Virtual Power Plant (VPP)

Pathway to the Uber of Energy

Dushyant Reddy
Global Business Head, Energy, Quest Global

Manoj Vivek
Director-Technology, CoE Leader-Energy & Industrial, Quest Global

Abstract:

*The term **Virtual Power Plant** (**VPP**) was originally envisaged as the technology which can aggregate the information from distributed energy resources (DERs) and treat it as virtual '**power plant**' to address the challenges of balancing power grid, as in the scenario of a conventional power plant in the conventional grid. In the scenario of large number of distributed renewables-based generation, the fluctuating and unpredictable power generation pattern is the specific challenge which was addressed by VPP.*

Data aggregation and taking decision based on that is just one element of the grid balancing act. Today, grid has evolved further smarter and complex by introduction and increased usage of information from demand response programs (DRPs), energy management systems at the consumption-end, complex market place dynamics (eg: power trading), introduction of large scale storage mechanisms, increased usage of power (EVs), more resilient & digital T&D infrastructure (digital substations, infrastructure for bi-directional power flow, WAMS…) etc.

It is important and essential to aggregate data from all these sub-systems to efficiently manage the grid and meet the interest of all stakeholders. Accordingly, to address this new challenge, VPPs are evolving much beyond the original virtual 'power plant'

*system to a holistic **Digital Grid Management Platform**, which takes a comprehensive view of every aspect of the modern grid, to provide the right information and control to the stakeholders.*

*This comprehensive digital grid management platform is also evolving as the "**Uber of Energy**" where all stakeholders can collaborate seamlessly.*

This whitepaper briefly describes the critical subsystems from which information is to be gathered to manage the complex modern, digital grid. The in-depth domain knowledge gained in most of the related subsystems helps Quest Global team to understand the challenges and visualize optimum digital technology solutions to address them. The word Virtual Power Plant (VPP) is used in this white paper to represent the comprehensive Digital Grid Management Platform.

Dushyant Reddy

"We are partnering with our customers, global leaders in power segment, to realize reliable, affordable and sustainable electric power systems to address the energy trilemma. We believe that, digitization of grid is an important enabler in realizing decentralization and decarbonization, and lead to sustainability.

At Quest Global, we are collaborating with our customers and ecosystem partners to accelerate the shift from conventional grid to smart & digital grid by embracing next-gen technologies and industry standards

We are committed to co-innovation with our customers to make a world of difference, by leveraging our twenty-five years' experience in the domain and in-depth expertise in digital technologies"

Manoj Vivek

"At Quest Global, we have a clear understanding of the challenges of digitization of modern grid. Our experience spans over the length and breadth of power grid. Be it Energy Management Systems for power system or energy efficiency management in industries/buildings, we have been considered as preferred partner by world leaders.

We stay ahead of the change. We are investing and building the capability in using the pervasive technologies to digitize the grid. Digital substations, WAMS, next-gen LV/MV tools, HVDC projects, O&M management suits for renewables, VPP, DR programs, power trading platforms etc. are just few of the areas where we have built robust digital solutions for our customers and enabling them to introduce platforms supporting new business models and respective revenue streams"

