Renewable Energy Integration In India

Challenges, Solutions and Transactive Energy Market Proposition

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***Abstract*— Building Transactive Energy Markets (TEM) to optimize Renewable and Distributed Energy Resources' grid integration in India.**

***Keywords* –** renewable energy, grid, markets, blockchain

I. INTRODUCTION

Growth of renewables and distributed energy resources (DER) such as large-scale grid connected solar plants, solar PV with batteries, storage, EV charging stations etc., and flexible consumption patterns at the edge of the grid offers a new opportunity for grid operators to optimize whole-system. If regulators, policy makers and grid operators plan to optimize grid operations for the benefit of every stakeholder then it is imperative for them to optimize utilization of these flexible supply and demand resources at all levels. However, it is easier said than done because these resources are growing at the high voltage as well as at the edge (medium/low voltage level) of network, and traditional mechanism of whole-sale market valuation (based on average or equilibrium estimates) and centralized control (predominantly driven by transmission & high voltage level) might not work effectively for optimal DER integration. There is need of a faster short-term balancing market and a retail transactive energy marketplace which is enabled by a distributed intelligent system that facilitates near real-time valuation of flexible services and offer federated control & faster response. This paper explores the possibility of TEM in India to optimize renewable energy resources' integration to the grid.

II. THE CONTEXT - INDIA RENEWANLE STORY

A. India Renewable vision, target and stakeholders

Vision-"To develop new and renewable energy technologies, processes, materials, components, sub-systems, products & services at par with international specifications, standards and performance parameters in order to make the country a net foreign exchange earner in the sector and deploy such indigenously developed and/or manufactured products and services in furtherance of the national goal of energy security" with this vision statement Government of India (GoI) has established the ambitious mission to achieve power and energy challenges[1].

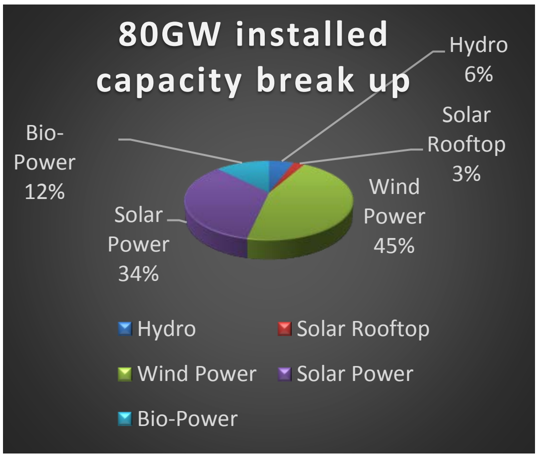
Target- In order to remain in line with Paris climate agreement, by 2022, India is targeting the installation of 175GW of renewable energy capacity, an ambitious target that will require a four-fold growth in the sector. In 2018, Indian govt further extended this target from 175GW to 225 GW by 2022 [7].

Stakeholders- The Ministry of New and Renewable Energy (MNRE) is a ministry which is one of the most important stakeholders and has been assigned with responsibility to look into all aspects of Renewables from stakeholders to private investors and from policy to trading.

Some of the other stakeholder are- Ministry of Power (MoP), Ministry of Finance (MoF), Ministry of Environment and Forests (MoEF), Central Electricity Authority (CEA), Power Grid Corporation of India, Ltd. (PGCIL), the Energy Secretaries of States, Commission for Additional Sources of Energy (CASE), Power System Operation Corporation Limited (POSOCO) Indian Renewable Energy Development Agency (IREDA); National Load Dispatch Center (NLDC), RLDCs, SLDCs, State Transmission and Distribution companies (Discoms), Generators, Consumers and other private stakeholders.

B. Actual v/s Target

India has set and highly ambitious target to achieve renewable commitments and to meet the energy requirement of its emerging economy. India already is the world's 5th largest renewable capacity holder with 80 GW of installed capacity till June 2019 [2]. Following is the current RE state in India:



In order to achieve the 2022 target, GoI has pushed all the doors and policies for maximum participation. As result of these measures the gap between target and installed capacity is reducing very fast. Below table gives details of category wise target, acheivements in FY-19, and cummulative numbers [2].

