Power Platform

Energizing the Electricity Value Chain

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TATA CONSULTANCY SERVICES

IN BRIEF

The global electricity industry has been witnessing an unprecedented transformation due to deregulation, mounting competition, new technologies, and fast-changing customer preferences. To minimize the uncertainties in the value ecosystem, utilities companies need to restructure themselves and strategize for greater flexibility and agility. TCS' Electricity Value Ecosystem Studio is a proven machine learning-based, comprehensive simulation platform for utilities players. The platform accurately models the ecosystem, enabling utilities companies to predict the behavior of the ecosystem, generating business insights in a cost-effective, low-risk, fast, and easy-to-use manner.

Major changes have marked the global electricity industry since the 1990s. Its structure has transformed. Many companies whose services earlier spanned the entire electricity value chain now operate in just one or two segments. Established power generators compete with smaller generation companies' cheaper rates. Renewable energy is a significant contender. Large grid operators sell network access to newbie retailers. Energy traders bid, buy, and sell power to small and midsize businesses (SMBs) at attractive prices. Regulators have allowed deregulation in some areas but intensified control in others. As demand grows, more players want a piece of the pie.

The slicing and dicing has spawned an entire value ecosystem. Not only have more companies occupied the erstwhile value chain, but many bundle ancillary services from related domains as well. Customers have more choices, of course. However, competition is keener, with new rivals coming in from multiple directions, introducing a new unpredictability.

Accentuating this is the second biggest change—the mushrooming of distributed energy resources (DERs) that use auxiliary technologies like small-hydro, biomass, biogas, solar, wind, hydrogen, algae, marine, hydrokinetic, and geothermal power. Technology has made these modalities more affordable.

Fact File

TCS Research: Next Generation Electric Grids

Outcomes: ELectricity VAlue eCosystem Studio (ELVACS) Platform, Tool for Short-term Forecasting of Demand and Price (webSTLF), and Tool for Network Usage Estimation (webNetUse). Among Top Two at the PowerTAC Retail Broker Challenge 2018

Principal Investigators: Venkatesh Sarangan

Academic Partners: Faculty at Indian Institute of Technology (IIT) Bombay, and International Institute of Information Technology (IIIT), Hyderabad

Techniques used: Machine Learning, Artificial Intelligence (AI), and Power Systems

Industries benefited: Electric utility companies, end consumers, regulators, generators, and renewable asset owners, to name a few

Patents: 5 filed

Papers: 7

Customers' need profiles have changed. Environmental concerns keep pushing greener alternatives. So, from standby power plants that cover outages spreading across days, to quick-start units that fill in short-term outages, to stored energy in battery arrays, bulk, and retail consumers are also producing electricity. Called cogenerators or prosumers—because they produce *and* consume—these have made electricity flow not only from generator to end-consumer, as earlier, but in the reverse direction too.

Business opportunities are moving away from generation and transmission—traditionally, the core of the power network—toward peripheral distribution systems, where the customers are. Industry fragmentation and the entrance of DERs have pinched company bottom lines but broadened customers' gains. The very philosophy around power has changed. The old law—generation follows demand—has been replaced with a new mantra: demand follows generation.

Three concepts are imperative for utilities companies' business success—interconnectedness, the holistic chain view, and hyper-personalization.

Three concepts for success

In this high-churn market, electric utilities need to spot where opportunities lie and tap those using new business models. They need greater flexibility and agility. They need to organize their data, observe the underlying information structures, and distill those into insights. For business success, utilities should enhance their effectiveness using three concepts:

Interconnectedness

This consists of mapping the domain—the business architecture, processes, services, and rules governing the utilities company's internal systems, and the interrelationships with peers, partners, competitors, regulators, customers, prosumers, and other entities in the ecosystem. An interconnectedness analysis helps develop a framework for the company to understand the efficacy of business models and set-ups, and the short-, medium-, and long-term impact of decisions taken, including

