SmartGrid Initiatives and Power Market in India

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Abstract—SmartGrids were introduced to make the grid operation smarter and intelligent. SmartGrid operations, upon appropriate deployment can open up new avenues and opportunities with significant financial implications. SmartGrids can continue towards enhancement of power market. The current status of the power market as well as initiations of SmartGrids in India are studied to scrutinize the potential power market enhancement with the advent of SmartGrids. This paper presents various SmartGrid initiatives and implications in the context of power market evolution in India.

I. INTRODUCTION

THE Indian power sector is expanding at a fast pace. India has a power sector characterized by deficient generation and high distribution losses. The first power exchange of India was introduced in June 2008. SmartGrid activity has been reported in some distribution pockets mostly by private players. Many utilities in power sector have now SmartGrid activity with high priority in their research and development agenda. The market functions which are likely to get affected due to SmartGrids are discussed. The priority of these functions depends on several factors such as policies, regulation, efficiency of the markets, costs and benefits associated with the functions, and service providers and traders etc. Though there are many barriers for these new developments, the Government of India has some policies to support SmartGrids in the distribution sector. Some of the key issues emerging for implementation of SmartGrid include secure communication, standard protocols, data management and an efficient architecture which can facilitate data exchange. These issues are discussed in the Indian context.

SmartGrids can bring in new market products also. SmartGrids can convert data into useful information and have the capability to take local decisions in distributed manner, and can also offer self healing. These features can be used for market enhancement as decision support. There is growing demand for "quality power" in power market. SmartGrids can offer effective solution to this demand. Some details on these aspects are covered. Finally, a comprehensive road map on the role of SmartGrids for enhancement of power market in India is reported.

The organization of the paper is as follows: In section II, an overview of Indian power market and its current operation structure is covered. Recently released market products are

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detailed. Section III talks about the SmartGrid vision and various initiatives in India. Section V points towards some of the required focus areas and needs for an efficient power market with the advent of SmartGrids in India. Section VI concludes the paper.

II. OVERVIEW OF INDIAN POWER MARKET

In India, electricity reforms started with the re-evaluation of Electricity Supply Act, 1948 and the Indian Electricity Act, 1910 which led to the Electricity Act, 2003. The Electricity Act, 2003 has been brought about to facilitate private sector participation and to help cash strapped state electricity boards to meet electricity demand. The Electricity Act, 2003 envisages competition in electricity market, protection of consumers interests and provision of power for all. The act recommends the provision for national electricity policy, rural electrification, open access in transmission, phased open access in distribution, mandatory state electricity regulatory commissions (SERCs), license free generation and distribution, power trading, mandatory metering, and stringent penalties for theft of electricity. One more welcome step that the Indian electricity market has taken is the implementation of availability based tariff (ABT) which brought about the effective day-ahead scheduling and frequency sensitive charges for the deviation from the schedule for efficient real-time balancing and grid discipline.

The fixed and variable costs of electricity production are treated separately in the ABT. Fixed cost, known as capacity charge, is associated with plant availability and its capacity to deliver MWs on day-to-day basis. Generating plant is paid the capacity charge according to its average availability over a year. Variable charge, known as energy charge, is the charge associated with the variable cost of energy production and the total amount paid to the generators is based on their scheduled energy production rather than actual production. The third component of ABT is called unscheduled interchange (UI) which is the payment for deviation from the schedule, and the rate is decided according to the system frequency. Beneficiaries are paid for the underdrawal or charged for the overdrawal according to the system frequency. Thus the UI mechanism acts as a balancing market in which real-time price of the electricity is determined by the system frequency.

