Innovative Metering Solutions in Open Access Regime

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1. INTRODUCTION

The reforms in the power sector brings equally challenging tasks to the metering industry as to the electricity supply industry (ESI). Challenges are accompaniment of process of reforms. A major shift has already taken place in ESI in India with introduction of ABT when interval metering systems were demanded by the new commercial mechanism. The commercial mechanism, described later, required pricing of power in consonance with demand-supply gap. In Indian context, the key challenge was to create metering solutions which are cost effective, easy-to-use, reliable, tamper proof and smooth data transfer process for billing. The results have been satisfactory as brought out by smooth transition and continuation of ABT in all regions of the country , having completed first anniversary in Western region.

2. ABT MECHANISM AT WORK

The grid problems in the regional grids in pre-ABT era were : large deviations in frequency from the rated frequency of 50Hz, low frequency situation when curtailment not affected by any constituents, high frequency as result of insufficient backing down of generation when the total consumer loads comes down during off-peak hours etc. Pre-ABT tariff mechanism did not provide any incentive for either backing down the generation during off-peak hours or for reducing the consumer load/enhancing the generation during peak-load hours thereby encouraging grid indiscipline.

ABT, devised to address these issues, were largely mitigated as seen from the experience of last one year in Western Region. ABT provided for incentives to CGS for enhancing the output capability of the power plants not necessarily generation, so as to enable meeting more consumer load during peak load hours and backing down during off-peak hours without resulting in financial loss to the station. The beneficiaries having well defined entitlements, and would be entitled to draw power up to this at normal rates. In case of over-drawls, they need to pay at higher rate during peak load hours, which discourages them to overdraw and pull down the frequency. This payment goes to the beneficiaries who received less energy than is scheduled.

The salient features of ABT are : tariff comprising of three components: (a) capacity charge, towards reimbursement of the fixed cost of the plant, linked to the plant's capability to supply MWs, (b) energy charge, to reimburse the fuel cost for scheduled generation, and (c) a payment for deviation from schedule, at a rate dependent on system conditions. All ISTS users i.e. Inter-State Generating Stations (ISGS) and beneficiaries are subjected to the third part, known as Unscheduled Interchange (UI).

The third part which is of much importance is – charges for deviations. These charges are payable for deviations of injections of ISGS and drawals of SEBs from their respective schedules

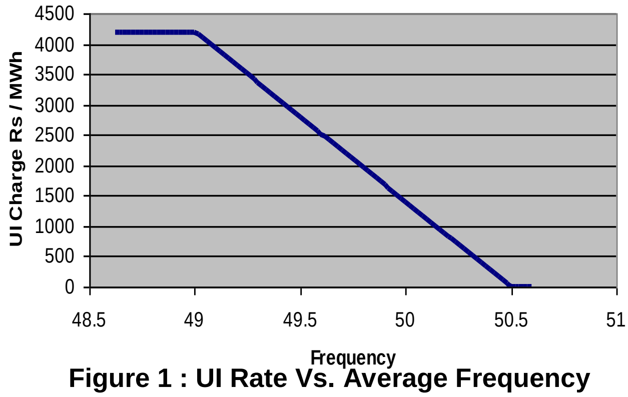

Figure 1 : UI Rate Vs. Average Frequency

and are linked to average frequency in particular 15-minute time-block. Schedules for SEBs shall be prepared on the basis of their requisitions from the declared capabilities of Central plants. The charges for deviations i.e. unscheduled interchange (UI) rates are maximum at 49Hz and below and zero at 50.5Hz and above, with constant slope between two extremes and prices applicable at steps of 0.02 Hz. The maximum rate (presently 420paise/kWh) has been linked to diesel-generation cost of power and minimum of zero is linked to over-flowing hydro power with zero incremental cost.

Utilities overdrawing /underdrawing during high-demand periods pay/receive at higher UI rate linked to frequency and vice versa. The third part meant for all utilities exchanging power at inter-state level and it can be applied to bilateral exchanges taking place among utilites.