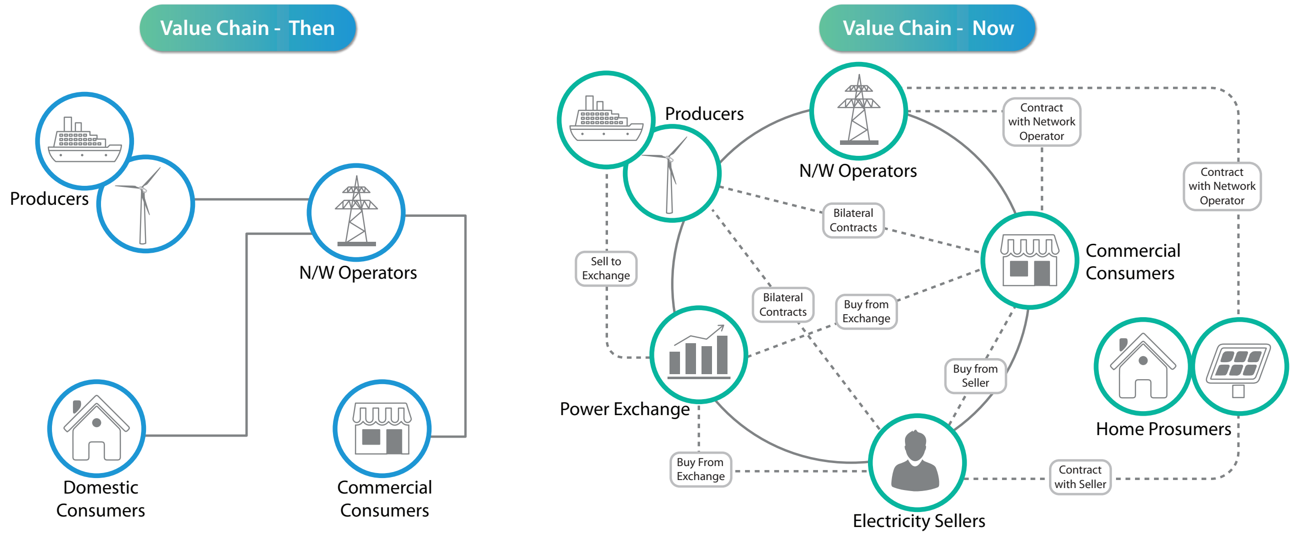

Figure 1: *New Energy Mix—New Distribution Models—Customer Preference in Energy—Changing Business Models*

the in-market introduction, withdrawal, and modification of products and services.

The holistic value chain view

In many geographies, regulations permit utilities companies to work across only one or two segments. As a result, a company cannot view the entire value chain (far less the value ecosystem), and is therefore unable to assess the strategic and operational impact of its actions on other entities. But because of the inherent connectedness of the value chain, the company's decisions have a ripple effect, both upstream and downstream. Therefore, companies must be equipped to analyze the entire chain – and, in fact, the entire value ecosystem—to determine impact.

Hyper-personalization

The third concept, hyper-personalization, concerns a utilities company's ability to offer micro-customized options for a wide variety of customer requirements, and its mechanisms of response when those customer preferences rapidly change. For example, a customer may not wish to use more than a certain number of units of energy in a month, while another may have low overall consumption but variable demand that goes up or down very quickly. A third may have a storage battery that the customer may use intermittently either for the company or to supply to a microgrid, while a fourth may have an electric vehicle. The company's success would then depend on its ability to responsively cater to its customers' lifestyle choices.

The electricity value chain simulation platform

The quality of utilities companies' decisions depends on the efficiency with which they use the three concepts to understand and predict the ecosystem. However, the heavy-investment, high-risk, and increasingly fluctuating and volatile nature of the industry begs a cost-effective, efficient, fast, easy-to-use, low-risk approach for what-if analysis, forecasting, planning, and strategizing.

That is why TCS has developed the Electricity Value Ecosystem Studio—a comprehensive simulation platform encapsulating rich domain knowledge and powered by machine learning and other artificial intelligence (AI) engines. Using historical data from a utilities player's own databases—for example, GPS and GIS data, asset maintenance and operational performance, productivity, and total cost data—and structured and unstructured data from the public domain, the platform's' algorithms unearth tactical and strategic decisions for operational excellence, value generation, risk mitigation, improved market intelligence, and best practices, among other uses; so that utilities decision-makers can better adapt to the evolving ecosystem.

In the platform's' virtual safety, utilities executives can also confidently venture outside their comfort zone to experiment with bold risk or reward scenarios that would make for dangerous play in real-life settings.

Any entity or stakeholder in the utilities ecosystem can use this platform—generators, energy network operators, energy traders and marketers, energy service providers and retailers, regulators, customers, environmental agencies, and whistleblowers.

TCS' machine learning-based Electricity Value Chain Studio, accurately models the utilities ecosystem.

The platform' machine learning- and ontology-based domain models simulate the behavior of generators, transmission networks, distribution networks, consumers and prosumers, as well as regulators. Thus, users can define a scenario; and ELVACS, mining detailed operations, transmission and distribution, and customer data collected from across the value chain, will run the required sequence of simulations, presenting the user with a detailed "to be" situation.

The platform has the interfaces that customers need, when choosing from a suite of pre-built applications. For customers who wish to create new applications, ELVACS also provides the necessary application programming interfaces (APIs). The Studio has end-to-end features – from simulation products, including domain-specific simulators, to analytics tools.