To promote power trading in a free power market, central electricity regulatory commission (CERC) approved the setting up of Indian energy exchange (IEX) which is the first power exchange in India, in June 2008. IEX has been modeled based on the experience of one of the most successful international power exchanges, Nordpool. At present, two power exchanges are operating in India, namely, IEX and Power Exchange

TABLE I
INDIAN POWER MARKET OPERATION STRUCTURE

Time scale	Market clearing	Approval of scheduling	Settlement
Long-term contracts	Traders and utilities	Nodal agency(RLDC/ SLDC)	Utilities
Short-term contracts	RLDC	RLDC	RLDC
Day-ahead	IEX/PXIL	RLDC	IEX/PXIL
Day-ahead scheduling of central and state generations (under ABT)	RLDC/SLDC	RLDC/SLDC	RLDC/SLDC
Real-time	through ABT-UI price signal	-	RLDC/SLDC

India Limited (PXIL). These exchange have been developed as market based institutions for providing price discovery and price risk management to the electricity generators, distribution licensees, electricity traders, consumers and other stakeholders. The participation in the exchange operations is voluntary. At present, exchanges offers day-ahead operations whose time line is set in accordance with the operations of regional load dispatch centers (RLDCs). Power exchanges coordinate with the national load dispatch centers/RLDCs and state load dispatch centers (SLDCs) for scheduling of traded contracts' to get up-to-date network conditions.

Currently, about 96% of the market transactions in India are in the form of bilateral (long and short terms) contracts. The rest is dealt by two power exchanges. The day-ahead market of power exchanges offers double sided auction and discovers the price incorporating the supply and demand side bidding. Network constraints are considered in deriving the price and market splitting approach is used to clear the market with congested lines. All buyers and sellers are expected to bear transmission charges and losses in their regional transmission system till the periphery of transmission system. They are also required to bear operating charges (a charge to cover costs of system operators) and transaction fee of the exchange which is nominal at INR 0.01paisa/kWh. The exchange, as of now, offers only day-ahead contracts of an hourly time blocks. However, the exchange has plans for future to offer the adjustments contracts and long-term contracts like forwards and futures to hedge the risk against uncertainty in electricity market. The Indian power market operations can be described as shown in Table. I.

A. Recently introduced market products and services in power exchanges in India

On August 31, 2009, the CERC accorded its final approval for the much awaited term-ahead market proposed by IEX. Following new contracts have been approved by CERC to be traded at IEX platform [1].

- *Day-ahead contingency contracts:* These are the contracts which will be available for trading after the day-ahead market for all the 24 hours of the next day i.e. the participants will be able to buy/sell power for any hour of next day. Trading will be organized from 15:00 Hrs

to 17:00 Hrs on daily basis. These region specific hourly contracts would enable participants to manage their next day contingency requirements on a day-ahead basis.

- *Daily contracts:* These are the contracts which will be available for trading on a rolling basis i.e. everyday seven daily contracts of the following week will be available. Each contract will be for specified block of hours of one day. The trading session for daily contracts will be organized daily from 12:00 Hrs to 15:00 Hrs. These region specific contracts are designed to enable participants to manage their requirements upto one week in advance with a delivery period of one day.

- *Intra-day contracts:* These are the contracts which will be available for trading on daily basis. These region specific hourly contracts would enable participants to match their same day contingency requirements for the duration 18.00 Hrs to 24.00 Hrs of the same day. The contracts will be traded from 12.00 noon and will continue till 17.00 hours of the same day.

  All the above contracts will be matched continuously on price-time priority basis i.e. buyers and sellers will submit bids on real time continuous basis. The seller with minimum price and buyer with maximum price will be considered as best seller and best buyer, respectively. The best buy bids will be matched with the best sell bids through out the trading period. Five best buy and sell orders will be displayed on the trading screen to all the participants on real time basis.

- *Weekly contracts:* These are the contracts which will be available for trading on all Mondays of the month and also on 15th day prior to the close of every month. These region specific contracts would enable participants to manage their requirements upto one month in advance with a delivery period of one week and maximum delivery period upto four weeks. The contracts will be traded from 12.00 noon and will continue till 14.00 hours of the same day.

Buyers can submit buy-orders in various regional contracts and will be considered as linked orders. In linked orders, the buyers will have the opportunity to put their buy bid in any of five operational regions (eastern, western, northern, southern, and north-eastern regions) [2]. Maximum bid volume in any of the regions will be considered as the maximum quantum buyer is willing to buy from all regions together and the quantum in other regions will be considered as the limiting quantum for that region.

