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Research paper

Evolving Competitive Electricity Markets: an Enablement through Digital Approach

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Abstract

Introduction: Globally instituting competitive electricity markets focus on enablement of suppliers and end consumers digitally to benefit from open access. Open access transformation is a crucial entry point for the establishment of wholesale and retail competitive electricity markets. Technology reforms have been acknowledged worldwide in the electricity sector to orchestrate transforming electric industry business models. In addition to initiatives viz., unbundling (a kind of Industry stakeholder restructuring) of vertically integrated monopolies, upgrade of legal and deregulation frameworks, setting up of management guidelines for energy and wire charges, etc. guaranteeing right data availability and assuring the best informed decision making capabilities with a right validation and security of data to all stakeholders have been recognized as key enabler through an appropriate evidence-based survey recently conducted in the state of Tamilnadu across consumers and suppliers of electricity. This paper is focussed on various approaches for digitally transforming transmission and distribution stakeholders of the electricity industry with an objective to advance reliability, accomplish costs and sales economically, sustain the availability, assure the security and energy sustainability for providing safe electricity supply and thus to empower superior benefits to the consumers.

Research Methodology: The study examined prospects and challenges for the establishment of wholesale and retail competitive electricity market in Tamil Nadu, India. This study included the survey of a sample size of 325 individuals from electricity consumers', and 80 individuals from suppliers' is collected in Tamil Nadu using a structured questionnaire.

Findings: The study proposes appropriate digital technology strategy along with high spot on proposed governance, legal and regulatory framework. This study deliberates various plans of Orchestrations and an approach to challenge the prospective Obstacles towards the establishment of competitive electricity markets in Tamil Nadu state.

Implications of the study: The study discusses influences on stakeholders of the electricity market in Tamil Nadu state to consider developing technology strategies.
JEL Classification: J11, C02, C15, C53, C55, C61, F17, F63, F64

Keywords: *Competitive Electricity Market, Wholesale Electricity, Retail Electricity, technology strategy.*

1. Introduction

Open access transformation is a fundamental access point for the founding of wholesale and retail competitive electricity markets. Introducing and promotion of autonomous state electricity markets is dependent on depiction of flexible and accurate electricity operations and market management solutions. The term Autonomous Market is in the context of describing maturity level of electric utility markets. At this stage of maturity, the regulatory environment would allow stakeholder organizations to define and run new business opportunities or models which are not conceding competitive environment themselves.Worldwide instituting competitive electricity markets focus on enablement of suppliers and end consumers digitally to benefit from open access.Competitive Generation Market provides an opportunity for Grid operators to buy or sell energy from Generators or other Grid participants. Wholesale Electricity Market provides an opportunity to those who can generate power, connect to the grid and sell their output to distribution utilities to third-party bulk consumers. These include electricity producers and traders that affiliates with utilities, independent power producers not affiliated with a utility, as well as capped excess generation sold by distribution utilities or bartered to other utilities on a time-space agreement.Retail Electricity Market comprises the sale of power from an electricity provider to an end-use consumer. These sales cover services for a large industrial, to small businesses and individual households.Full retail competition means customers may choose between their obligatory last resort utility supplier and an assortment of competitive providers, instead of existing as a captive customer to a monopoly provider.Retail providers may offer a variety of package plans that provide consumers and businesses elasticity in their energy purchases. In addition to this customers are given flexibility to move to Last Resort Provider (may also be distribution network provider), whose cost fixed through governance of expenditures of utilities by allowing a rate of return on most costs through regulatory commissions generally and higher price than other competitors.

