

UI Part-1: REALISING A COLLECTIVE VISION THROUGH NON-COOPERATION

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The uniqueness of electricity lies in its anonymity and its invisibility. In an interconnected grid, electricity is omnipresent, omnipotent and unbiased in its benevolence to those that seek its blessings. It does not carry the tag of ownership and forms a homogeneous mixture without discriminating between the caste and creed of its generator. In spite of being bestowed upon with such divine virtues its vulnerability to fall for the path of least resistance (like ordinary mortals!) renders its invincibility amenable to some discipline and control.

Needless to say that efficient exploitation of such a wonderful product as electricity, calls for an extraordinary physical system and commercial mechanism. Several authors have beautifully elucidated the peculiarities encountered in trading this commodity. One of them is Sally Hunt who in her book ‘Competition and Choice in Electricity’ says, “Transporting electricity is physically more complicated than transporting most other goods. Transmission requires split-second timing of electricity flows from producers or the system will go out of control with disastrous consequences. In physical terms transport and production are inevitably closely related but the physical attributes of an electric power network make it impossible to match physically any particular seller of electricity with any particular buyer of electricity. All the power flows over a system according to the laws of physics there is no way to tell whose power actually went to whom.” Generators put the electricity into a big pool and the buyer takes the electricity out of this commingled whole.

The supply and demand in the electrical cosmos must be

instantaneously balanced to maintain the frequency, voltage and stability of the network. But unfortunately the variable demand for electricity and the need for instantaneous response mean that there will always be a difference between what was agreed and what was actually delivered. These imbalances could be inadvertent or sometimes deliberate. The pool must not only be robust to bear the imbalances but it must also be capable of dispatching and settling them in a manner that stands the test of equitability and economic prudence.

The power network demands cooperation from all its members. It expects its beneficiaries to huddle together and hold on to one another’s arm to enhance reliability and security of the public utility service rendered by the network. All those hooked on to the synchronous system have to bear in mind that the efficient operation of electric networks is subject to the classical “commons” problem wherein one person’s abuse of the service influences the legitimate usage by the other. The pool therefore requires a system of incentives and disincentives, which motivates the beneficiaries to make conscious efforts towards compliance of the ‘model code of conduct’ and also work for quick restoration of the equilibrium. Though the expected features of the mechanism and the objectives thereof may appear to be conflicting and contradictory yet the unscheduled interchange mechanism adopted in India encompasses most of the features comprehensibly and comprehensively addresses the concerns of all the players in the power system, economists, regulators, policy makers, and grid operators.

Pool Operation in India

In India we have loose regional power pools wherein each state constituent is responsible for meeting the load within its control area, by using its own generated power and/or through power purchased from the central/joint sector utilities (Inter State Generating Stations)/other constituent utilities/independent power producers. Coordinated multilateral model has been adopted for dispatching the available resources. The State Load Dispatch Centers have autonomy of scheduling their own generation while taking into account their daily entitlements (worked out from the declared availability) from external sources. These entitlements from external sources could be through long term or short-term bilateral agreements. The regional grid operator collates all the information regarding the bilateral entitlements & a corresponding requisition furnished by the constituents and issues an exchange schedule (drawal/dispatch schedule). Sometimes moderations may be required in these schedules due to network constraints but once they are finalized these schedules are to be considered as a commitment from the supplier to inject an agreed quantum of energy into the pool at the specified time during the day & from the buyer to consume an agreed amount of energy from the pool during the day.

The mismatches are allowed and are settled through the frequency linked operating and settlement mechanism. The exchange schedules issued by the system operators are treated as a datum for calculating the deviations. The scheduled energy exchanges with the grid are priced as per the sale/purchase agreements between the buyer and seller utilities while deviations (positive or negative) from the scheduled exchanges (datum) are termed as ‘unscheduled interchanges’

(UI) and these are priced at a dynamic price known as the ‘UI Rate’. The UI rate during real time reflects the system marginal price at that instant. The mechanism thus provides a real time negative feedback loop in the power control system, which allows the generating utilities to assist in the control of frequency deviations and also get rewarded for that support and likewise for the drawee utilities. The normal operating frequency band as per Indian Electricity Grid Code (IEGC) is 49.0-50.5 Hz. Where 49.0 Hz denotes an extreme deficit condition. At this frequency it is expected that even the costliest generating unit (usually load center diesel generator) be put into service. 50.5 Hz denotes a surplus situation. At this frequency the UI Rate represents the marginal cost of run of the river hydro.