3. REACTIVE ENERGY CHARGES SCHEME

With the implementation of Indian Electricity Grid Code (IEGC), the scheme for reactive energy charges have also become effective concurrent with ABT mechanism in all the regions. The prime objective of the scheme is to induce SEBs to install capacitors timely and thereby releasing MVAR drawals, MVAR flows on long EHV lines and resultant large voltage drop. This scheme is primarily meant for SEBs which have been reluctant to install capacitors and insist on their consumers to install induction motors with sufficient compensation. In view of prevailing situation, prohibiting SEBs from VARs drawal from EHV grid has not been insisted upon in the Grid Code (clause 7.6.1). Therefore, this scheme includes pricing of VARs drawn/injected into EHV grid at a nominal cost which is priced at the rate derived from cost of capacitors. The salient features of the scheme are as enumerated below:-

- Beneficiary pays for VAR drawal when voltage at metering point is below 97%.
- Beneficiary gets paid for VAR return when voltage is below 97%
- Beneficiary gets paid for VAR drawal when voltages above 103% and
- Beneficiary pays for VAR return when voltages above 103%.
- No charges for VAR drawal/return between 97%-103%
- No charges for SEBs drawals directly from ISGS bus bars.

The reactive energy charge rate was fixed at Rs.40/MVARH for the year 2000-01 with 5% escalation every year. Present tariff is Rs. 46.10/MVARh.

4. NEED FOR SUITABLE METERING SYSTEM FOR ABT MECHANISM

The ABT mechanism was to take care of active energy pricing and reactive energy charges scheme was to take care of reactive energy. The required metering system which had to be compatible with the above scheme at the same time easy to use, cost effective and with provision for reliable and tamper-proof data communication. At one end, innovative tariff scheme was developed to mitigate all the major grid problems affecting the regional grids of the country on the other, the same without effective end-to-end metering solutions.

The conventional meters of 0.5class accuracy were used in all the regions. ToD meters were commissioned in WR and NR of 0.5 class accuracy in 1994-95. The meters had facility of recording half-hourly meter readings but they failed in data communication side, which took one and half hours for downloading the data from meters to a RAM card in hand held device. The meters could not be found useful for ABT purposes. The conventional meters having 0.5 class accuracy and no facility for interval recording and data transfer were not useful for ABT.

As per the ABT requirements, the most important parameters were not the energy and maximum demand, but deviations from the agreed MW drawal schedules. Hence special energy meters were required to be developed for installation at all inter-utility exchange points. To determine the deviations from the agreed MW schedule, it is necessary to determine the MW flow for the whole recording period that too with accuracy. This was done by measuring and recording the MWh for each 15-minute block. This was the first and foremost requirement of the special metering device. Minute-by-minute MW variation were not really necessary. Also, all commercial transactions are traditionally based on energy (Wh) meter readings and not on measurement of MW meters/transducers, and the above approach was in line with this accepted convention. The accuracy of the above energy measurement was crucial, particularly on EHV inter-connections carrying hundreds of MWs. The best accuracy class for which energy meters available was 0.2S as per IEC-687, and the same has been adopted for the EHV circuits, considering that even 0.1% error in energy measurement could mean a substantial monetary implication.

The special meters were to be static, three-element, four-wire meters for obtaining a high accuracy, since the EHV systems invariably have solid neutral grounding and were basically four-wire systems. The special meters were also designed for working from the PT supply for reliability, and suitable for a wide range of voltage variation from minus 30% to plus 15% of the nominal value instead of the conventional plus/minus 10%. It has been ensured in the design that the data of the meter is stored in a non-volatile memory backed up by an internal long-life battery to take care of the RTC (real time clock) during power off conditions.

Since it is necessary as per the above tariff structure that the energy be linked with system frequency, the average frequency is also measured and logged for each successive 15-minute block. Although the frequency is same all over an integrated grid and may not be required to be logged at each metering point, however, a network could split at times and therefore it is desirable to measure and record the average 15-minute frequency at all metering locations. A very precise measurement of average frequency and the standard time (upto a minute resolution) is essential since the Rupees per KWh rate would be different at the different frequencies. A resolution of seconds for time measurements would not be required; rather a resolution upto a minute would suffice.

The UI rate is based on 15-minute integrated frequency , therefore, deviations at all inter-utility points would need time-synchronised computation of net energy which requires an internal clock of high accuracy and calendar with facilities for time correction. On-line time synchronisation required extensive synchronizing facilities apart from affecting the accuracy, and hence was avoided in the first phase of development. The same feature can now be included with technology available at cheaper cost.

The fifteen minutes MWh data was normally thought to suffice for all inter-utility tariff requirement for active energy and MWh. The total cumulative energy register was not really necessary, but was been included for cross-checking and record purposes. Logging of this register's reading at every midnight was incorporated in the specifications.