Ministry of New & Renewable Energy

Programme/Scheme wise Physical Progress in 2019-20 & Cumulative upto June, 2019

Sector	FY- 2019-20 Target	FY- 2019-20 Achievements (April-June 2019)	Cumulative Achievements (as on 30.06.2019)
I. GRID-INTERACTIVE POWER (CAPACITIES IN MWp)			
Wind Power	3000.00	742.51	36368.47
Solar Power - Ground Mounted	7500.00	1114.75	27499.05
Solar Power - Roof Top	1000.00	253.94	2050.29
Small Hydro Power	50.00	11.65	4604.80
Biomass (Bagasse) Cogeneration)	150.00	28.00	9131.50
Biomass (non-bagasse) Cogeneration)/Captive Power	100.00	0.00	674.81
Waste to Power	2.00	0.00	138.30
Total	**11802.00**	**2150.85**	**80467.22**
II. OFF-GRID/ CAPTIVE POWER (CAPACITIES IN MW_{EQ})			
Waste to Energy	10.00	0.00	178.73
Biomass Gasifiers	1.00	0.00	163.37
SPV Systems	400.00	3.04	918.64
Total	**411.00**	**3.04**	**1260.74**
III. OTHER RENEWABLE ENERGY SYSTEMS			
Biogass Plants	86900.00	1680.00	5028340.00

In another set of analysis on the grid connectivity of renewable generation against the installed renewable capacity, it was found that only 51.28 GW (64.1%) [3] of installed renewable capacity is connected to the grid and interestingly only 4.3 GW [4] (less than 6% of total installed capacity) is tradable through Renewable Energy Certificate (REC) over power exchanges.

Category	Capacity	% Share
RE installed	80 GW	100%
RE grid connected	51.3 GW	64%
RE tradable (through REC)	4.3 GW	5.4%

This investigation reveals that MNRE needs to contemplate on the existing challenges and potential solutions to optimize renewable installations and grid integration across India. They, also, need to innovate market mechanisms to improve RE participation in spot trading. The upcoming section throws highlight on these issues.

III. Current RE Grid Integration Chalanges in India and Proposed Solutions

While economic, environmental and energy security concerns have been the key influencers for promotion and development of Renewable Energy Sources (RES), these sources are characterized by inherent issues like variability, intermittency and fast ramping, etc.

This section will cover view on major challenges in RE business specific functions, which are acting as roadblocks or can become bottleneck in future in India, and solutions which can ensure seamless RE integration.

A. Regulations and Policies

Challenge- No clear definition of Roles and Responsibilities of System Operators for renewable resources connected at different voltage levels

Solution- "A larger number of resources at the customer side, providing a range of services to the grid (including energy, capacity, voltage control and frequency response) and likely willing to make transactions with other distributed resources, demands the need for a system operation role at the distribution level, and regulation to enable distribution system operators to shift from network operator to digital platform providers. Policy makers will have to decide on the appropriate way to incorporate this new distribution system operation function in their overall system design. They will also have to tackle issues around the coordination with transmission operators, RE asset ownership, avoidance of conflicts of interest between the network and system operators, and the operating model for distributed resources. The good example is *National Grid, UK* who has moved to separate their functions of system operation and the development and ownership of assets after calls from regulators and policy-makers" [8].

Challenge- Constrained revenue model and minimal incentive to expedite the RE integration for grid operators [5].

Solution – In India, the grids are state controlled. Hence it is important for regulators to incentivise grid operators to prioritise allocated investments in solutions that facilitate faster RE integration. There are mutiple approaches possible to promote this objective. The first approach can be, policies reward players for reaching policy goals (such as energy efficiency, peak shaving, data sharing), instead of picking specific technologies. The second approach removes the incentive for utilities to invest only in additional network infrastructure and encourages them to invest also in non-wire alternatives, including network digitalization, active network management or procurement of services from local distributed energy resources.

Challenge- RE resources do not have access to markets

Solution- "To ensure that distributed energy resources can play a role alongside large-scale centralized generation, and that their value is optimized, policy-makers should ensure the RE resources have access to energy markets. Doing so requires that DERs are clearly defined in terms of their role, asset type and ownership. Adequate market design is to be enabled, allowing independent aggregation, network operators to procure services from distributed resources, time and location-based valuing of distributed resources and improved connection speed and economics. Market mechanisms paired with regulatory incentives should reward distributed resources where it is most valuable for the system. Locational value of DERs – where it would have

greatest grid value – can be assessed by combining pricing data and data from substation locations.” [8]
Also enable inter-state RE transactions- This effectively increases the balancing area and isn’t so transmission burdensome when the favorable sites are near the border and will provide more flexibility of operations.
Enablement of RE resources’ access to markets will also require regulators to contemplate a time varying pricing model that provides lucrative arbitrage opportunities to all stakeholders while optimizing RE grid connections.