UI vector has undergone several tinkering and would always be under scrutiny. The UI prices operate at time scales where quasi-steady state assumption is no longer valid. The scheme could be referred to as ‘real time pricing’, ‘dynamic pricing’ or ‘responsive pricing’ but ‘the rose by any other name would smell as sweet!’

The beauty of the scheme also lies in a simple and transparent metering and settlement system where accounts are issued within ten (10) days of the end of each weekly settlement period (Monday-Sunday). Payments flow in and out of the pool account in the next ten days. Thus the settlement cycle for a week W_1 (Monday-Sunday) is complete twenty (20) days after Sunday. No disputes! No complexities in computing hourly system marginal prices (SMP) and its associated problems! Such a simple, quick and dispute-free settlement system would have few parallels worldwide.

UI: A renaissance in grid operation

The pricing signal is linked to the system frequency and hence it gets transmitted across the grid at the same speed as the dynamics to be controlled. The utilities are then able to do course corrections and suitably adjust their operating behavior. The UI mechanism has thus stretched real time pricing scheme to its physical limits. These prices are effectively being used in load frequency control and are serving as an economic load shedding policy to assist the direct control by electric utilities. The in-built checks and balances in the scheme induce everyone to maintain the quality of electricity supply and assist in bringing in economy. Constituents including all generators deliver their best during peak hours. During off peak hours costly generation is backed down and the hydro potential wherever available, is being utilized in the best possible manner. “Producers work harder for a reward, especially one that coincides with reliability and patriotism-Mark Lively”.

In the decentralized dispatch scenario, the UI mechanism provides the Automatic Generation Control (AGC) for the Indian electricity grids without employing a vast set of inputs, processing software and last mile connectivity to the generators. The sliding curve from 0 to 570 paise/kWh (depending upon the system frequency) has introduced a negative feedback loop into the power control system, which has enhanced the stability of the system. The grid has seen remarkable improvements in system parameters and a drastic reduction in minor and major grid disturbance ever since it was implemented.

The system operator has been greatly relieved of the fire-fighting job of controlling grid parameters. Constituent states and generating stations have become flexible (as they

have incentive) shedding their rigidity. Gone are the days of high decibel debates, frantic calls and high drama ‘filled with sound and fury’ (courtesy Shakespeare). All this has dramatically transformed the ambience in the control rooms and enabled the system operator to concentrate on further optimization.

The earlier system of command and control has been replaced by the contractual approach. The system has brought in accountability and seriousness in grid operation without resorting to coercive measure and penalties for non-compliance. The SLDCs and plant operator are now empowered to contribute in the grid frequency control, which made the system self-healing and self-correcting. The responsibility of maintaining the grid parameters is now a collective responsibility shared among all the beneficiaries and the grid operator. What a wonderful way to do away with the need for ancillary services (related to active power) and the paraphernalia associated with it! It has left no room for the long drawn haggling about allocation of gains from the real-time trade under the balancing and spot market model adopted in other countries. Perhaps this could be another reason for the western world to look towards the orient, especially India.

Competition through a virtual Power Exchange

Even today Electric Supply Industry is assumed to be a natural monopoly with little scope for competition. As a result, it is subject to regulation, to control costs and for making investment decisions in the absence of competition. It is generally believed that regulation is a ‘surrogate for competition’ to be used when competition is unworkable. But UI mechanism has displayed that competition is feasible even in a regulated environment. We have a system where cheaper generation constantly strives to displace a costlier generation, resulting in a natural merit order operation in the grid. Since the real time imbalances are treated as if they were instantaneous spot transactions (sale of electricity arranged at infinitesimally short notice for immediate delivery), UI transactions compete with bilateral transactions as a means of trading electricity. Every generator becomes a potential supplier in the unscheduled market and every wholesale customer becomes a potential customer. In this zero sum game the system stabilizes at a desired Walrasian equilibrium, which causes economy as a whole.