For implementation of the reactive energy tariffs, voltage related VARh registers, one for voltage high and one for voltage low conditions, were required. These registers were to operate on a continuous basis and there was no need to have any 15-minute data for this purpose. Actual voltage thresholds were also not critical, and 103% and 97%, limits were specified for data logging of the readings of the two VARh registers at midnight.

These meters were to be totally tamper-proof, without any possibility of adjustment or programming at site, which in turn meant that the CT and PT ratios should either be permanently preset at factory or accounted for separately. The latter was preferred since it allowed inter-changeability of meters. The meter were also required to be sealed for life and any repair possible only at the manufacturer's works.

To recapitulate, the special meters to be deployed for inter-Utility exchanges were specified to measure and record

i) Wh transmittal for each successive 15-minute block
ii) Average frequency (codified) for each 15-minue block
iii) Cumulative Wh register readings at each midnight
iv) Cumulative VARh register readings for voltage high and voltage low conditions at each midnight.

These readings were to be properly dated and time tagged, and also tagged with unique meter identification number. In addition, all 15-minute time blocks in which a PT supply abnormality occurs were also to be identified and stored in the meter's memory.

In view of specific provision for weekly energy accounting, weekly data collection, volume of data and data transferring time, a memory of ten days was felt to be sufficient. Accordingly, the data of these special meters were to be recovered by the Data Collecting Device (DCD) through an optical interface once a week and dumped on a local PC from which the data could be transmitted to a central processor located at the Regional Load Despatch Centre using any available communication link eg. through telecom, PLCC, Satellite etc.

5. DEVELOPMENT OF THE SPECIAL METERS

Since meters with above specifications were not available, POWERGRID placed a Prototype Development contract with several reputed manufacturers in the field of static metering. This was followed by an intense Field Trials phase in which five of the successful prototype meters were installed at the 400kV sub-station and their performance observed for a period of around one year. During this phase, certain more meters where extensively type tested for conformation to the required Standards. On successful completion of the Field Trial phase, orders were placed on the successful manufacturer, M/s. Secure Meters Limited of Udaipur, India for large scale supply of these meters, which are now installed at all inter-Utility exchange points and at the generating units of the central power plants in three Regions.

The measurement technology was based on ASIC (Application Specific Integration Circuit) which incorporated digital signal processing techniques apart from other capabilities of a processor. The metering system consisted of class 0.2 S three-phase, four-wire energy meter, a data collection device (DCD) for reading the meters and computer software for analysing the recorded data.

The special metering demanded 4-quadrant metering scheme with provisions for implementation of proposed tariff. Since the tariff required linkage for active drawals to frequency and reactive drawals to voltage, a RT (Real Time Clock) chip was required for ensuring consistency between frequency linked tariff and time. A net reactive energy registration was also required for desired voltage ranges as against conventional reactive measurement.

The data registration was implemented in NVM (Non Volatile Memory) using special coding and recording algorithms for efficient storage. A mechanism for fault detection was implemented along with the recorded information for operations.

The said meters were of accuracy class 0.2 S and the same was tested and achieved in all 4 quadrants. The manufacturer made special testing jigs and invested in high precision measurement systems. The RTC was based on high stability quartz and since periodic clock correction may be unavoidable, a time correction mechanism for correcting the time by one minute at a time has been incorporated, with a feature to block further time corrections upto one week. The one minute correction is carried out by making the meter clock advance/retard by only 10 seconds at a time for the next six consecutive 15-minute time blocks where time correction has taken place is also logged in the meter's memory.

The application involved fault-tolerant real-time software design using behavioural state diagrams. The application software was implemented using about 25 state machines and was efficiently implemented along with data storage in 8 KB of NVM. New methods were designed for testing and debugging during the development cycle through simulation of real field situations. Data security was ensured using time proven security algorithms. A portable calibrator for testing/certification of meters, was also developed in the process.

Extensive pre-despatch testing and inspection of each of the meters has been carried out by POWERGRID before acceptance of the meters together with thorough and detailed type testing of one meter out of a batch of 100 meters. The approach has ensured a through compliance of the technical specifications and a high quality, which would be necessary for meters to be used for inter-utility bulk power measurement.