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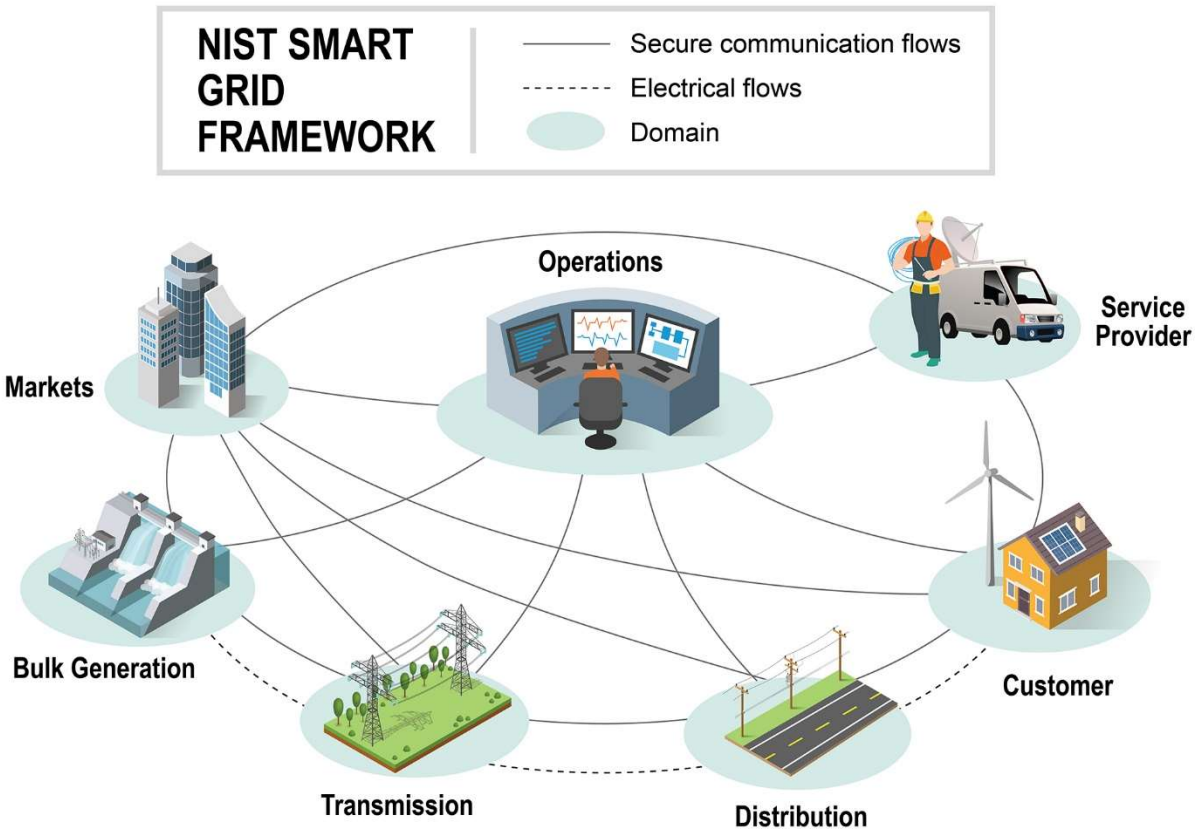
Introduction:

Virtual Power Plant consolidates and manages data from distributed renewable-based generators, gas generators, energy storage devices, and also the residential, commercial and industrial loads. The VPP platform gets the information of all energy assets into a single, central information system and helps to balance the power system. It opens up new opportunities for all stakeholders. Distributed Energy Resources (DERs) can actively participate in the energy market, real-time, to regulate voltage and frequency to make the grid stable.



VPP brings value to all stakeholders, such as traditional utility companies, asset owners, regulators, and consumers/prosumers. Most importantly, VPP increases grid stability by way of better decisions based on accurate and detailed information and forecast of supply, demand, and energy prices. Increased market participation brings higher returns to asset owners and encourages more investments in renewables and leading to a cleaner and more sustainable energy supply, ultimately benefitting the consumer.

The advancements in software and digital technology make VPP very powerful and help to evolve as a full-fledged digital grid management platform. Few key technology elements which are making a major impact in this direction are the ability of today's digital systems to transfer large volume data in real-time, advanced forecasting algorithms, and innovative strategies for optimum dispatch. Data science and machine learning algorithms significantly improve the accuracy of the forecast of renewable power generation, demand fluctuations, and electricity price.

