Virtual Power Plants (VPPs) for Smart Energy
A 4-step approach towards successful VPPs
Introduction

The energy sector, relatively unperturbed for decades, is in the midst of disruptive innovation, accelerating the pace of change as the “new normal”.

Technology disruption is driving new business models in both supply and demand sides. The need to adapt to disruptions to the status quo is evident in the rise of distributed self-generation that continues to increase in affordability and deployed on a larger scale, mounting pressure on conventional grid-supplied energy.

New market entrants are also challenging major incumbents with smart technologies enabling the consumer to gain better control of their demand and supply needs. In addition, regulators are grappling with the challenges facing traditionally protected linear, close-knit supply chain. While democratisation of energy is introducing uncertainties in the long-term planning and short-term supply of energy, it is also presenting immense opportunity.

Smart Energy
Smart Energy infrastructure overlays real-time information on the existing energy network to make it more flexible, efficient, reliable and resilient. Solar PV, Energy Storage, Virtual Power Plants, Micro-Grids, Internet of Things (IoT) and Analytics, are some typical building blocks of the Smart Energy Infrastructure.

Virtual Power Plant (VPP)
A VPP is a platform to virtualize and balance dispersed power supply resources, multiple distribution routes, and various demand centres.

Internet of Things (IoT)
IoT in Smart Energy covers intelligent energy assets that are connected, virtualized, and infused with data measurement capabilities. The IoT facilitates efficient decision-making for an optimised energy market.
Transformation of the Energy Value Chain to an Energy Web

**Ancient Past:**
Disconnected Energy Value Chain

**Recent Past:**
Vertical Energy Value Chain

**Now:**
Bi-directional Energy Value Chain

**Touching Distance:**
Interconnected Energy Web

Innovations in the field of Smart Energy infrastructure, particularly IoT capabilities within energy resources, are shaping the vision of an interconnected web of energy in the future. The Energy Web is envisioned to lead to near real-time optimised consumption and supply of energy.
Virtual Power Plants (VPPs) enable the virtualization of infrastructure and services by providing functionalities such as distributed asset monitoring and control, renewable energy management, energy storage management, electric vehicle charging asset management, and demand side management.

The key enablers for VPPs include:
(1) a strong regulatory framework,
(2) associated Smart Energy Infrastructure;
(3) active consumer participation; and
(4) an innovation ecosystem.

Types of VPP Services

**Resource Aggregation**
Using distributed energy resources like RE, ESS, EV, CHPs, and load centers, VPPs can create real-time aggregated load centers and offer services to retailers.

**Demand Response**
VPPs can work with various small and large resources in providing Demand Response services such as load reduction and peak shift.

**RE Intermittency**
VPPs can provide RE intermittency control services by using ESS or aggregating geographically distributed RE power sources.

**Non-critical Reserve**
VPPs can participate in the non-critical reserve market where response time for providing services like interruptible load, ESS-driven brown start, and spinning reserve is more than 10 minutes.

**Regulation Services**
VPPs are also able to participate in the critical reserve market to provide frequency regulation and black start.

**Network Reliability Services**

Virtual Power Plants (VPPs) enable the virtualization of infrastructure and services by providing functionalities such as distributed asset monitoring and control, renewable energy management, energy storage management, electric vehicle charging asset management, and demand side management.

The key enablers for VPPs include:
(1) a strong regulatory framework,
(2) associated Smart Energy Infrastructure;
(3) active consumer participation; and
(4) an innovation ecosystem.
Distributed Energy Resource Management (DERMS)

The pervasive transformation of the energy infrastructure is giving rise to several competing and complementing concepts. Distributed Energy Resource Management (DERMS) is one such concept. DERMS is a software solution that serves to balance the requirements of the utilities with the energy generated by distributed energy resources (DERs) at the distribution end. As shown in the table below, VPPs and DERMS have several competing aspects on how they manage DERs. One key difference is that VPPs focus on the consumer whereas DERMS target network utility.

<table>
<thead>
<tr>
<th>Functionalities of VPPs</th>
<th>Virtual Power Plant</th>
<th>Distributed Energy Resource Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distributed Asset Monitoring</td>
<td>Centralised monitoring of the distributed demand, power generation, energy storage, and measurement assets.</td>
<td></td>
</tr>
<tr>
<td>Asset Analytics</td>
<td>Monitoring and data analytics (condition monitoring and predictive maintenance, e.g., in the building energy management, are possible) [Frost recommends removing this from VPP as such functionalities are typically a part of Enterprise Asset Management systems.]</td>
<td></td>
</tr>
<tr>
<td>Distributed Asset Control</td>
<td>Simple remote management of the distributed demand, power generation, energy storage, and measurement assets.</td>
<td></td>
</tr>
<tr>
<td>Renewable Energy Management</td>
<td>Provision of additional functions such as intermittency control, forecasting, and dispatch to handle and promote Renewable Energy Sources (RES) integration to the wider grid.</td>
<td></td>
</tr>
<tr>
<td>Energy Storage Management</td>
<td>Integration of storage assets through direct or indirect controls.</td>
<td></td>
</tr>
<tr>
<td>Electric Vehicle (EV) Charging Asset Management</td>
<td>Management of EV charging assets to allow optimised energy consumption.</td>
<td></td>
</tr>
<tr>
<td>Demand Response/Demand Side Management</td>
<td>Assets’ participation of ancillary services through the management of consumption and/or generation</td>
<td></td>
</tr>
</tbody>
</table>
The Asia-Pacific region is estimated to have more than 500 million installed Smart Meters. Decreasing investments indicate greater spending on replacement. China, Japan, and Australia lead the installed base of smart meters.

