Margins

Approach adopted by Regional Load Despatch Centres in India

The approach adopted in by Regional Load Despatch Centres (RLDCs) in India is also on similar lines. The five RLDCs declare the Total Transfer Capability for import as well as export of power from the respective regions in advance. The transfer capability is worked out three months in advance and is based on anticipated network topology, anticipated load and anticipated generation for that month.

Transfer Capability between two areas is calculated with the help of simulation studies. The power system is modeled along with the anticipated load generation. The load is increased in one area and the generation is increased in the other area till constraints are hit. Several credible single contingencies are taken for studies. The interchange between the two areas at the point when constraints were hit for a single contingency is

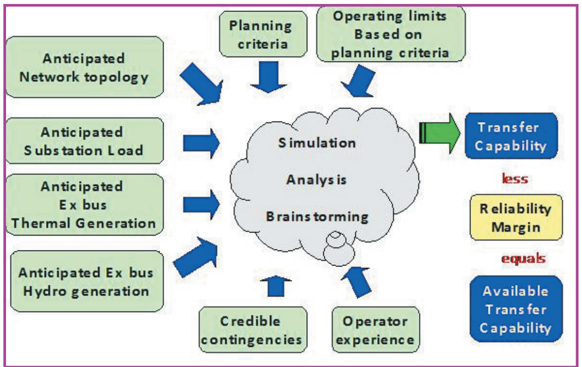

Fig. 3: Methodology for assessing Transfer Capability in India

taken as the Total Transfer Capability.

The Reliability Margin is typically taken as 500 MW in view of the largest unit size of 500 MW in the grid. The Available Transfer Capability for Long term (LTOA), Medium term (MTOA) and Short term Open Access (STOA) is calculated by reducing the Total Transfer Capability by Reliability Margin.

ATC (LTOA + MTOA + STOA) = Total Transfer Capability – Reliability Margin

The Long-term and Medium term transactions have a higher priority that the Short-term customers. Therefore the Available Transfer Capability for short-term customers is obtained as follows.

ATC (for STOA) = TTC – RM – LTOA – MTOA

Going by the past data it would be seen that around 60 % of the TTC is utilized by STOA. This percentage may change in future depending upon the growth in LTOA and MTOA.

Relevance of Transfer Capability in the Open Access

RLDCs have been declaring transfer capability and posting the details on their website every month. These figures are revised whenever there is a significant change in network topology, load pattern and generation. Reliability Co-coordinators for each RLDC discuss the simulation results and examine it from the reliability aspect and any special dispatch conditions arising during the month before finalizing the figures. These figures are considered by the Open Access coordinators while approving the requests for open access as per the regulations on short-term open access. The open access customers are categorized into long-term, medium term and short-term on the basis of the duration of their access. The long-term customers have the highest priority over the transmission followed by the others in sequence. Within the short-term category open access, there are several products viz. 3 months in advance, First-come-first served, Collective or day-ahead Power Exchange, Day ahead bilateral, intra-day or contingency. There is a clear time line and gate closure time for each of the products. When the window for day-ahead market through PX opens, the day ahead bilateral market closes. As long as the margins are available, the open access applications are approved as per the priority based rules established by the CERC regulations. The transfer capability declarations establish a base line for calculating the margins available in the grid for commercial use. Normally as one approaches the D-day, the margins get consumed gradually. However, sometimes the margin may get enhanced due to enhancement in the transfer capability or due to cancellation of an approved transaction.

Congestion

CIGRE Working Group 5.04, technical brochure 301 defines congestion as "a situation where the demand for transmission capacity exceeds the transmission network capabilities, which might lead to violation of network security limits, being thermal, voltage stability limits or a (N-1) contingency condition."