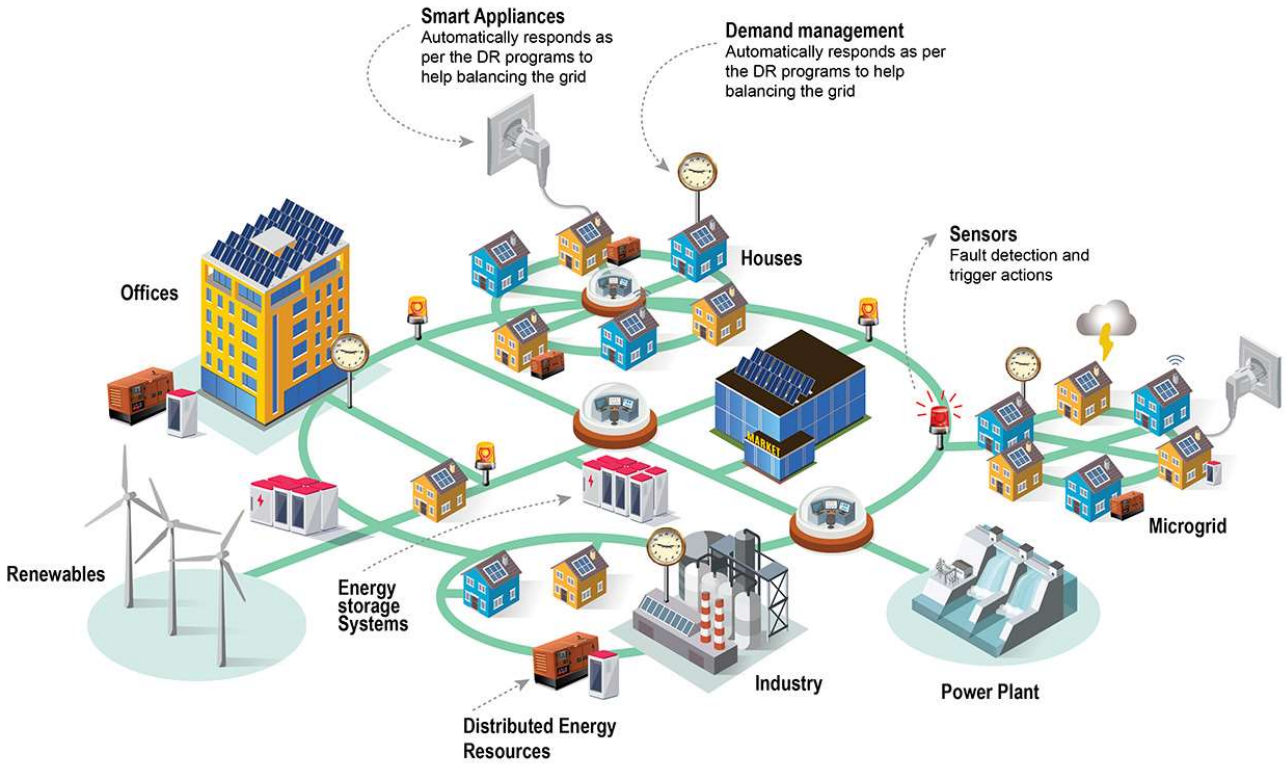
As a service provider with the right mix of domain knowledge and digital technology capabilities, Quest Global is uniquely positioned to accelerate the journey of world leaders in realizing digital grid management platforms. Many of the major OEMs investing and building the next generation digital grid platform already leverage Quest Global's services to conceptualize, architect, and implement the solutions, and address very specific challenges of digital grid management.

Sub-systems, Characteristics and Benefits:

It is important to have a holistic view of the sub-systems, characteristics, and benefits expected from the digital grid. One who conceptualizes and implements the digital grid management system has to have the knowledge of specific complexities, characteristics of the sub-systems, which need to be built and integrated into the platform. Quest Global is a leading service provider in this space, with two decades of collective knowledge in the respective sub-domains/sub-systems.

There are different stakeholders who exchange information to make the smart grid ecosystem work as desired, to maximize the benefits. Stakeholders include bulk power producers, T&D companies, operations, service providers, markets, and consumers. VPP is expected to manage all the related interactions effectively to get the best benefits from the modern grid. The digital grid includes various technologies such as Automatic Voltage Regulation (AVR), Energy Management System (EMS), Automatic Generation Control (AGC), Advanced Metering Infrastructure (AMI), Meter Data Management (MDM), Distribution Management System (DMS), Geographical Information System (GIS), Outage Management System (OMS), Wide Area Management System (WAMS), and Demand Side Management (DSM).