Challenge- Land acquisition is still a tedious process and many projects are stuck in litigations due to lack of land acquisition law clarity for RE. CEA guidelines are still generic and doesn’t specifically state renewable energy rules and regulations [6].

Solution-Simplified laws specific to renewable energy land acquisition must be put in place to accelerate the current RE commissioning and integration speed. Also, CEA laws must be amended specific to renewable energy generation and distribution, specifically for better Right of Way (ROW) clearance definition, protection equipment requirement, synchronization standards, voltage limit, frequency, power factor etc. Only large scale RE generators have been considered in 2013 CEA guidelines and a big chunk of smaller, but potentially significant, generators are still outside the purview of CEA.

B. Grid Operations

Challenge- Network capacity constraints for target RE grid connections

Solution- The transmission capacity of grid must match the RE installation capacity with provision of n-1 redundancy. Each new RE installation must be passed through technical feasibility and usability process from grid operations perspective. Innovate technical and commercial solutions to overcome network capacity constraints such as Active Network Management, Managed or Capped renewable connection contracts etc. Using this approach grid operator can explore non-wire solution to provide faster RE connections in congested areas.

Challenge- Lack of visibility of accurate renewable power generation, scheduling and dispatch

Solution - The use of continuous and accurate forecasts in grid operations can help in predicting the amount of renewable energy available and reducing the uncertainty in the amount of RE generation that will be available to the system. Integrating continuous forecasts in system operations and unit commitment practices can reduce the cost of integrating renewables and reduce the need for reserves. Generation accuracy is directly linked to power scheduling and dispatch which in turn helps in reliability and synchronization management at grid level.

Challenge- Silo operations along the value chain (e.g. between Transmission System Operators (TSO) and Distribution System Operators (DSO))

Solution – “If the distribution network is transformed by the increasing number of DERs and the role of network operators evolves, the need for coordination and data & information exchange between regional and state load dispatch centers increases. Breaking siloes is fundamental to ensure secure and safe operation of the network and in performing tasks such as congestion management, balancing, use of flexibility, real-time monitoring and control & network planning”. [8] Completely digitized network can enable real time management of these resources, as well as support the quantification, qualification, verification and settlement of the DER-related services across voltage levels. This could be achieved through the proposed Renewable Energy Management Center(s) (REMC), which should coordinate with state and regional load dispatch centers. Data sharing is especially important for wind power, which has much more granular variance than solar power, especially on a kilometer scale. REMCs need not be a large or complex institution – these could be envisaged as virtual centers in synergy with Load Dispatch Centers.

Challenge – Lack of visibility and control mechanisms of DER resources at last mile of voltage level

Solutions - IT-OT capability enhancements at all voltage levels, Implementation of smart meters and intelligent electronic devices (Sensors, RTUs etc.) & Implementation of real time renewable resources management systems such as DERMS, SCADA, ADMS and OMS need to be contemplated at all voltage levels. This will require change in control architecture from centrally controlled to distributed & federated control mechanisms.

C. Technology and Engineering

Challenge - Inherent issues like variability, intermittency and fast ramping with RE resources - Increasing the number of RE resources creates uncertainty in load and power supply generation, which also presents an additional strain on the system. These uncertainties will affect the voltage and frequency variation, reactive power stability, protection, and safety issues at fault levels. RE resources present non-linear characteristics, which require effective coordination and control methods.

Solution - Move towards latest RE technology: Technologically, RE could provide more than simple kWh generation, such as reactive power, if it were incentivized to do so. In addition, India must plan for the ability of such generators to handle Low Voltage & Fault Ride through capabilities, something that China grappled with but ultimately enforced in recent years. The difficulty of a weak grid is exacerbated when RE generators cannot handle low voltages or faults – they trip, further weakening the rest of the grid creating a cascading effect. The good news is that most newer turbines and equipment, technologically, could handle this – the problem remains for existing old capacity which does not support these mechanisms – should these be upgraded?