Congestion is sometimes encountered in the Indian grid as well. In case of bilateral transactions, when the quantum of requests is higher than the available transfer capability, all the applicants are informed and the situation is termed as 'congestion'. The applicants then have the opportunity to revise their requests or to bid for the congested corridor. The highest bidder gets to schedule its transaction. In case congestion is encountered in the day-ahead Power Exchange, it is resolved by adopting the market splitting based approach. Congestion in the network is a threat to grid security and hence may result in denial of approval to open access requests or increase in the overall cost of delivered power. However the situation is unavoidable because short-term open access transactions are allowed to utilize the margins already available in the grid after utilization by the long-term users for whom the transmission system is planned and constructed. Experts argue that congestion is common phenomena in a large meshed grid. It is a sign of growth and vibrant market. It is a natural corollary to open access and must be managed by appropriate modifications in market design and congestion alleviations methods.

While in case of road traffic, construction of flyovers and widening of roads does result in a slight increase in average speed of vehicles in certain stretches. However over a period of time, congestion sets in and average speeds fall. Public safety is not however endangered as the average speed of vehicles fall and chances of a fatal accident become remote. The same cannot be said of electricity network. If any element in a heavily loaded transmission corridor trips there is a serious risk of cascade tripping, separation of power systems and a collapse in the entire electricity grid as events occur within seconds and much beyond the operator's response time. This has a high social, economic and political cost. The stakes involved in secure operation of electricity grids is therefore very high.

Concerns of the electricity traders with respect to transfer capability

In the recent past concerns have been expressed, particularly by the electricity traders, that the prime reason for congestion in Indian grid is the conservative transfer capability declarations by System Operators in India. They also believe that the Reliability Margin set aside should also be made available for short-term open access trade instead of allowing it to be utilized by unscheduled interchanges. The issues above can be dissociated into four parts.

- Transfer Capability declared is conservative and it is equal to the transmission capacity
- Reliability Margin is eating away the margin available for trade
- Unscheduled Interchanges should be zero

Each of the above is discussed in the following paragraphs.

As explained in the preceding sections, the transfer capability is directional and dependent on parallel flows in the network that are highly influenced by the network actual network topology as well as the time, location and quantum of the ever changing load-generation in the grid. Thus transfer capability would always be lower than the algebraic sum of the individual transmission capacities. Transfer capability is the manifestation of dynamic behaviour of the individual elements when operating collectively in an interconnected system. It is analogous to individual capacity vis-à-vis the collective capability. 'A chain is as strong as the weakest link'.

A survey of transfer capability declared by European Transmission System Operators reveals that there is no definite benchmark for the ratio of transfer capability to transmission capacity.

Sl No	Interconnector	Gross Transmission Capacity (GTC)	Net Transfer Capacity (Similar to ATC in India)	% of NTC/ GTC
1	France to United Kingdom	2000	2000	100%
2	United Kingdom to France	2000	0	0%
3	Denmark (East) to Sweden	2010	1700	85%
4	Sweden to Denmark (East)	2010	1300	65%
5	Italy to Slovenia	2017	480	24%
6	Slovenia to Italy	2017	380	19%
7	Austria to Hungary	2124	500	24%
8	Hungary to Austria	2124	200	9%
9	Sweden to Finland	2230	1800	81%
10	Finland to Sweden	2230	1600	72%
11	Czech Republic to Austria	2249	600	27%
12	Austria to Czech Republic	2249	0	0%
13	Italy to Austria + Slovenia	2274	0	0%
14	Lithuania to Kaliningrad	2287	700	31%
15	Slovakia to Hungary	2492	1100	44%
16	Hungary to Slovakia	2492	200	8%
17	Poland to Slovakia	2504	750	30%
18	Slovakia to Poland	2504	750	30%
19	Croatia to Hungary	2688	100	4%
20	Hungary to Croatia	2688	100	4%

Source: www.entsoe.eu

Table 2: Transfer Capability vis-a-vis Transmission Capacity in Europe

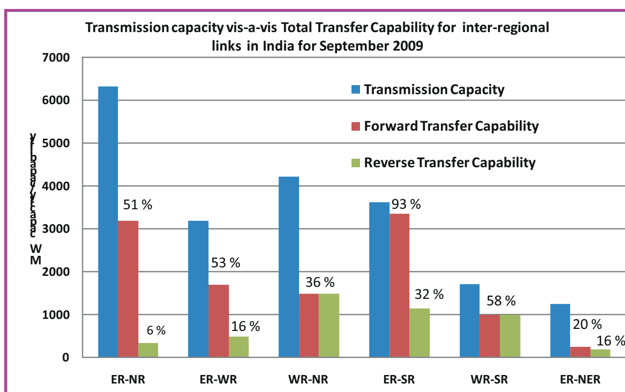

Fig. 4: Typical Transfer Capability vis-a-vis Transmission Capacity in India during September 2009

capacity.