With great efforts and cooperation from metering industry, the meters were developed at fraction of the cost as compared to those available outside country. The cost of meters in 1994 was about Rs.80,000/- which latter was brought down to Rs.30,000/- per meter. The modality of data collection and its conveyance to a central place which is RLDC of the region were made simple, practical and at the same time tamper-proof. More than 2000 SEMs were put in place all across the country and weekly accounting is being carried out on the basis of 15 minute block–wise readings. (2286 meters procured)

6. REQUIREMENTS OF METERING FOR OPEN ACCESS

The Electricity Act, 2003 has opened floodgates for utilisation of bottled up power trading opportunities. Now, buyer can choose its supplier and he would need to pay only for wheeling charges and surcharge for utilising third party transmission network. The energy accounting for exchanges between Generator to End-consumer, Genco to Discom, Discom to Discom at distribution level would involve more complex arrangements when two utilities fall in different control areas. The power would be supplied at one point(s) and drawn at other point(s), the intermediary network may belong to other transmission licensee(s). Due to inherent power system characteristics, the power flows on AC networks cannot be controlled and therefore the buyers consumption and suppliers delivery of energy would not match. The power drawn would obviously have to match with power injected on **real-time basis**. Ensuring simultaneity of two transactions would be a task which SLDCs/RLDCs would need to undertake through pricing mechanism. The more important but less discussed questions are how to ascertain:

a. Contracted power is actually delivered by supplier or not ?
b. The buyer is consuming more or less than the contracted power ?
c. Deviations of both 'supplier' or 'buyer' from their contracted quanta in the same time frames and suitable pricing for the same.

Such requirement can only be met with interval metering. The interval should be as small as possible. The world over, the interval commonly chosen is half-hour and planning to shift to quarter-hour. ABT metering system provides for recording energy on 15-minute time block-wise basis. This would suit the purpose.

The regulators at state levels would need to consider this aspects when 'Open Access' in the intra-state systems is introduced. We have already apprised SERCs with our proposal for pricing these deviations to the integrated frequency for 15-minute time block. Having implemented ABT in the inter-state systems, the next logical step is to bring consistent mechanism at intra-state systems since the treatment of deviations at inter-state and intra-state systems should be consistent with each other. This would also incentivise utilities to inject/draw as per system conditions. Therefore, frequency, time and active energy recording for each 15-minute would be required, at the minimum. The regulators , may seek to introduce Time-of-Use(ToU) pricing for deviations, even then same meters can be used.

With increase in open access transactions and remoteness of drawal/delivery points, the communication of data from meters to a Central Station would assume importance. Therefore, additional features of 'remote metering' would be required so that the information from 'supplier' and 'buyer' are collected at Central Station and deviations from 'schedules' at both points can be computed and priced.

7. REQUIREMENT FOR METERING FOR INTRA-STATE UTILITIES

Before ABT, the lacunae in the system operation existed at intra-regional inter-utility level. Some of them are : power system operation by the utilities at their will without regard to grid parameters resulting in very high frequency during low-demand periods and low frequency during high-demand period, ISGS generating without regard to beneficiary's requirements etc. All theses have largely been solved with ABT implementation. But with unbundling of SEBs, again same problems will emerge at intra-state level between GENCOS & DISCOMS of the States. In the post-reform June,2004 period, the commercial mechanism would need to be put in place to incentivise deviations in drawal/injections of GENCOs/DISCOMs and end-consumers so as to give correct and grid-friendly signals. The commercial mechanism would also require compatible end-to-end metering systems. The metering systems provided for ABT would be base solution and further improvisation would be required for unbundled utilities.

Minimum Requirement for Metering Systems would be :

a. Accessible Display for instantaneous and cumulative displays
b. Accuracy as per IEC 687
c. Capable of registering and recording flows in each direction
d. Electronic data recording and data storage facilities stamped with time, average frequency and Wh and VARh for time-blocks
e. Electronic Data transfer facilities from metering installation to central metering database
f. Capable of communicating from meter to local PC

Further suggested improvisations are as enumerated below:

a. Dynamic Error Compensation

The advantages of creating modularity in the meters where measurement, data computation and storage are carried out in different modules. Any data correction required for CT/VT errors should be possible to be done in the firmware. The errors compensation should also include error curves of CT/VT. Same functions can also be carried out through software programs at the user's end but accuracy would be better in case these corrections are carried out at the meter level in real-time. Moreover,

b. Watch-dog Function

Meters should be able to sense the abnormality in data to alarm the users. The alarm events should be logged along with date and time stamping so as to facilitate the understanding the errors in metered data in comparison with its check meter.

c. Remote Meter Reading

Initially the cost, poor communication infrastructure at remote 132kV, 220kV substations in India discouraged POWERGRID to use remote meter reading for data collection for ABT. But today, this is not the case. This feature should be essentially provided in the metering system.