Testing the platform in real-world scenarios

TCS has been field-testing the Electricity Value Chain Studio's technology through five use cases – wholesale bidding, autonomous retail broker agents, dynamic microgrids, transactive energy (TE) modeling, and electric vehicle (EV) penetration.

Bidding in wholesale electricity markets

In wholesale electricity markets, generators typically place energy or price orders based on next-day demand projections, and the market determines the price. However, price determination is based on numerous factors. Moreover, the bids are made by human traders, who could have momentary lapses that result in significant losses to buyer or seller because of the high trading volumes involved. Therefore, replacing the trader with an intelligent machine would help.

The place or bid scenario becomes even more complex when one considers unusual factors such as network constraints: transmission line congestion, for instance (if the trade involves power being supplied between two cities), which would affect the power being delivered and hence, its price or for that matter, even its sale. (A similar effect on the trade on energy volume could be caused by a sudden change in weather conditions.) Automated tools that intelligently address such issues, while also considering competitor behavior, do not exist yet.

But that will soon change. For a large utilities customer, TCS is working on an automated solution that will account for such factors. And we are using machine learning for meeting such advanced computing requirements.

We are also working on building models that predict the possible effects on other trading parties of a given bid.

Building autonomous agents for retail trading

On the retail side are big industrial plants, large businesses operating in a non-utilities domain, neighborhoods, and small utilities companies. These can participate in local (and wholesale) energy markets. We are therefore building a solution that incorporates different techniques by which such local utilities entities can bid in the wholesale market, revising tariff structures so that end-consumers benefit, while the utilities companies maximize revenue.

We are building autonomous power trading agents based on the Electricity Value Chain Studio's technology. These agents, operating in a simulated market, automate utilities brokers, manage power purchase in a wholesale market, and sell the power to end-consumers using appropriate tariff structures.

Our autonomous power trading agents participated in an open competition called Power Trading Agent Competition (PowerTAC) 2018. PowerTAC is a competition in which the power trading agents of utilities research groups around the world—from both industry and academia—compete. PowerTAC is run jointly by Carnegie Mellon University, the Delft University of Technology, the Erasmus University's Rotterdam School of Management, the University of Minnesota, and the University of Zagreb, as a part of the annual international