The exchange will carry out trading in such contracts through closed auction session only i.e. closed auction means that the members can not see the other bids/offers submitted. Both buyers and sellers enter anonymous orders for contracts. Members can input several orders each with limit price and quantity. Orders from buyers and sellers are processed and matched. Members are allowed to enter, modify or delete bids during call period but not during auction freeze state. At the end of call period, such bids/offers are aggregated as demand and/or supply curve and intersection of two will determine uniform clearing price referred as equilibrium price. All orders

in the contract having prices, better than the equilibrium price are executed and the ones that have a price equal to the equilibrium price are executed according to a first in first out (FIFO) algorithm.

All the above contracts will be available for all five regions i.e. Northern, Eastern, Western, Southern and North Eastern. Sellers will quote bids for selling at their respective state periphery i.e. interconnection of regional entity with CTU however buyer can buy power from any of the five regions.

III. TOWARDS SMARTGRIDS

A "SmartGrid" is a concept for transforming an electric power grid by using advanced communications, automated controls and other forms of information technology. It integrates new innovative tools and technologies from generation, transmission and distribution all the way to consumer appliances and equipment [4]. This concept, or vision, integrates energy infrastructure, processes, devices, information and *markets* into a coordinated and collaborative process that allows energy to be generated, distributed and consumed more effectively and efficiently. Though the deployment strategy for SmartGrid encapsulates all stages of the electric power life cycle (generation, transmission, distribution, metering, customer), it should initially focus on sustainable options for customers at the distribution, meter and customer phases. Hence, a "SmartGrid" enables devices at all levels within the grid (from utility to customer) to independently sense, anticipate and respond to real-time conditions by accessing, sharing and acting on real-time information. Simply stated, SmartGrid is the convergence of information and operational technology applied to the electric grid, allowing sustainable options to customers and improved security, reliability and efficiency to utilities. A modernized grid would create a digital energy system that will: [4], [5]

- Detect and address emerging problems on the system before they affect service,
- Respond to local and system-wide inputs and have much more information about broader system problems,
- Incorporate extensive measurements, rapid communications, centralized advanced diagnostics, and feedback control that quickly return the system to a stable state after interruptions or disturbances,
- Provide to consumers with timely information and control options,
- Deploy and integrate distributed resources and generation, including renewable resources,
- Integrate "smart" appliances and consumer devices like hybrid cars, electric vehicles, etc.

For example, the combination of three emerging technologies i.e., advanced metering infrastructure, distribution automation, along with integration of distributed energy resources would constitute a *Distribution SmartGrid*. It is identified that one of the ways to succeed in implementing a SmartGrid that can enable a wide range of intelligent applications well into the future is the usage of "standards based approach" and the focus on dual interoperability of technologies.

A. SmartGrid Maturity Model

SmartGrid Maturity Model (SGMM) is one of the tools which can guide the transformation of an entire power grid forward towards smarter grid [9]. This will assess the utility grid state for moving towards the vision of SmartGrid. Some of the utilities are planning their SmartGrid road maps and investments using SGMM. This helps to establish a shared picture of the SmartGrid journey, communicate the SmartGrid vision, internally and externally assess current opportunities, choices and desired levels. This also helps in the strategic and decision making framework to develop business, investment and rate cases, build an explicit plan to move from one level to another, measure progress using key performance indicators (KPIs), benchmark and learn from others.

Various organizations like IBM, software engineering institute (SEI), etc has created the SGMM to evaluate the utilities current status [9]. Usually SGMM has different levels to rate a utility grid.

- Level 0 - Just started
- Level 1 - Initiating and Exploring : contemplating Smart-Grid transformation; may have a vision, but no strategy yet; exploring options; evaluating business cases and technologies; may have some SmartGrid elements already deployed.
- Level 2 - Functional Investing: making decisions, at least at a functional level; business cases in place and investments being made; one or more functional deployments under way with value being realized; strategy in place.
- Level 3 - Integrating Cross Functional: SmartGrid spreading; operational linkages established between two or more functional areas; management ensuring decisions span functional interests, resulting in cross-functional benefits.
- Level 4 - Optimizing Enterprise-Wide: SmartGrid functionality and benefits realized; management and operational systems rely on and take full advantage of observability and integrated control, both across and between enterprise functions.
- Level 5 - Innovating Next Wave of Improvements: new business, operational, environmental, and societal opportunities present themselves, and the capability exists to take advantage of them.