The key characteristics of a modern gird managed by VPP include the ability to integrate DERs based on sustainable energy sources, to perform dynamic operations and optimizations continuously, leverage digitalized information to enhance reliability, resilience, and efficiency, integrate storage devices, include and manage demand-side responses, integrate intelligent devices and manage respective information across the grid and resist cyber threats.



The benefits of a smart grid managed by VPP are mainly in significant improvement in the reliability and resilience of the grid. It also enhances overall power system efficiency through predictive maintenance and self-healing. By promoting widespread usage of renewable-based generation it leads to lower greenhouse gas emissions in line with sustainability initiatives.

Key components to be integrated:

Distributed generation, demand response, energy storage systems, and the communication infrastructure are the four important components of the smart grid and the related information system (VPP). At Quest Global, we keep our focus on all these four areas with due importance to proactively build the expertise and capable capacity.

The widespread usage and expansion of sustainable resources, resiliency needs, and related technological advancements paved the way for distributed generators to become the backbone of future grid infrastructure. Distributed generators are small-scale geographically spread renewable-based generators installed near the load centers, which can work in islanded mode or grid-connected mode. This can replace fossil fuel-based generation and also address growing demands. Processing and integration of information from such distributed generators involve a significant amount of data and intelligent control capabilities. Integrated information of distributed generation enables VPP with computational flexibility to have better demand-side management.

Demand Response Programs (DRP) are the schemes by which the consumer can actively participate in the grid operations by way of adjusting their energy consumption behavior. The control algorithm can be built to have dynamic control of loads, curtailing the power consumption of the controllable devices, to have the frequency regulated. While the independent demand response program improves the stability of islanded microgrids, collaborative demand response programs help to address the peak needs in the grid where a large set of microgrids are connected.

Energy Storage Systems (ESS) are one of the important components of the smart grid, which store energy at off-peak hours and provide back to the grid during peak hours. Information from ESS also needs to be integrated and its role in the smart grid to be managed by VPP.

Demand Side Management & Dynamic Pricing:

Demand Side Management (DSM) includes load management through Demand Response (DR) programs and the energy efficiency management at loads. Implementation of dynamic pricing management in the VPP is key to have the active participation of consumers and have efficient demand response programs implemented. Time-of-Use (TOU), Critical Peak Pricing (CPP), Real-Time Pricing (RTP), and Day-Ahead Pricing (DAP) are some of the dynamic pricing methods being adopted by smart grids. Though complexity and cost involved restrict the adoption of dynamic pricing, it is gaining momentum, and the VPP to address the same.

Time of usage (TOU) being a static-time-dependent pricing scheme, it is simple and preferred by utilities and comfortable for consumers (no unexpected/dynamic variations in pricing). It is essential to have the accurate and frequent acquisition of time-based consumption data through smart metering to have TOU-based pricing implemented successfully. VPP coordinates and manages advanced TOU schemes through integrated intelligent devices.

Real-Time Pricing (RTP) is a dynamic pricing method that uses the real-time spot price of the wholesale market. On the basis of trading in the electricity marketplace, the market operators approve pricing and share the information with the participants to decide on their consumption. This pricing could be as per a specified time frame, could be a day ahead or an hour ahead. While TOU sets pricing in predefined time frames, the pricing in RTP varies frequently in response to dynamics of the market and hence the VPP plays a much significant role to manage this scheme. Remote management of consumption through intelligent devices is a key requirement in this case since the user should be able to manage his consumption in real-time, from remote, if there is a need.