Also contemplate installing energy storage devices and capacitor banks at strategic locations to balance the deficit or redundancy of supply emerging because of variable intermittent nature of RES. Hot spot analysis of grid at national and state level can help in identifying such sites and investment requirements.

Challenge – Rapidly evolving grid infrastructure technologies such as Electric Vehicle, Storage etc. with heterogenous communication and interfacing protocols and multi-vendor landscape

Solution – "Several actions can be taken to ensure that the necessary infrastructure is in place to enable new business models and the future energy system, including the following:
Define the model to deploy enabling infrastructure that is flexible, open and interoperable. Ensure customers and third parties can benefit from data generated by DERs and the digital grid. The model of deployment of enabling infrastructure encompasses three main dimensions:
i) Defining what is considered enabling infrastructure (for example, recharging stations, storage services, broad-band telecom, smart meters and intelligent devices)
ii) Removing uncertainty by deciding rules on ownership and cost-recovery of enabling infrastructure – targeting a market-based approach whenever sensible
iii) Convening open standards and requiring interoperability for DERs and communication infrastructure to ensure multiple services can be combined" [8].

In summary, one of the prominent messages that can be derived from previous section is that RE installation and integration can be optimized with the intervention authorities to address above challenges. Also, RE integration will be more effective if RE resources are given faster market access. Hence, the upcoming section highlights the fact that how faster markets make a good business case for RE integration and what is required to be considered to establish fair and neutral markets for RE resources in India.

IV. Contemplating Market Mechanisms for faster integration of RE

A. Why Faster Markets are Preferred

Study conducted by NREL [9] supports the hypothesis that sub-hourly scheduling and dispatch is preferred with higher density of renewable resources. Sub-hourly dispatch increases system efficiency, improves reliability, cuts the amount of reserves required for system balancing, and enables systems to integrate higher number of renewable resources of variable renewable energy generation. If the dispatch is scheduled more frequently then the amount of imbalance in system is also reduced. While the costs of managing the overall system increases because of sub-hourly scheduling and dispatch as it increases frequency, but the overall reserve requirements are reduced resulting in a net benefit.

Faster dispatch can enable the system to access reserves from active units at little or no extra cost. It can also lessen the need of regulation reserves, which are the most expensive types of reserves, because there are less short-term deviations between load and generation when the system is re-dispatched frequently. With hourly dispatch mechanisms, generators must follow a set schedule every hour, with the level typically set an hour advance.

Sub-hourly scheduling in interstate regions, as compared to intra-region, can drive more operational efficiencies and facilitate for faster balancing. This is because sub-hourly dispatch facilitates greater access to active and available generation as compared to hourly dispatch.

The benefits of sub-hourly scheduling are much higher between interstate boundaries with substantial penetration of variable renewable generation. If grid constraints exist, then faster scheduling across interstate boundaries can enable the variable generation to be more efficiently integrated with grid through faster and coordinated dispatch with connecting states and markets.

"The Western study found sub-hourly scheduling to be important for minimizing regulation requirements on the system. By scheduling resources every 5 or 15 minutes, rather than every hour, the study found that the need to ramp units providing load following can be substantially reduced. The Western study case of high wind and solar penetration (30% energy) with sub-hourly scheduling required half the amount of quick maneuvering of combined cycle plants from what would be required with hourly scheduling. The amount of fast maneuvering of combined cycle plants was about the same in the 20% renewable energy penetration scenario with hourly scheduling and the 30% renewable energy penetration case with sub-hourly scheduling.

This finding demonstrates that the use of sub-hourly scheduling can certainly help in accommodating higher penetrations of renewable energy on the system. Also, through minute-to-minute simulations, the study found that hourly scheduling has a greater impact on regulation requirements of the system than the variability introduced from the wind and solar.

The TradeWind study found that intraday markets for cross border trade are important for facilitating higher levels of wind penetration. The introduction of intraday trading resulted in savings of 1-2 billion euros annually compared to a scenario with only day ahead cross border trade.