There are eight domains of logical groupings with related capabilities and characteristics at each maturity level as shown in Fig. 1. The levels are defined for each domain to assess the current state of utility grid towards SmartGrid vision. As of July 2009, 53 utilities have completed the SGMM assessment of under SEI [10] around the world. Results of different utilities shown in Fig. 2 indicate that most utilities are just starting the smart grid implementation.

The key point is that the SGMM is not a report card with those utilities reaching the highest maturity levels "winning the game." Instead, each utility uses the SGMM to understand how the SmartGrid can help optimize its planning and investment to achieve its aspirations.

IV. SMARTGRID INITIATIVES IN INDIA

Demand side management (DSM) is essential for optimized and effective use of electricity. In the face of scarce resources,
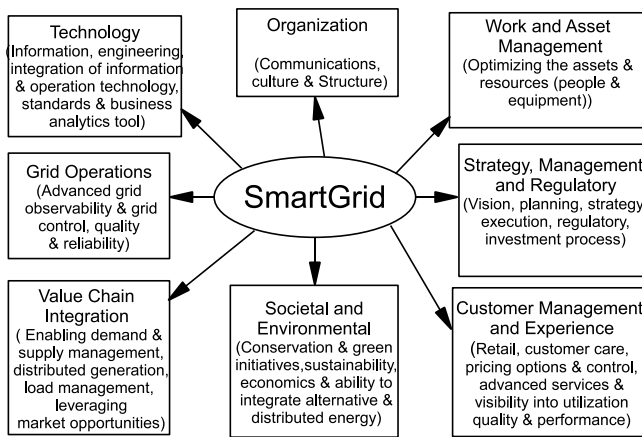
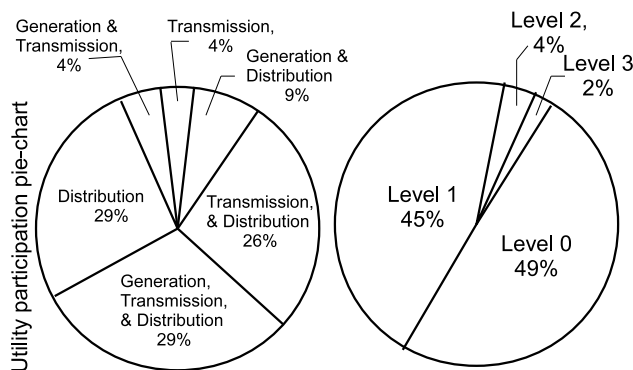Fig. 1. Eight SmartGrid logical domains and important elements

Fig. 2. SGMM analysis results of different utilities all around the world

DSM is the major issue identified in the Indian system, where demand is in excess of the available generation, inevitably leading to load curtailment [7]. DSM is the implementation of those measures that help the customers to use electricity more efficiently by shifting their peak load pattern. DSM can be achieved through:

- Improving the efficiency of various end-uses through better housekeeping correcting energy leakages, system conversion losses, etc.
- Developing and promoting energy efficient technologies, and
- Demand management through adopting soft options like higher prices during peak hours, concessional rates during off-peak hours seasonal tariffs, interruptible tariffs, etc.

To achieve the above objectives, electricity grid intelligence is inevitable, which requires advanced control and communications technologies integrated with the utility network, thus providing the requirements of "SmartGrid". Reference [6] details the some of the SmartGrid deployment strategies for the Indian scenario. To facilitate demand side management, distribution networks are to be fully-augmented/upgraded for IT enabling. IT enabling in distribution will help in improved network planning, improved operation and maintenance, energy accounting and auditing at each level, graded load shedding measures to flatten the demand curves, eventually results in improved customer service. Adoption of IT has

been mandated in the Restructured APDRP [2]. Ministry of power [2] also participated in the SMART 2020 event with the climate group [8] and the Global e-Sustainability Initiative (GeSI) in October 2008.