Energy Storage
The Asia-Pacific region is forecast to grow by 50% driven by increasing requirements for power from China and India.

AMI
The solar PV market is forecast to grow by 50% driven by increasing requirements for power from China and India.

Micro-Grids
The solar PV market is forecast to grow by 50% driven by increasing requirements for power from China and India.

Demand Response
Demand Response services in Australia, New Zealand, and Japan are expected to stimulate the adoption of Demand Side Management.

Solar Power
The solar PV market is forecast to grow by 50%

Growth of Smart Energy solutions are key enablers for VPPs
VPP-Ready Countries

Retail Competition
Retail competition is required for an innovation ecosystem to flourish in the electricity sector. Introduced in Australia (33) and New Zealand (28) over the past decade, retail competition is believed to be successful in driving better services and prices to customers. Japan and China have opened their markets to competition in the past two years, resulting in a surge of retail participants (more than 300) entering the market.

Time of Usage (ToU) Tariff
The ToU tariff structure enables the customer to utilise electricity price signals to determine their consumption. Retailers in Australia, New Zealand, and China offer a ToU tariff structure to consumers that have had smart meters installed (in China it is only available to commercial and industrial users). Japan has yet to introduce the ToU tariff.

Demand Response Program
Australia and New Zealand have commercially successful DR programs that incentivise consumers to manage their power demand. Japan is conducting trials using ESS to participate in DR services. Similarly, China recently laid out its policy on Energy Efficiency and pilot projects to be organised.

Smart Meters
Smart meters support the information layer of the Smart Energy infrastructure. China leads in the overall smart meters deployment with more than 300 million installed units and growing, followed by Japan, Australia, and New Zealand.

RE Penetration
The contribution of wind and solar PV in overall electricity generation is highest in Australia, with the country offering the largest deployment of rooftop solar PV units especially in the household sector.

Energy Storage
Energy Storage is a vital component of the VPP as it provides the potential to commoditise electricity to be used for traditional back-up services or market arbitrage opportunities. Currently, ESS offering VPP services are mostly in the pilot stage, primarily in Australia and Japan.
Countries with an Emerging Smart Energy Market (TBC)

Singapore
Singapore has introduced retail competition for non-residential customers with at least 2MWh monthly electricity consumption. In 2018, the retail competition will be extended to all consumers. In addition, a market-driven DR pilot program is currently underway with market participants.

Philippines
The Philippines is completing the National Wholesale Power Market as part of its efforts to generate competition. Currently, electricity market participants in the Philippines struggle to extend the power network across the vast number of islands in the country cost-effectively, leading to the widespread adoption of diesel genset-based power supply infrastructure. Using micro-grids with a hybrid of RE and storage, a VPP set-up can be considered as a viable solution to increase the electrification ratio in the country.

South Korea
To be updated

Indonesia
With a vast number of islands, The Philippines electricity market participants struggle to extend the power network in a cost efficient manner. This leads to a widespread adoption of diesel genset based power supply infrastructure. Using Micro-grids with a hybrid of RE and storage a VPP setup can be considered a solution to increase the electrification ratio.

The Case for VPPs

Energy sustainability while managing energy demand and import requirements are critical challenges facing many energy-intensive economies in the Asia-Pacific region. Distributed energy assets with high RE penetration could be considered a panacea for the Asia-Pacific’s energy issues.

Despite the benefits of distributed energy assets in solving the overall energy problems, they do present several hurdles for market participants.

1. RE is known to have intermittency issues and subject to inclement weather conditions.
2. A vast number of distributed assets can lead to challenges in managing multiple and complex sets of interfacing standards.
3. With the number of assets, potentially reaching millions, the sheer volume of information available in real-time can be overwhelming in terms of decision-making in the power markets.
Challenges for VPPs

The identified challenges for market participants make a strong case for Virtual Power Plants