A survey of grid operators from a variety of countries also supports the notion that faster scheduling and dispatch leads to more efficient system operations and helps to manage variable generation. Respondents that work in areas with and without wholesale electric power markets indicated that frequent generation scheduling, and dispatch are efficient methods of managing variable renewable generation on the grid". [9]

Benefits of Faster Markets:

System Operator's and Market Benefits

- Incentivises latent capacity to come online immediately
- Increases system security
- Avoids strategic late bidding that distorts market prices
- Signals investment to types of generation required – i.e. fast response

- Optimizes renewable & low carbon resources utilization
- Promotes healthy competition and fair prices

Generator's Benefits

- Aligns payments with volumes delivered at dispatch interval prices – avoids dilutive effects of average prices
- Allows profitable bidding for new types of generation

Consumer Benefits

- Allows C&I customers to provide demand response in shorter, more workable intervals
- Allows DR to part take more directly in wholesale prices
- Increases the range of offers to aggregate and monetise investments made in behind the meter technologies
- Potential reductions in wholesale prices as price averages would reduce

Based on above findings, one of the solutions we propose for optimizing renewable energy integration and usage in the India market is to develop faster transactive energy markets (TEM) in India. The upcoming section elaborates on the TEM concept.

B. Transactive Energy Markets (TEM)

<u>What is Transactive Energy (TE)?</u>

"A system of economic and control mechanisms that allows the dynamic balance of supply and demand across an entire electrical infrastructure using value as a key operational parameter. The market that facilitates transactive energy transactions is termed as transactive energy market. Following are 11 key attributes and 6 principles identified for TEM by *GridWise Architectural Council, USA*" [10].

<u>TE Architecture-</u>
All TE tools and methodologies are described as constituents or subsystems of a system architecture. A key distinction is whether the architecture is centralized, distributed, or a combination of the two.

<u>TE Extent-</u>
A TE system will typically apply within some geographic, organizational, political, or other measure of extent. A geographic extent, for example, might be within a region and apply across multiple participating entities. An extent may be described organizationally, for example, if an implementation is intended for use within a single utility, building, or campus. Likewise, a transactive system may apply across political boundaries with different regulatory or policy constraints. Extent may also be considered relative to the topology of an electrical infrastructure including end-users. Thus, a transactive system may apply in transmission, distribution, or both; it may also be useful for managing energy within buildings or by end-users of electrical energy.

<u>Transactive Parties-</u>
Fundamentally, TE involves transacting parties. In most cases these will be automated systems, possibly acting as surrogates for human parties. In some cases, humans may be in the loop. A TE system must be explicitly describable by the entities that are parties to transactions. Because a TE system will provide services to various parties, its success in delivering these services will depend in part on the expectations and needs of each group and in part on the qualities of the delivered service. Understanding such criteria is a critical aspect of the monitoring and assessment of a system.

<u>Transaction-</u>
A TE system must clearly define transactions within the context of that system. The following questions (and possibly others not anticipated here) must be able to be answered: Who are the transacting parties, what information is exchanged between them to create a transaction, and what is exchanged between them to execute a transaction? What are the rules governing transactions? What is the mechanism(s) for reaching agreement?

<u>Transacted commodities-</u>
Although the primary commodity transacted is energy, derivative products such as reliability-driven call options (e.g., Ancillary Services) may also be transacted among the transacting parties.

<u>Temporal Viability-</u>
Transactive systems may interact across different timescales. For example, transactions within a single system may range from sub-second to five minutes or to the longer periodicity. It is also possible for transactions to be event-driven. In characterizing a given transactive system the timescale(s) of transactive interactions need to be specified and analyzed for compatibility. This will be a key to interoperability between different transactive systems.

<u>Interoperability-</u>
Transactions are enabled through the exchange of information between transacting parties. There are two elements to consider here: technical interoperability and cognitive (semantic) interoperability. The systems must be able to connect and exchange information (emphasizing format and syntax), and they have to understand the exchanges in the context that was intended in order to support workflows and constraints. For any given transaction the information exchanged during a transaction must be explicitly identified. Furthermore, one should be able to explain how interoperability has been addressed in support of the information exchanges.