A. Crompton Greaves SmartGrid Initiatives

Crompton Greaves (CG) is India's largest private sector enterprise. At present, CG is actively taking part in the SmartGrid research and development activities [14]. It initiated the development & integration of products like

- Integrated SCADA solution for SmartGrid environment on in-house developed crompSCADA platform as per IEC 61850 standard
- Substation asset management solution that includes IN-TERNET based on-line condition monitoring devices for transformers and switchgears
- Smart bay control unit
- Smart protection IEDs
- Enterprise level information grid as per IEC 61968 standard
- Smart load controls and shedding solutions
- Automatic power outage management solution
- Smart load break switches / sectionalizers
- Smart metering solution
- IT solutions for power distribution

B. North Delhi Power Limited (NDPL) SmartGrid Initiatives

NDPL is a joint venture between Tata Power Company and the Government of Delhi, India, announced that it has joined hands with GE SmartGrid Technologies and has become the first power distribution utility in India to realize the performance advantages of an advanced Outage Management System (OMS). This will help NDPL respond more quickly to power outages and provide accurate, updated restoration-time estimates. The system's network analysis tools identify and assess outages and gets into action even before the consumers call to report them.

NDPL distributes electricity in North & North West parts of Delhi and serves a population of 5 million. The company started operations on July 1, 2002 post the unbundling of erstwhile Delhi Vidyut Board. With a registered consumer base of around 1 million and a peak load of around 1180 MW, the company's operations span across a geographical area of 510 Sq. Km. NDPL has to its credit several firsts in Delhi: SCADA controlled grid stations, automatic meter infrastructure, GSM based street lighting system, geographic information system (GIS) platform with fault management system. To ensure complete transparency, the company has provided online information on billing and payment to its customer base of over one Million.

Earlier, in Sept. 2008, NDPL has joined hands with IBM to become a member of a global Intelligent Utility Network (IUN) coalition convened by IBM. NDPL also becomes the first Indian utility to join the IUN Coalition which includes utilities in North America, Europe and Asia-Pacific regions - all working together to accelerate the development of common standards, technology solutions and processes for intelligent

and smart networks. It has built its SmartGrid Maturity Model (SGMM) to realize the SmartGrid vision and target. The Capability SGMM from Carnegie Mellon and the Software Engineering Institute changed software development globally. NDPL operating in this environment would benefit:

- More automation in monitoring and control of the power usage and the electric grid,
- Greater integration of the grid to create an end-to-end system from the utility to the home, and from the home back to the utility, and
- Greater responsiveness to changing market conditions and regulatory compliance

C. Bangalore Electricity Supply Company

Bangalore Electricity Supply Company (BESCOM) is responsible for power distribution in eight districts of Karnataka [13]. BESCOM covers an area of 41,092 Sq. Km. with a population of over 16.8 million. At present, the outage faced by a customer on an average is 86 hours per year with large interims per outage. BESCOM plans to drastically reduce the outage average by 80 percent, ensuring that any interruption does not last for more than 3 minutes. There is a tangible benefit of increased revenue gain over a period of time. Intangible benefits involve loss reduction, ensuring reliable and quality power with least interruptions, quick turnaround on breakdowns and helping the company become socially responsible and accountable.

V. FUTURE DIRECTION FOR INDIAN MARKET WITH THE ADVENT OF SMARTGRIDS

The previous sections have covered the current Indian power market structure and operations, and SmartGrid initiatives. This section details some of the identified areas for enhancement and required new market products with the advent of SmartGrid movement.

A. Data management System

The market information grid is crucial in the future markets in SmartGrid paradigm. Future Indian market information grid at all levels with the advent of SmartGrid paradigm is shown in Fig.3. Data surge can be forecasted due to increased complexity of market operation by enrollment of end-users, DGs, MicroGrids into the markets. The two-way metering data may be voluminous. Hence, there is a need for standardizing the information exchange and data formats. It requires focus on adopting the developed standards and improving the standards according to the new requirements. So, data standards and data management of market data is to be taken care of in a proper manner.