Increased efficiency

Since the UI rate is linked to the frequency (an indicator of the power availability conditions in the grid) it closely reflects the system marginal price. A generator will generate only if the cost of own production is less the current or expected UI rate regardless of the contract price. It implies that the generating plant will be used only when it is efficient. UI mechanism achieves the same result as efficient central dispatch based on marginal cost without infringement of the right of state constituents to schedule their own generation and load. Moreover the UI mechanism safeguards against distortion of operating decisions based

on Power purchase agreements. The combination of bulk power contract and UI pricing therefore offers the prospect of much greater efficiency than PPAs. It has enhanced bilateral trade (both inter & intra regional), which has resulted in better utilization of national resources. Unscheduled Interchange regime is the strongest impetus towards achieving the Pareto’s allocative efficiency which says that “if there are considerable interregional differences in demand conditions, such as consumer willingness to pay and supply costs due to heterogeneous production technology, competitive market prices can clear the relative supply demand imbalances through transferring electricity from low cost regions to excess demand regions.”

Inculcates a spirit of self righteousness

In a competitive market producers will not generally allow their costs to be scrutinized by the others. The UI rate is linked to the grid frequency and hence the price for the real time trade is dictated by the demand supply position in the grid without regard to the costs of the buyer and the seller concerned. This prevents sellers from gaining a higher (or lower) price by manipulating their cost information. Since the UI price is the opportunity cost of the commodity being traded, the sellers/buyers can themselves act in their best interests without being subjected to scrutiny for price disclosures. The scheme thus upholds the principles of corporate sovereignty that we value so much.

Diffusion of market power and choice to buyers & sellers

In his recent paper titled “Creating an automatic market for unscheduled electricity flows” Mark Lively has applauded the UI mechanism. He agrees that unscheduled market has not only allowed the new players in the market to participate economically in the inadvertent market between utilities but also offered the customers an alternative way to buy their electricity. The customer being able to buy electricity in the unscheduled market would diminish any market power that the local utility has. Further even the customers can assume a role of a seller in this market by underdrawing from the grid during shortages. Generators need not sell their output at a price lower than the UI rate. Similarly customers need not agree to buy electricity at any price higher than the value (tangible or intangible) of feeding that loads. A win-win situation for everyone!

Fertile ground for the sector to flourish

The entire scheme has had a crucial role in giving a wonderful launch pad for the new economic order in the electricity market. It has the capability to unleash the latent potential of the captive and co-generation power plants, which is yet to be tapped. The UI mechanism is an innovative and indigenously developed model for real time trading in electricity. It is the ultimate open access that one can dream of. It offers a wonderful alternative for the Independent power producers and merchant power plants to sell their surplus power to the grid and get paid for without having to bother about commercial agreements with the buyers. The scheme has immense potential for increasing the viability of pumped storage hydro. These aspects have been duly acknowledged in the Economic Survey, 2003-04 -“UI mechanism facilitates the

spot sale or purchase of electricity into or out of the electricity grid and does not require the services of a trader. As UI mechanism is an alternative to formal trading it provides a sort of benchmark price for the trading of electricity and does not allow the price of traded electricity to shoot up. These developments take the market for electricity closer to other normal markets in the economy.”

Social welfare through the Adam Smith’s ‘invisible hand’

Adam Smith in his work titled ‘Wealth of Nations’ said “every individual necessarily labors to render the annual revenue of the society as great as he can. He generally neither intends to promote the public interest, nor knows how much he is promoting it... He intends only his own gain, and he is in this, as in many other cases, led by an invisible hand to promote an end which was no part of his intention. Nor is it always the worse for society that it was no part of his intention. By pursuing his own interest he frequently promotes that of the society more effectually than when he really intends to promote it. I have never known much good done by those who affected to trade for the public good.” The relevance of the ‘invisible hand’ is not hard to see especially in the Indian context. The mechanism does not demand a very tight frequency control. So the public utility organizations have a liberty to deviate from the committed schedules unless there are explicit instructions in this regard from the grid operator during grid exigencies. The utilities while trying to maximize their returns from the market are also trying to maximize their social welfare obligations. The UI mechanism complements their profit motive.