<u>Value discovery mechanism-</u>
A value discovery mechanism is a means of establishing the economic or engineering value (such as profit or performance) that is associated with a transaction. Fundamentally, a value discovery mechanism is the process by which transacting parties come to an agreement on value. The inclusion of this attribute recognizes that the mechanism may be simple or complex. For at least some transactive

systems, the value discovery mechanism is a key element of value-driven multi-objective optimization. Value realization may take place through a variety of approaches, including an organized market, procurement, a tariff, an over-the-counter bilateral contract, or a customer's or other entity's self-optimization analysis. Value discovery mechanisms should include considerations of economic incentive compatibility and acceptable behavior.

Assignment of value-

Assignment of value is fundamental to value discovery. For sub-elements of a TE system, a means may be needed for assigning value to objectives that cannot be addressed through a discovery mechanism or for values that do not have a common dimension that can be used for valuation. For example, end-users of electricity may have non-quantitative values such as comfort that require a mechanism to translate them into elasticity, thus enabling quantification in a transaction.

Alignment of Objectives-

A key principle in the broad application TE systems is the continuous alignment of multiple objectives to achieve optimum results as the system operates. This alignment enhances the economic and engineering impacts of the dynamic balance(s) achieved by TE systems. Note that optimal relates to balancing the entire transactive system, and to achieving an optimum balance necessary to optimize objectives, variables, and constraints. It is important to understand that optimization does not simply add intelligence to existing business processes, it changes business practices.

Assuring Stability-

The stability of grid control and economic mechanisms is required and must be assured. Consideration of system stability must be included in the formulation of TE techniques and should be demonstrable. Unfortunately, there are no public benchmarks for the stability of TE systems and during numerical optimization minor errors can build on each other, and sometimes spiral out of control. It is important to mitigate optimization instabilities because grid stability may be compromised by poor value optimization techniques. In addition to the need to assure stability from a control systems point of view, stability should also be assured with respect to existing grid stability limits. [10]

C. Principles of TEM

The transactive energy market has mainly 6 principles which are as follows [10] -

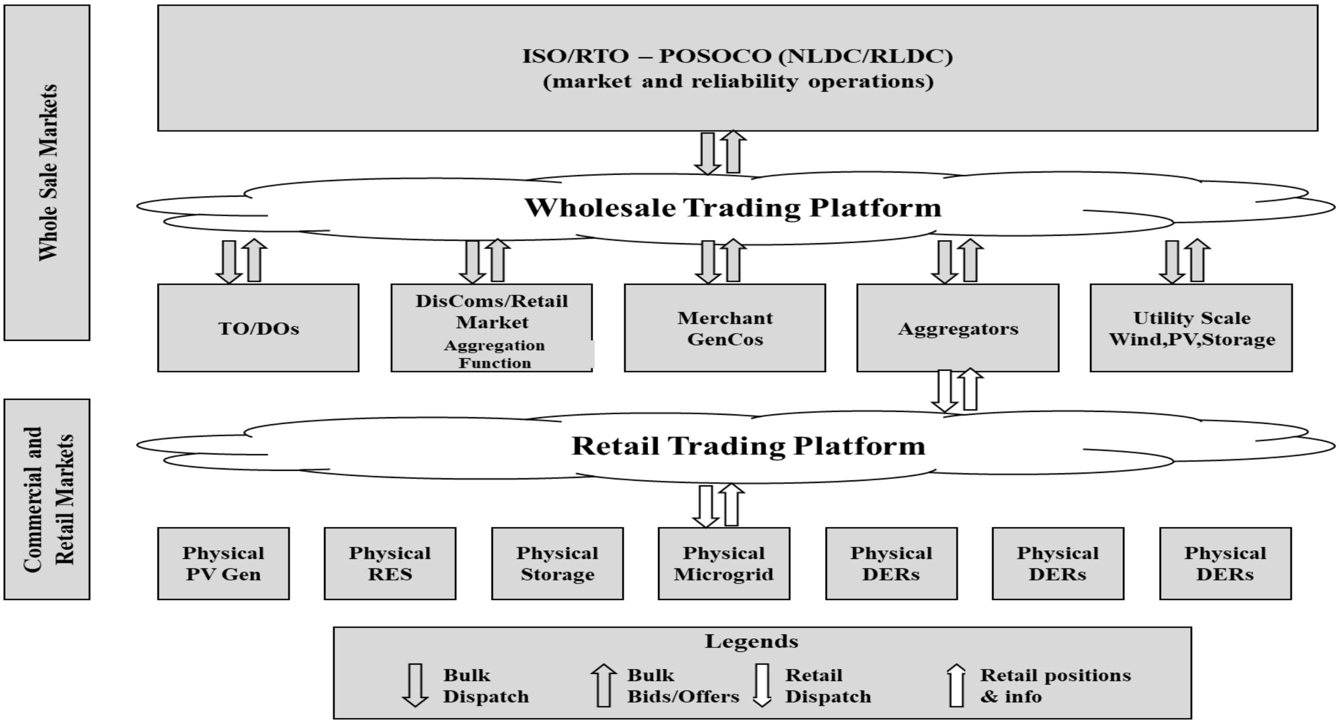
- Transactive energy systems implement some form of highly coordinated self-optimization
- Transactive energy systems should maintain system reliability and control while enabling optimal integration of renewable and DERs
- Transactive energy systems should provide for non-discriminatory participation by qualified participants
- Transactive energy systems should be observable and auditable at interfaces
- Transactive energy systems should be scalable, adaptable, and extensible across several devices, participants, and geographic extents
- Transacting parties are accountable for standards of performance