1) Data Standards: Usually, the data sources do not always communicate via common standards. However, the two dominant standards existing are the common information model (CIM) standard and Multi Speak. Both define a standard data interface that supports batch and real-time data exchange. Multi Speak originated with the National Rural Electric Cooperative Association and CIM is an open-source standard through the IEC.

Another option is IEC 61850, a standard for data communications among intelligent electronic devices (IEDs) across a power system, which encompass as the CIM model as part of IEC 61970 and IEC 61968.

- IEC 61970: A standard incorporating a Common Information Model (CIM) for power systems and application programming interfaces at Energy Management System (EMS).
- IEC 61968: A standard incorporating CIM and standardized XML messaging for Distribution Management Systems (DMS).
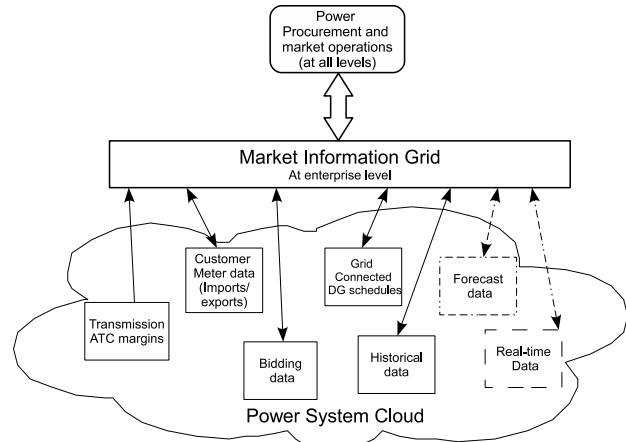

Fig. 3. Future Indian market information grid at all levels on the advent SmartGrid paradigm

These open standards should be implemented at the EMS and DMS end for all the utilities and utilities should be open to dual interoperabilty. So that it lays a strong intern foundation for data exchange of Market Management System (MMS) by ease in operations.

2) Data Management: The preliminary estimate at one utility is that the SmartGrid will generate more than 20 gigabytes of data each day from its 2 million customers [15]. Especially this may originates from the retail markets. Mere data collection will not suffice. Data management has to start at the initial reception of the data, and reviewed it for market operation events which will trigger alarms into related management systems and other real-time systems. Then, and only then, should normal data processing start. In addition, storing of large data is not typically useful, so a data storage and roll off plan will be critical to managing the flood of data. Most utilities may not be ready to handle this volume of data.

Load information might be best served on a 5 or 15 minute basis. Engineering analysis may need a full year of available data for analysis. This knowledge continuum can be briefly characterized into three major categories:

- *Operational/Analytical Data:* These are the real-time or near real-time operational applications like available transfer capability (ATC) margins, customer meter data, spot bidding, Grid connected DG tracking information.
- *Front-end analytics:* These functions help the business operate beyond real-time management of the grid. Examples include forecasting models that support generation

planning and spot market power purchases or demand management programs. These data uses are typically same-day, same-hour applications, but there is time to scrub the data and even to try again to get information from the field.

- *Back-end analytics:* These are the non-real-time applications that provide rate analysis (settlement mechanisms) and/or decision support, based on the processing of data from the SmartGrid. The analytics transform data into actionable information. This is where the accountants, engineers, planners and standards engineers will find the data they need to do their jobs.

Planning and building an integrated SmartGrid market data management is a complex collection of decisions and tasks. Hence, it requires new data architectures cyber security protocols. However, at this point, research for proper data and event architectural solutions is ongoing by clearly giving justification to the various services organized in the architecture along with their interaction, and the ways of deploying intelligence. Last but not the least concern is that they should question the possible theories for their real world realization.