A peep into the future

Congestion management

Pricing unscheduled flows of electricity on a locational basis could be effectively used for congestion management. A locational pricing plan for unscheduled flows of electricity would provide rewards for generators and loads to change their operations in ways that provide that relief without having to resort to the draconian option of load regulation from the regional control center.

Further optimization

The concept of real time prices could be extended further so that it convincingly addresses the issue of losses and also adapts to seasonal and regional variations. These refinements could be brought in through change in the slope, change in frequency range, multiple slopes/kinks, different curves for buying and selling, different curves for different seasons or by introducing time of the day element.

Catalyst for transnational power exchanges

UI mechanism could perhaps be instrumental in facilitating transnational power exchanges. It offers the opportunity for enhanced cooperation and collaboration between nations. The UI mechanism would naturally help harvest diversity in demand. If materialized it would be a tribute to Dr. R. Buckminster Fuller who saw a single, continuous worldwide electrical energy grid as a number one solution to solve many of the pressing problems of the world. He also saw power grid as the way to reduce human suffering, preserve the environment and make war obsolete.

Endnotes

Imbalance is a necessary evil in any pool operation but the UI mechanism has employed it as an effective remedy for several congenital disorders of the

Indian power systems. In the UI regime, frequency is collectively controlled and democratically stabilized, which is a reflection of our cultural tradition and national ethos of unity in diversity. A spirit of collective ownership and concern for the health of the grid has been kindled in every heart that beats in synchronism with the grid.

In a nutshell, the frequency-linked real time pricing mechanism for unscheduled interchanges has assumed an axiomatic stature in the Indian power sector. It offers the right mechanism to enable the participants to become productive and responsible citizens. Further it inhibits exercise of ‘market power’ by any generator and thus nipped the evil in the bud. In the words of William Blake the UI mechanism has empowered each one of us *“to see a world in a grain of sand and heaven in a wild flower; Hold infinity in the palms of our hand and eternity in an hour.”* Unscheduled mechanism has radically transformed the frequency landscape and remarkably improved grid management in the country. It is a fundamental concept that unifies and guides everything, an edifice that provides the foundation for further evolution of electricity market in India. It simplifies all complexities, contradictions, challenges and dilemmas of grid operation to simple-indeed almost simplistic-hedgehog ideas. The UI mechanism is a remarkable implementation of the ‘NASH equilibrium’ and non-cooperative game theory wherein a cooperative objective is achieved through non-cooperation. The UI mechanism has been widely acclaimed and appreciated but what other compliment would be bigger than that given by the Central Electricity Regulatory Commission in their order, which says, “ABT, without deterrent UI charges, is like Hamlet without the Prince of Denmark.”

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magic box, which holds the fortunes or misfortunes of the inborn gamblers and practitioners of game theory. Last but not the least the author salutes all the unsung heroes and proponents of the scheme for whole-heartedly supporting it from conceptualization to its implementation.

References

1. Choice and Competition in Electricity - Sally Hunt and Graham Shuttleworth; National Economic Research Associates
2. Power System Economics Designing Markets for Electricity- Steven Stoft; IEEE Press, Wiley Interscience; John Wiley & Sons
3. Making Competition Work in Electricity - Sally Hunt; John Wiley & Sons, Inc
4. Designing Markets for Electricity - IEEE, Wiley Interscience
5. Market Operations in Electric Power Systems, Forecasting, Scheduling and Risk Management - Mohammad Shahidehpour, Hatim Yamin, Zuyi Li; IEEE, Wiley Interscience; John Wiley & Sons Inc. Publications.
6. Regulating Regional Power Systems- Clarke, IEEE press
7. Real time pricing to assist in load frequency control- Arthur Berger & Fred C. Schweppe, IEEE Transactions on Power Systems, Vol.4, No. 3, August 1989
8. <http://www.livelyutility.com>
9. <http://www.cercind.org>
10. Host of literature in the web on balancing & spot market and market design