D. Proposed TEM structure for India

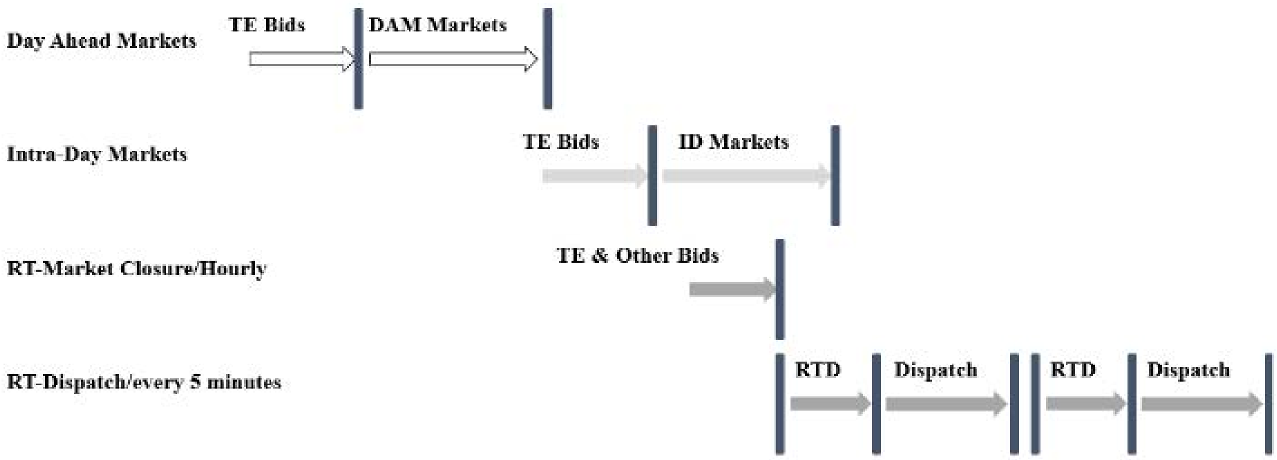
The previous section already described 11 key attributes and 6 principles that need to be adopted to implanted transactive energy markets as defined by *GridWise Architectural Council, USA*" [10]. We extend the current concept of Indian Energy Exchange to demonstrate how it can be transformed into fast scheduling and dispatch based TEM concepts. Different areas that need to be addressed for Distribution Level System Operators (SLDCs, DISCOM and Retail Markets) for implementation of TEM are (non-exhaustive list)

- Aggregator Function
- Bidding system and Market algorithms
- Retail Market Clearing
- Result as retail schedules
- Results as bids/schedules to NLDC/RLDCs
- NLDC/RLDCs Interfaces
- Metering
- Contract Management, Billing and Settlements
- Communications through Standards
- Dispatch to aggregators as instructions or to devices as setpoints
- IT systems and Processes
- Organizational Management