Along with otherkey initiatives viz., Industry stakeholder

restructuring of vertically integrated monopolies, advancement of legal and deregulation frameworks, setting up of management guidelines for energy and wire charges, etc. assuringaccurate data accessibility and guaranteeing the greatest informed decision making capabilities with a right authentication and security of data to all stakeholders have been recognized as key enabler through an appropriate evidence-based assessment recently directed in the state of Tamilnadu across consumers and suppliers of electricity. National Institute of Standards and Technology (NIST) defines various roles and responsibilities of the lifecycle stakeholders of electricity industry business industrywhich include strategic orgainisations like government agencies, regulatory bodies, strategic planning& standards bodies and executing institutions like generation companies, transmission and distribution organizations and wholesale and retail companies performing commercial operations e.g., who perform buying and selling of electricity, as well as other ancillary and auxiliary system service providers.

Surrounded by various complexities of the electricity industry, one of the key features which would permit survival of this industry stakeholders is empowerment of each organizations with digital capability to accomplish their role with reliability, efficiency, security, quality and economy. And it also should safeguardgrant of disruptive innovation to be introduced, corroborated and authenticated through existing knowledge and information. Stimulating dynamic peripheral system in which a business competes is the key consternation for most countries to promote economic growth & development. In this environment more stakeholders (sellers of a similar product or service) competes, enjoy economic viability and does not get castigated due to missing data to make informed decisions to perform business.Technology reforms have been accredited globally in the electricity sector to coordinate transforming electricity industry business models.

This article discusses technology enabler aspects of survey, analysis and assessment results that helps the shape focus of electricity industry approach and also describes some of key features and capabilities requirements for the key applicationsviz., transactions of energy. The authors' last article discusses the optimization of energy sales or procurement cost is linked with uncertainties in demand and supply. Demand of electricity follow various uncertainties such as economic parameters, government policies on renewables, storage, energy efficiency, weather parameters, holidays and special events like rally, election etc., on a short, medium and long term basis.This paper is focussed on various approaches for digitally transforming transmission and distribution stakeholders of the electricity industry with an objective to advance reliability, accomplish costs and sales economically, sustain the availability, assure the security and energy sustainability for providing safe electricity supply and thus to empower superior benefits to the consumers.

2. Literature Review

Competition, the process of challenge between organizations striving to gain sales and make profits, is the driving force behind markets. Former Undersecretary General of United Nations, Nitin Desai specifies (Pradeep S Mehta, 2007) that the competition is the one that promotes efficiency and accountability, ensures access for the citizen-consumer and widens his / her choices. Pradeep discussed elaborately about prospectus and challenges of electricity and telecommunication markets in India. He also focused mainly on existing state of infrastructure and provides a way forward in building the competitive electricity markets in India. He also stressed the need for detailed methodological study focusing on electricity competitive markets due to its inherent slow path of transformation. While comparing competitiveness and progress of telecommunication industry with electricity, the report termed the progress as failure and describes various aspects to focus on success path.

2.1 Electricity Market Status in India

India ranks as 3rd largest energy generators in the world with the current installed capacity of 329.231 Gigawatts (CEA, India, 2017), producing about 5.4% of global energy(IEA, 2016). As per the current estimates, by 2021 India would need to meet electricity peak demand of 300 Gigawatts with the consumption set to reach about 1,915 Terra watt-hours. Although the current installed capacity is much larger than electricity peak demand on account of faster addition of generating plants, the lack of appropriate management and marketing behavioral changes leads to lower plant utilization factors, larger outage duration, larger undelivered energy and as well lowers reliability of the power network. All India Plant utilization factor calculated for Jun 2017 stood at 57.47% (CEA, India, 2017, p. 10 of 32). It is also to be noted that electricity theft is a major concern which accounts about 23.65% (CEA, India, 2017, p. 11 of 32) average across India. This exorbitant energy theft curtails country's Gross Domestic Product growth rate approximately by 1.5%.