B. Secure communication and standard protocols

Communications among regional market operators, utilities, service providers and consumers are necessary. There should be dual interoperability. In view of supporting all the data sources on the grid, a high-bandwidth communication infrastructure must be in place. A wide range of wired and wireless communications technologies are available to transport data, but there is no one best choice. Any SmartGrid initiative will have to pick two or three communications methods, and mix and match as required to get to the required level of coverage. Some may be owned and operated by the utility (e.g. fiber to the substations), and some may be commercial networks (e.g. cellular phones). Broadly, there are four levels of cyber standards:

- Media-related standards specific to fiber optics, microwave, WiFi, CATV, wires, telephones and cellphones
- Transport-related standards such as Internet standards including Ethernet, IP, TCP, HTTP, OPC
- Application-related standards such as HTML, XML, IEC 61850, Common Information Model (CIM)
- Security-related standards such as AES 256, IEC 62351, PKI, secret keys, and Certificates

From the view of enhancing power market data security, there is a need for implementing power system communication and data security open standards like IEC 62351. This is because communication protocols are one of the most critical parts of power system operations to ensure proper market functionality. These protocols were specialized, "security by obscurity" has been the primary approach.

C. Introduction of power quality based services and increase priorities towards "retail" players

In India, there are no full-fledged retail markets present. End-users are not participating in the markets. Integration of renewable resources are going at one end. Upcoming policies are encouraging the integration of small-scale renewables to the utility grid. At this situation, it is predicted that advent of SmartGrids in India may enable retail markets which can open up competition avenues for the entry of end-users/customers. The integration of green power into the market is also an important function in SmartGrid movement. This requires metering standards and effective communication protocols. Apart from these compulsory requirements, there will be a need for upgrading the present market products. In this direction, this paper has identified the need for introduction of quality bids to few retail markets as per the customer requirements in the respective market. The reason behind this proposal is the increasing needs of reactive power at the load-end and increasing focus on power quality due to increased usage of sensitive equipments. The envisaged future Indian market structure is shown in Fig. 4.
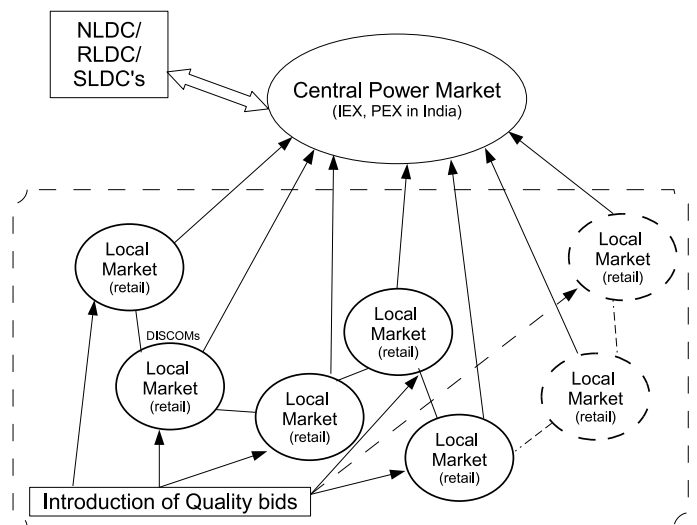

Fig. 4. Future market structure in India

VI. CONCLUSIONS

The power markets in India have started their operation in 2008. An overview of power markets along with the new proposed products is described. Many utilities have plans to built SmartGrids with particular reference to distribution systems and renewable energy sources. The SmartGrid maturity model will help these utilities to identify their position and provide pointers for future transformation. To realize the advantages claimed by the SmartGrids, the supporting technologies, standards and infrastructure will play crucial role. Power markets are generally characterized by the poor demand side response for the lack of proper infra structure. SmartGrid can elegantly address this issue. Few initiatives in India are reported briefly with some details of the future plans also. The need for new standards for efficient market operations in the SmartGrid paradigm is emphasized. Introduction and integration of retail markets with proper communication protocols are needed. The huge data to be handled in future will call for efficient database management, data mining techniques and architecture which can support seamless exchange of data at various points in

the system. Few quality sensitive customers may be able to specify their power quality requirement through SmartGrids.

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