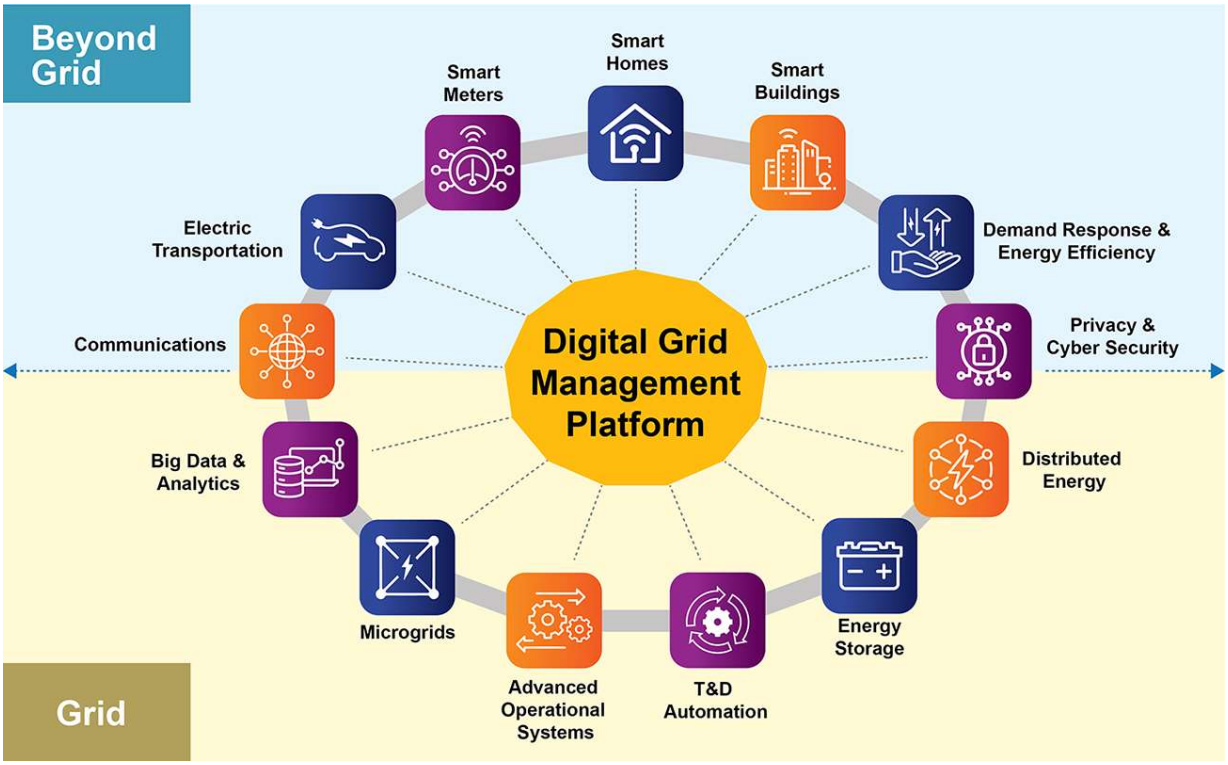
Critical Peak Pricing (CPP) is an extended version of TOU. TOU works basically as an incentive-based, fixed-time-based scheme, which is inadequate to address the heavily loading conditions (critical peaks). CPP introduces penalties during critical peak loads and pushes the consumer to reduce consumption. Power system constraints cause critical events, which are usually announced a day ahead, and hence CPP does not follow the prices in the wholesale market during critical peak loads.

Day-Ahead Pricing (DAP) policy is a time-based scheme, which sets the pricing details a day ahead. This helps consumers to plan and set their consumption pattern to maximize the benefits from off-peaks. This scheme looks attractive but the challenges are related to load forecasting, supply availability forecasting, climatic forecasting, and energy price forecasting. The respective information gathered by VPP and the algorithms used for forecasting plays an important role in the success of DAP.