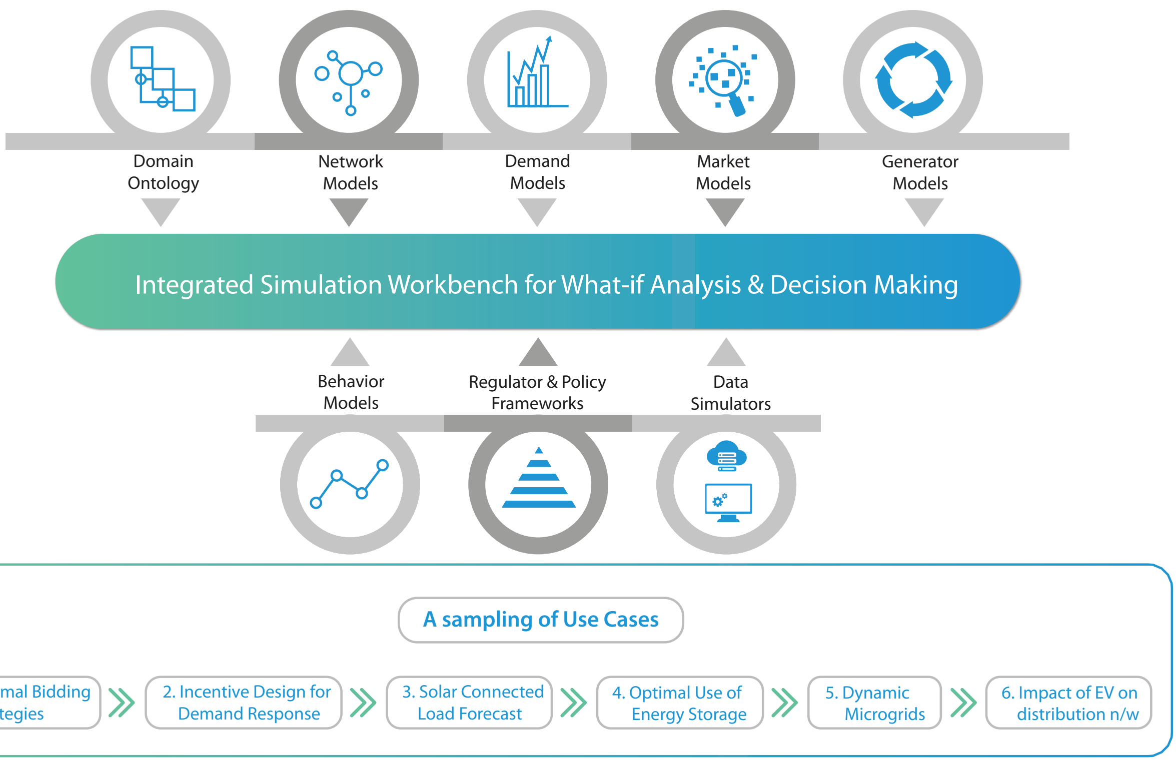

Figure 2: *A Platform where Domain Knowledge and AI Come Together*

conference AAMAS, the flagship conference of the International Foundation for Autonomous Agents and Multi-Agent Systems. (AAMAS is the world's largest, internationally renowned research- and practice-focused agent and multi-agent systems conference.) At the close of trading, agents are ranked based on the revenue and profits earned. TCS' power trading agent came second in the 2018 edition of the competition.

Developing dynamic microgrid architectures

The distribution end of the utilities value chain has a large scope for new architectures because prosumers have introduced bi-directional power flow (from generator to consumer and back). We therefore visualize local self-sustaining micro-grids. Although such grids have been tested across the world, what we are proposing is the concept of dynamic microgrids—microgrids that autonomously change and re-configure themselves, based on current network conditions. Line faults and tripping, for instance, can trigger rearrangement or reorientation in the microgrid so that customer service is not adversely affected. Similarly, a sudden sunny day (read increased solar energy input) would cause the grid to automatically reconfigure to increase the utilization of renewables.

Transactive energy modeling

In dynamic micro grids, network reorientation and consumption and production of energy are two sides of the same coin. Therefore, when some consumers produce more energy that others consume, an automated market mechanism becomes necessary to determine energy price- and track-related transactions. Note that such market mechanisms are needed even in traditional network architectures to encourage peer-to-peer retail energy trading. We are therefore exploring how to leverage cryptocurrency exchanges such as blockchain in innovative retail market models—which belong in a category called the transactive energy (TE) model. We have showcased our work on the TE model at the National Institute for Standards and Technology's Transactive Energy Modeling and Simulation Challenge in Gaithersburg, where researchers and companies demonstrate their work in power grid simulations.

Deepening DER penetration

A question being increasingly asked in developed economies concerns the move from internal combustion engines to electric vehicles (EVs) and its impact on the grid. Deeper penetration of this type of DER is desirable—EVs are green, can double up as virtual power plants because they have storage batteries, and EV batteries can be moved from place to place. So if an EV population in a neighborhood can be incentivized to stagger EV use and charging, the network is not overloaded and people can use their EVs as they please. Our platform can also help develop the required market mechanisms for this to work.

ELVACS empowers utilities users to create tailored applications embedded with a certainty in results.

Unique to the Electricity Value Chain Studio

Incentive or tariff design and demand response programs

To foster a supply-led demand economy, one must incentivize end-consumers to reduce load (when loading is on an up-trend) so generation companies would not need to start their plants that pollute more, purchase energy at high cost, and so on. This, known as demand response, could be actuated by signaling consumers via push messages, alerting them to likely tariff increases, with projected increases set to be larger as loading tends to peak, or to discounts, when consumers reduce consumption.

Designing such incentives (or deterrents) is not a trivial problem. Called "incentive design", it's an area in which TCS has done a lot of work, addressing issues such as how utilities companies determine which customers to target, and the quantum and form of win-win incentives for all entities in the value ecosystem.

We have also studied scenarios in which demand response has embedded dependencies; for example, a whole neighborhood subscribing to a common power resource such as a district cooling plant—the demand response of one customer impacts those of the others.

Masked loads

In some geographies, customers installing battery-powered solar cells are not required to keep the grid utilities companies informed. However, customers switching between grid and solar cause sudden load spikes or drops. Weather changes too could affect grid power drawn. Then network operators cannot control loading, anticipate demand fluctuations, and maintain system stability. Their ability to bid in appropriate markets suffers. Solving the "masked load identification problem" helps, and is another one of our successes.

Venkatesh Sarangan

Venkatesh Sarangan is a Principal Scientist at TCS Research and Innovation and heads the "Next Generation Grids" Research Program. Along with his fellow scientists, he currently develops AI-driven, domain-infused, digital solutions that make electrical grids agile, intelligent, and future ready. He holds a Bachelor's Degree in Electrical Engineering from College of Engineering, Guindy, Chennai. He has received his PhD in Computer Science and Engineering from the Pennsylvania State University, University Park, USA. He has worked with the Computer Science department at Oklahoma State University, as an Assistant Professor and then as a tenured Associate Professor.

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