2.2 Electricity Market Status in Tamil Nadu

Tamil Nadu has turnaround from the level of a power starving state to a power surplus State. As per Policy Note (Energy Department, 2017) released by Energy Department of Tamil Nadu in the year 2017-18, its electricity position will continue to be a power surplus. The average power demand of Tamil Nadu in the year 2016-2017 is about 13,750 MW to 14,250 MW. As on 29 Apr 2016, Tamil Nadu met the maximum requirement of 15,343 MW, and Chennai alone met an all-time high demand of 3,332 MW as recorded on 30 May 2017 and the maximum consumption of 64.830 million units on 02 Jun 2017. The daily average State consumption has increased from 200 million units during 2011 to 320 million units in 2017, and the maximum use was 345.617 million units on 29 Apr 2016. Also, the Central Electricity Authority in its Load Generation Balance Report has positively stated that as in the previous year, Tamil Nadu will continue to be a power surplus State in the year 2017-18 also with an energy surplus of 8,663 million units and with a peak power surplus of 2,227 MW.

Tamil Nadu government proclaims that they are a leader in Renewable Energy. At present, the total installed capacity of renewable energy including solar and wind energy is 10,480 MW. In the last wind season, the State has harnessed around 13,000 million units of electricity from wind generators, which is a record. Also, the state has leveraged approximately 1,644 million units of energy from solar generators during 2016-17. Proactive steps are being taken to maintain this prominent position in renewable energy.

2.3 Roadmap towards Autonomous Maturity and India Status

Adaption and enablement of consumers towards autonomous maturity were constrained due to various factors. Thus it is vital to understand the obstacles and take appropriate steps towards the progress of open access transformation. The ability to perceive and assess the limitationsof the culture and to develop it adaptively to achieve the core objectives is the basis. This research focused on the relative analysis of one of the Indian state electricity distribution organizations with restraint towards establishment and progression of competitive wholesale and retail markets. Key outstanding areas were shaped based on the relative comparison with other global utilities has progressed in their open access transformation. This study also reviews and presents other global developed market reform lessons, the impact of unbundling on vertically integrated organizations and the subsequent reforms.

Figure **Error! No text of specified style in document.**-1 provides an overview of current status of Indian electricity business on a five steps maturity model concerning global utilities and highlights on various stages of maturity of evolving electricity business model.

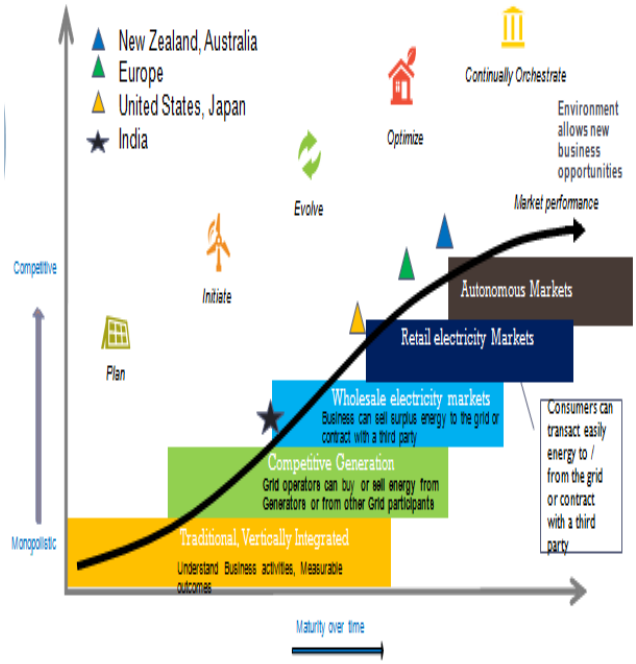

Figure Error! No text of specified style in document.**-1**Overview of Indian electricity industry's competitive status w.r.t. Global utilities

This paper focuses on key subject area advanced analytics, transaction and information integration management areas.

3. Methodology

This section covers approach and methodology into two parts; first part related to establishing importance of operation technology solution through consumer survey and second part related to detailed requirements of operation technology solution to support market management.

3.1 Survey Conducted on Electricity Consumers and Suppliers

A survey was conducted on electricity suppliers and consumers. Respondent profile of consumers was grouped as Consumer Categories viz., Residential, Commercial and Industrial. Similarly this was also grouped into various Organization Categories viz., Individuals, Private and Public. The following questions related to Infrastructure & Technology were raised.