VPP also facilitates power trading. Power trading happens in the marketplace mainly since the power cannot be stored in bulk and it is traded as per short-term and long-term agreements. Apart from such agreements between major power producers and consumers, trading is done in real-time, peer-to-peer between two parties. Trading platforms facilities negotiations on volume and prices and it could be P2P or between multiple producers, consumers, or prosumers. The increasing presence of Energy Storage Systems will have an impact on power trading, and eventually, the integration of such systems is expected to promote trading further. Blockchain technology is being piloted to have a trustworthy transaction in power trading and which is expected to form part of VPP platforms when proven.

"At Quest Global, we have built a block-chain based energy trading platform to showcase how the reliable transactions can be done over a digital platform where large number of stakeholders participate. This is just an example of various innovative concepts piloted or introduced by Quest Global. Many of our key customers consider us as the innovation house to conduct the feasibility studies or implement PoCs which will eventually form part of their product/platform."

The Big Energy Data and Cyber Security:



The information system to manage the grid should comprise intelligent data systems to meet the intended objectives. Handling big energy data needs to address the challenges of volumes, reliability, scalability, as well as data security and privacy. Acquiring and processing a massive amount of information needs to address the complexity related to the acquisition, pre-processing, integration, analytics, storage, visualization, and decision-making. Quest Global is supporting a world leader in architecting the futuristic cloud-based system handling the specific challenges of high-volume data requirements of smart grid. The collected data is to be processed, integrated, stored, analyzed, visualized, and used for making the appropriate decisions by VPP. The traditional grid uses data of voltage, current, and demand which are collected through a limited number of devices like RTUs/IEDs/Meters. The modern digital grid needs to capture an enormous amount of real-time data from devices like smart meters, dispersed sensors, PMUs, digital substations, transmission & distribution management systems, DERs, DRPs, weather forecast systems, load profile patterns, and market data. Data collected from smart meters and PMUs are of very large volume and the respective sub-systems are designed to handle such humongous data and provide the summary and insights for further analysis and decision making. Quest Global is also a partner to a world major to design and develop the modern WAMS (Wide Area Management System) which acquires, analyses, and provides situational awareness for some of the world's largest WAMS installations.

Data integration in the VPP empowers electric utilities and consumers by providing the ability to monitor and control the behavior of the grid continuously, however, the larger play of information systems significantly increases the security constraints and vulnerabilities. Threats, cyber security issues, vulnerabilities, and countermeasures are being investigated and information systems, processes, and protocols are being developed to address the same effectively. There are different types of attacks such as Denial of Services (DoS), Reply attacks, and Deception attacks. While DoS attempts to disrupt the system resources and make it unavailable, reply attacks contaminate the valid data. Deception attacks manipulate the integrity of the transmitted data. Cyber-attacks are aimed to degrade or destroy the performance of the power system and immobilize the power system temporarily or permanently. So, it is critical to have the VPP built with robust software sub-systems, which can resist cyber-attacks.

Conclusion:

VPP is emerging as the all-in-one digital platform for the management of modern gird. It is also said to be the "uber in the making" for energy, where eventually all stakeholders can collaborate seamlessly and directly (avoiding third parties). Consumers will have the power to select the source of energy and producers will have the power to sell the same to the needy directly. In the highly distributed yet integrated ecosystem sourcing/selling could be from/to the stakeholder who is next door or far.

Today, since VPP is seen as the catalyst to accelerate the growth of decentralized of renewables-based power generation, and improves energy efficiency, it is also considered to be the accelerator for decarbonization. VPP accelerates the journey towards net-zero and helps to meet climate goal commitments. Quest Global, is helping its clients in the energy segment (O&G, Power, and Industrial) on decarbonization, and VPP programs have been identified as the related topic in the power industry to make investments and build capability.

Considering the increasing adoption of VPP across the globe and the significant investments needed to develop such a platform, VPP is evolving to VaaS (VPP-as-a-Service). Major utilities, OEMs/software platform solution providers, and engineering service providers collaborating to build the VPP as a full-fledged digital platform and to offer it as VaaS. The entire platform is being built as a cloud-based solution and services can be subscribed by all stakeholders. It is expected to emerge further and Quest Global is all set to play a pivotal role in the journey to realize a full-fledged digital grid management platform.