Already, POWERGRID is in process to begin trial for remote meter readings at 400kV Bhiwadi substation.

d. Real-Time Metering Data Access

In today's fast-paced, information-based world, access to continuous real-time data is an exciting prospect. The multi-location companies having power intensive units at far-flung places viz. Railways, Steel companies, Cement companies etc. would like to access meter data in real-time to check their drawal patterns. This would be a costlier substitute for SCADA. Need for real-time meter data access is also being felt by utilities. Though, they may not ready for the cost.

e. Metering System Standards

The metering systems provided by different vendors would have to at least conform to minimum common specifications. And utilities involved in settlement systems should be able to use single software program for using data files from metering system of different vendors. Common standards with regard to following would help create modular metering systems and interchangeability would be win-win for both utilities and vendors.

i. Common protocols/format for data storage
ii. Common tags for data tamper, meter problems like low voltage stamps, meter advance/retarding, time synchronisation etc.
iii. Common communication protocols for remote metering
iv. Data conversion software for conversion of coded file to different file formats like txt, CSV or XLS, DBF etc., may differ in their features but the output format should be same so that user can develop a common programme for reading such files.

The meters should have additional functionalities for display of hourly, daily and monthly load curve with maximum, minimum and average demand.

f. Multi-Mode Communication

The communication through internet is most cost effective and common method of data communications in present ABT mechanism. Almost 100% of data transfer from substation take place through internet. The communication barrier is a possibility in case some of OA customer who are at remote places. Therefore, data transfer through other modes viz., GSM, CDMA, PLCC and VSAT network would also need to be provided.

g. Scope of Metering Data Agencies – New Ancillary Services.

The deregulation and consequent complex data collection and settlement system present scope for growth of a new ancillary services. The data collection and creating database may be assigned to private agencies for smooth and cost-effective settlement. Some of data collection have already been entrusted by utilities like GRIDCO to private agencies. With growth in Open Access customers and opening OA to smaller commercial and industrial units would take us closer to retail competition. The metering data would grow exponentially and require a separate infrastructure. Metering Data agencies in private sector would be a necessity.

h. Internet Based Data Collection

The metering industry may think of developing 'MeterNet' to allow energy utilities and OA customers to enter data from anywhere or directly from meters. This can be achieved by keeping a meter connected to PC which is connected to net. The

8. RECENT REGULATORY CHANGES

CERC, also having appreciated these concerns, had provided for similar metering arrangements for Open Access customers in their order dated 14^{th} November,2003. The clause 44 provides for SEMs capable of time differentiated measurements (15-minute) of active and reactive energy as per RLDC/CTU requirements.

They have also ordered in clause 40

"Section 61(1)(a) of the Act stipulates that State commissions are guided by the procedures and methodologies specified by the Central Commission for determination of tariff applicable to generating companies and transmission licensees. It needs to be emphasised that only when States follow the regional accounting procedures and implement ABT, the intent of the Act in respect of open access shall be completely implemented."

Therefore, metering solutions as suggested in the paper assumes greater importance not only for inter-state exchanges but all the utilities connected with open access.

9. CONCLUSION

ABT mechanism has benefited the regional grids significantly and one-year of operation in WR has resulted in huge savings. Definitely, improved metering system is not enough but is an essential accompaniment to effective commercial mechanism. The unbundling of vertically integrated utilities like SEBs and Open Access provisions are regulatory changes meant to unbottle the idle generating capacities in the system as well as bolster capital infusion into the cash-starved ESI. ABT metering system based on quarter-hourly recording of active energy. The important feature is standardisation of data collection, transfer and processing system to maintain uniformity across the country. This has ensured smooth settlement systems across all five regions. The similar systems would be required for unbundled SEBs so as to create grid-discipline among Discoms and Gencos. Harnessing captive generation and pumped storage plants would also require similar metering systems.

Metering industry should closely work with power system engineers to develop meters suitable in Indian conditions. Once expertise has already been put to test the same spirit may continue. POWERGRID charted out with developing specifications followed by prototype and thorough type and field testing and have shown that we need not imitate the solutions developed in the advanced countries. To reduce cost, we must use made-to-order systems. There is no alternative to interval metering systems in Open Access regime.

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