Energy & Power System (EPS) Infrastructure

- Do you consider that the existing power system infrastructure is sufficient to support the requirements of open access?
- Do you consider that the infrastructure to manage distributed generation is sufficient to support the requirements of open access?
- Do you consider that the existing energy storage infrastructure is sufficient to support the requirements of open access?
- Do you consider that the existing demand response infrastructure is sufficient to support the requirements of open access?
- Do you consider that there is not much need for major investment to improve existing Energy & Power System Infrastructure to meet open access requirements?
- Do you consider that step by step investment in Energy & Power System Infrastructure could help meeting the open access targets?

Information Technology (IT)

- Do you consider that the existing Information Technology infrastructure and applications is sufficient to support the open access transformation?
- Do you consider that there is not much need for major investment to improve existing IT infrastructure and applications that enable open access requirements?
- Do you think that step by step investment in IT infrastructure and applications could help meeting the target transformation?

Operation Technology (OT)

- Do you consider that the existing Operation Technology infrastructure and applications is sufficient to support the pre-requisite of open access?
- Do you consider that there is not much need for major investment to improve existing Operation Technology infrastructure and applications to meet open access requirements?
- Do you think that that step by step investment in Operation Technology infrastructure and applications could help meeting the target transformation?

Market Systems (MS)

- Do you consider that existing Market operation and management systems is sufficient to support the pre-requisite of open access?
- Do you consider that there is not much need for major investment to improve existing Market Systems infrastructure and applications to meet open access requirements?
- Do you consider that step by step investment in Market and enterprise systems and applications could help meeting the targets?

Customer Systems (CS)

- Do you consider that electricity suppliers are doing well to manage customer acquisition and retention?
- Do you consider that there is not much need for major investment to improve existing Customer Systems and applications to meet open access requirements?
- Do you consider that step by step investment in Customer Systems and applications could help meeting the targets?

4. Results and Discussion

This section covers results and discussion to two parts; first part related to establishing importance of operation technology solution through consumer survey and second part related to detailed requirements of operation technology solution to support market management.

4.1. Impact of infrastructure and Technology Factors on Open Access Electricity Market

Infrastructure and technology factors such as EPS Infrastructure, IT, OT, MS and CS are used as inputs in regression analysis to identify predictors of open access market. The method used to predict the open access market is Multiple Regression Analysis.

Hypothesis:

Ho: There is no significant impact of Infrastructure and Technology factors on open access market

H1: There is a significant impact of Infrastructure and Technology factors on open access market

Table 1 Multiple Regression Model for Open Access Market Based on Infrastructure and Technology factors

Independent variables	**Unstandardized Coefficients**		**Standardized Coefficients**			**Statistical inference**	
	B	**Std. Error**	**Beta**	**T**	**Sig**		**F value**
Constant	4.103	.454		9.042	.000	R = 0.330 R^2 = 0.109 Adjusted R^2 = 0.097	9.746***
X1	-.079	.015	-.331	-5.404	.000***		
X3	.029	.040	.057	.705	.481		
X4	.175	.039	.252	4.481	.000***		
X5	-.040	.057	-.053	-.691	.490		

***Significant at 1% level

In this study, open access market (Y) is dependent variable; EPS Infrastructure (X1), IT (X2), OT (X3), MS (X4) and CS (X5) are predictor variables. Multiple regression analysis on the impact of Infrastructure & technology factors determines that enhancements to Energy & power system infrastructure and Customer systems play a significant role on open access market. In this interpretation, the result exposes that the variable Market systems (β =0.252, $p<0.01$) is the most influential variable exerts a statistically significant and positive influence on open access. However, the variables Energy & power system infrastructure (β = - 0.331, $p<0.01$) and Customer systems (β = - 0.053) are applying a statistically significant and negative influence on open access market. Evidently, it is highly significant to address Orchestration by promoting appropriate Infrastructure & technology constituents to accomplish the task towards the establishment of open access transformation.