A comparison of transfer capability in Europe and India would reveal that the percentage of transfer capability to the transmission capacity is high in case of HVDC interconnections (100 % from France to England in Europe and 93 % from Eastern Region to Southern Region in India). It is also evident that transfer capability in the reverse direction is generally not equal to the transfer capability in forward direction. The data also proves that if one considers diversity, complexity of physical system, climatic conditions, operation philosophy and prevailing inadequacies in the Indian power system the transfer capability declared by System Operators in India is rather optimistic.

International literature strongly advocates keeping aside reliability margins in the interest of system security. Steven Stoft, the renowned expert in power market, states, "Power markets are the only markets that can suffer a catastrophic instability that develops in less than a second…. The extent and speed of the required coordination are unparalleled". (Power System Economics). In view of the above, North American Electricity Reliability Corporation advocates setting aside Transmission Reliability Margin and Capacity Benefit Margin with following arguments -

- "The beneficiary of this margin is the "larger community" with no single, identifiable group of users as the beneficiary."
- "The benefits of reliability margin extend over a large geographical area."
- "They are the result of uncertainties that cannot reasonably be mitigated unilaterally by a single Regional entity."

So the reliability margins must be reserved in the System. The issue is to maintain it always so that they are not eaten away by the persistent and deliberate manner by a few utilities. However this is a challenging proposition in an electrical system where precise control over interchanges is difficult. The power system is dispersed over vast geographical area and is influenced by technical, human as well as weather related interventions. Even if the schedule of a utility is infinite, some imbalance would always occur by virtue of random events and dynamic variation in load and generation. Thus inadvertent unscheduled interchanges (over drawal or under drawal) are unavoidable. This leaves us to the issue of deliberate and persistent UI. The market design in India permits a floating frequency and deviations from schedule within a permissible band to cause economy and efficiency in power system operation. There are still a few utilities that resort to persistent violation of the market and grid discipline. The issue is being addressed through multipronged regulatory initiatives such as tightening of operating frequency band, revision of UI ceiling rates, surcharge on UI when frequency is below a threshold, congestion charge, petitions in Regulatory Commission and other modifications in the market design.

Conclusion

Electricity Act mandates the RLDCs to ensure integrated operation of the grid, facilitate nondiscriminatory open access and schedule in accordance with the contracts. As per the CERC regulations on short-term Open Access in inter-State transmission system, the RLDCs are the nodal agencies for facilitating open access subject to margins available due to design, variation in power flow and inbuilt spare capacity for future. They also have been given the discretion to curtail approved transactions in case of perceived threat to system security. Further the Tariff Policy states that all the available information on available transmission capacity and load flow should be shared with intending users by the CTU/STU and the load dispatch centers. The methodology adopted by the System Operators in India has been giving a reasonable and dependable indication of transfer capabilities; recognizes time variant conditions, simultaneous transfers, and parallel flows; recognizes the dependence on points of injection / off-take, reflects regional coordination to include the interconnected network, conform to planning criteria, grid standards and grid code; accommodates reasonable uncertainties in system conditions and provides flexibility.

The transfer capability is determined by the System Operator to facilitate open access in a transparent and non-discriminatory manner without compromising the security of the grid. There has been a concern among the stakeholders on account of congestion. The concern is genuine because congestion is a threat to grid security and if not managed and alleviated it may lead to grid disturbances besides throttling the nascent electricity market in India. Several initiatives in the physical system, market design as well as transfer capability assessment procedures are being taken to create a truly competitive electricity market in India. ■


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