Proposed TEM market structure for India



Proposed Market Timelines for Transactive Energy Markets

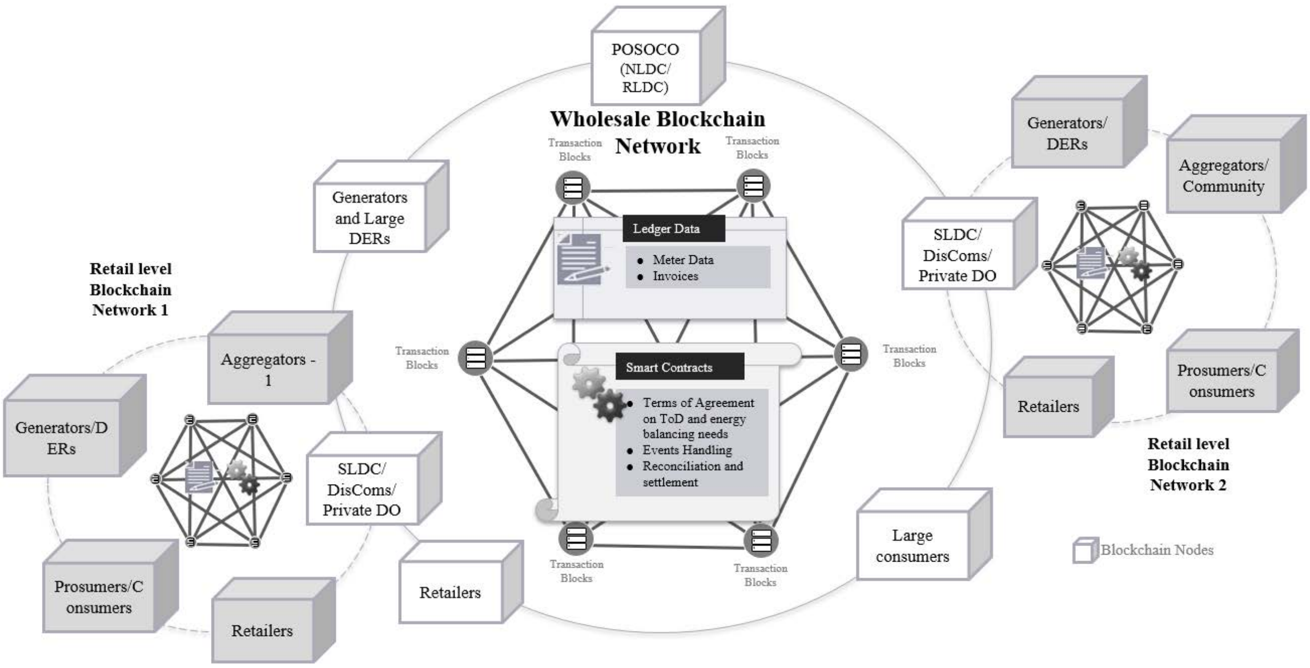


E. Blockchain and Potential Technology to promote Transactive Energy Markets

Some of the cutting-edge technologies those will be required to implement TEM are – Internet of Things, Big data analytics, Artificial Intelligence, Blockchain. From faster markets perspective as the precise and secure settlements are big concern. Blockchain is getting lot of traction in western world and many proof of concepts are under development to validate usage of Blockchain for faster, reliable and automated settlements. Following are the key considerations for Blockchain based markets:

- DSOs or RLDCs/SLDCs provide platform for retail market functions
- Market participants are defined as nodes, transacting parties
- Distributed Ledger for retail bids, purchases, sales, dispatch instructions, meter data, billing, settlement
- Market Clearing as smart contracts
- Consensus Mechanism

Conceptual architecture of Transacting Parties and their Extent in the TE markets of India as Blockchain Network



F. Phased roadmap to the journey

In conclusion, the journey to optimize RE integration using market mechanisms is long but has a significant business case & value. This section summarizes a high-level road map and key actions those are required to move one step closer to the TEM. Following is the high-level roadmap & approach:

i. Define Regulations and Policies
   - Define regulatory and policy-level objectives from TEM
   - Identify system qualities and functional capabilities required
   - Decide on roles, responsibilities and market structure
   - Design new dynamic pricing structure

ii. Infrastructure Enablement
   - Prioritize critical processes and system architecture to be implemented
   - Identify enabling infrastructure, technologies and platforms
   - Define industry and interoperability standards
   - Implement small pilots

iii. Scale the Markets
   - Scale the market beyond state and country level boundaries
   - Create seamless customers/stakeholders experience
   - Tailor offerings to create interest
   - Define new business models

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VI. BIOGRAPHICAL INFORMATION

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