Digital Transformation

The original research included the impact of people, other technologies and organization environment and behavior framework. And this paper explains on other enabling technologies such as internet of things (IOT), cloud, social and mobile to support enabling utility organization to perform better towards competitive autonomous journey. This also envisages that in order to empower every stakeholder with digital experience, it is important to focus on extracting maximum benefits from any targeted technology investments includes advanced analytics, cognitive solutions powered by cloud, IOT and mobile capabilities will bring success in the journey of autonomous transformation. It is proposed to discuss every challenges and do deep dive into design of utility system architecture and also to provide insight on data governance and management methods which would play vital role in shaping the utilities analytics and cognitive journey in future.The study emphasized the need for the establishment of Energy Information Authority (preferably self-sustainable not to profit entity) to:

- Be responsible for collecting, maintaining and providing data for managing (e.g., availability, demand, planning info, pricing, fuel info, constraints, trends) electricity business to all stakeholders on demand/push basis
- Be responsible for creating managing Performance metric requirements and implementing the same with appropriate incentive and penalty structure.
- Be responsible for creating benchmarks of new development costs, wheeling charges etc., based on various technical factors such as region, distance etc., and provide guidance for further optimization. Be responsible for ensuring elimination of subsidies forming the part of energy and wheeling cost structure.
- Support stakeholders on integration with other data sources (e.g., weather services, metering services, manufacturer data services), performing analytics (e.g., energy forecasting, energy optimization, asset optimization), reporting

It also stresses a significance of Market operations and management solutions which play an important role in shaping the electricity market and thus help large scale implementation of the wholesale and retail electricity markets. As the number of market participants grow especially with the number of prosumers and consumers moving towards buying and selling electricity through the energy exchange, accuracy of forecasting becomes highly significant. This means availability of cost effective advanced analytics solutions and its ease of practice by every market participants to make them digitally enabled will impact the end establishment and performance of the competitive electricity markets.

4.2 Enablement through Advanced Analytics & Cognitive Solutions

This section covers how each utility stakeholder globally are progressing to attain their target goals through the use of advanced analytics and cognitive solutions powered by infrastructure solutions such as Cloud, Internet of Things and mobile. The Figure depicts a functional overview of utilities solutions to enable its stakeholders such as generation, grid, customers, retailers, energy service, renewable providers, market exchanges etc.

Although it covers key solutions under the category of advanced analytics and cognitive solutions,the entire solution portfolio needs to be upgraded depending on the evolving business model and its eco system. With the review of technology factors it is clearly an opportunity for the stakeholders to progressively promote digital with better understanding of factors such as Data Explosion, Diminishing Expertise, Disruptive Innovation, Digital experience, societal inclusion and Economic sustenance. Both advanced analytics and cognitive solutions are complement to each other and are becoming business imperatives.

Advanced Analytics

Complexity of global utilities increases with their challenge of managing ageing infrastructure, diminishing skilled resources, managing their own distributed energy resources, as well as providing an ability for market operations to perform with more efficiency and economy. The system architectures to be utilized by all stakeholders must be equipped to play a challenging role. Traditionally utilities companies are cautious adopters of technologies due to its inherent regulatory and public apprehensions. However many global utilities have reached the requisite state of competitive transformation. In India, business

models are still evolving – some are privatized, many of vertically integrated utilities have started unbundling, now new franchisee models pop up, multiple suppliers in same region especially in metros, open access is on for large customers and being targeted for small scale consumers in the future. Customers are more engaging than ever before in utilities business and holds high expectations than those are currently realized. All these challenges combined with market forces are compelling executives to think beyond the traditional approaches and embrace the new technologies. Thus thoughtful application of each solutions in an innovative way is essential. Also convergence of Information & Operation technologies (IT & OT) (example, smart meters sending power quality & consumption data every 10-15 minutes increases volume by of meter read by approximately 2800 times compared to once a month read) which are causing exponential data growth. Although various sources are contributing to growth, it is essential to empower stakeholders leveraging of type and other attributes of data11. Typical example of benefit areas for grid companies include a) Predict Asset performance and defer network investments b) increase operational efficiency c) Optimize Outage restoration d) Power portfolio optimization etc. It is important to note that new challenges being spanned due to additional analytics deployments. Here it is not just volume, but velocity & variety of the data are also increasing. As we discussed earlier, these new opportunities12 should address the challenges caused by the three famous 'V' of big data being experienced by utility.

Volume: Smart meters, PMUs, sensors, integration with Supervisory Control And Data Acquisition (SCADA), Energy Management Solutions (EMS) and Distribution Management Solutions (DMS), are generating new data in a volume that utility staff or systems were not designed to handle

Velocity: Time scale of data arriving ranges from few milliseconds from PMUs and Advanced Metering Infrastructure (AMI) interval data to all the way to once a month from customer payment and all time intervals in between.

Variety: Sources of data ranges from utilities internal & trusted sources to blogs from customers, format of data can be a well-defined structure or free unstructured format text.

Use case from various grid companies' represents predicting peak load which involves high complex customer energy models, segmentation models, demand forecasting based on various other parameters such as weather, cloud etc., and help optimize dispatch through demand response solutions.

Cognitive Solutions

Cognitive solutions uses natural language processing and machine learning to reveal insights from large amounts of unstructured data. Typically for utility industry unstructured data set includes manuals and user guides, thermal images, videos, operational or transactional notes, social & weather interactions etc. A cognitive solution helps to observe, interpret, evaluate and make informed decisions. It self learns knowledge, converts into hypothesis and further facilitate stakeholders or employees to perform better. Through the study of effects of ageing workforce and data growth as explained above sections, it is evident that there is a need for a set of solutions with self-learning capabilities and as well could capture the human and machine (both structured and unstructured) knowledge through capabilities such as natural language processing, and help apply statistical & network analysis. It should also facilitate information exploration capabilities such as hypothesis generation and evidence expression. The Figure 7 explains the approach to encounter increasing customer expectation with ageing work force and increasing data13. It suggests that upgrading or speed up the time to resolve per each workers is essential. This means implementation of cognitive solutions could help through knowledge capture, retention and reapply into analytics to provide insights for the newly skilled or unskilled resources. It is intended to discuss detailed use cases in next publications including the topics such as microgrid14, WAMS/WACS including setting less protections, etc.,

Secure and Open Source Platforms

With increased renewable addition into the grid and thus exponentially reducing prices of new electricity generation, the customary methods to electricity supply, distribute and pricethroughregulatorycontrol and mass retailing basically cannot accomplish the benefits guaranteed.With an appropriate deregulation steps, use of efficient infrastructure, to manage increasing the level of competition with prevailing incumbents across the value chain, and refining the economic signals to market participants. It is important that governments & organizations shall promote secure open-source technology and platforms such as block chain that will provide components to perform transactional activity by the current energy participants' viz., metering data providers, energy invoicing, procurement and trade of all energy systems including distributed energy components and provide secure basis for commercial settlement at an economical cost of service to all stakeholders. Smart contracts should interface with the existing stakeholders of the grid and enable all market participants' viz., grid providers, energy suppliers, ancillary energy service providers and auxiliary service providers to securely interact with extensive international embracing from the commencement. These transaction services should also enable complex multi-party peer-to-peer trades. An extended set of applications should also help promote all stakeholders digital transformation of their internal and external tasks and activities to better assist in customer engagement, wholesale and retail market collaboration.

5. Conclusion

5.1Research Implications and Policy Implications

The original Study combined with review of global utility stakeholders' approaches suggests that for realization of autonomous market maturity requires coherence of appropriate strategy & roadmap followed by step by step implementation of various solutions which includes not just technology applications but also various initiatives to align their people, legal & regulatory framework, social & organizational behavior.

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