<table>
<thead>
<tr>
<th>Need for regulatory support</th>
<th>Impact over time</th>
</tr>
</thead>
<tbody>
<tr>
<td>VPP services are in the early development stages in the region. The offerings rely heavily on the energy policies and market operations.</td>
<td>HIGH</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Current RE penetration level does not justify RoI</th>
<th>Impact over time</th>
</tr>
</thead>
<tbody>
<tr>
<td>VPP players identify the current level of RE penetration as being insufficient in managing the RE intermittency issues without using storage.</td>
<td>HIGH</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>High cost of ESS</th>
<th>Impact over time</th>
</tr>
</thead>
<tbody>
<tr>
<td>The cost-to-efficiency ratio of BESS needs to develop to the extent that the lifetime benefit is adequate to offset the Life Cycle Cost of the systems in operation.</td>
<td>HIGH</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lack of EV charging standards</th>
<th>Impact over time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lack of standardisation for EVs chargers from OEMs or charging station manufacturers could limit attaining economies of scale. Issues such as different designs, composition, and battery location make compatibility with all charging stations a challenge.</td>
<td>MEDIUM</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Resistance from incumbent utilities</th>
<th>Impact over time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relatively low interest to participate among utilities, as they fear VPPs becoming a source of revenue erosion amid concerns about grid safety and stability.</td>
<td>MEDIUM</td>
</tr>
</tbody>
</table>

4-Step Approach to Successful VPP Projects

1. Business Objectives
2. Prototype
3. Validation
4. Scaling Up
01 Business Objectives

Identifying the needs and pain points of market participants

Today’s distribution grid network is increasingly populated with RE generation sources, energy storage systems, and demand response services. What are the key business needs for the utility, power retailer, RE operator, DR aggregator and Smart City managers?

What are critical metrics for the VPP Manager to meet to ensure reliable and efficient operations for market participants?

Several business needs of stakeholders are as follows:
- Utilities may want to defer investments in network assets
- Power retailers may want to enable smaller prosumers to gain better value in the energy market
- DR aggregators may want better control over their customers’ energy usage
- Smart City managers may want aggregated monitoring of energy assets

Several pain points stakeholders face include:
- Connecting and optimising energy resources in real-time, and balancing supply and demand
- Enabling energy trading by the proper management of assets
- Ensuring customers’ energy service needs, while simultaneously minimising the cost and risk associated with investments

The next step involves formulating a plan to execute a trial POC project. The VPP is set up by integrating distributed energy resources in a community comprising residences, commercial buildings, and small industrial plants. A VPP Platform interconnects these diverse assets as shown in Figure 5.1.

Key assets connected are solar PV plants, wind turbines, demand response resources, ESS, and EV charging infrastructures, along with sensors and smart meters.

Assets embedded with sensors receive and send signals to the VPP. Every second, the data collected from these sensors are analysed and key decisions are taken by the platform, to balance the power generation outputs of solar and wind farms, ESS and grid supply, against the load demands from offices, industrial plants, and residences. The excess energy can be traded in the wholesale electricity market, based on the electricity spot prices, or stored in ESS for later usage.

Vendor or Partner Support
- A solar/wind power plant must be built in case the selected zone does not have one. Vendors and system integrators have to be engaged.
- Collaborate with the ESS vendor for its installation. The VPP platform must have a clear understanding of the economics of charging and discharging of the ESS to decide its proper management.
- It is crucial for the VPP platform to interact effectively with the sensors (connected to all assets) and smart meters to read the data and take the necessary steps for smooth operation.
- Work in partnership with a DRMS provider for its installation at customer sites. Engage with the customer for load scheduling and DR dispatch operations.
- Interact with EV charging infrastructure vendors to determine the V2H charging functionalities to ensure proper operation during peak hours.

02 Develop a Prototype

Formulating a trial Proof of Concept (POC) project

VPP platform helps in deciding generation bids, ancillary service bids for Energy Trading

Figure 5.1: Trial POC Project Utilising the VPP Platform

Virtual Power Plant Ecosystem

Assets
- Solar PV generation
- Wind Turbine
- Energy Storage Systems
- EV Charging Infrastructure
- Demand Response
- Smart Meters

Key Stakeholders
- Power Utilities
- Renewable Energy Operators
- Demand Response Operators
- Energy Retailers
- VPP operator
- Building Managers

VPP Platform Functionalities
- Asset Monitoring
- Renewable Energy Management
- Energy Storage Management
- Demand Response Management
- EV Charging Infrastructure Management
03 Validate the Proof of Concept

Analysing data from the trial project

During this phase, data collected from the operation of the VPP platform in the POC project is studied in detail.

Key benefits are examined, while critical shortfalls are listed requiring further validation.

Before and after comparisons using the baseline defined in the Business Objectives phase, teams can then conduct a thorough analysis of the new status and situation compared to the benchmark. In reference to the main challenges identified during the trial run, several key benefits and suggested metrics are shown in the table below.

Further examination of these validation points is necessary before the Scaling Up phase to facilitate the proper energy management of all the assets. Additional steps can be finalised based on the findings. The test-bed is run again with the new energy management protocols.

<table>
<thead>
<tr>
<th>BENEFITS</th>
<th>VALIDATION REQUIRED</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Demand Response</strong></td>
<td>Peak load reduction, reduced operation of peaker plants, and low carbon emissions</td>
</tr>
<tr>
<td></td>
<td>Reductions in electricity prices, benefitting all customers</td>
</tr>
<tr>
<td></td>
<td>Financial compensation for DR participants</td>
</tr>
<tr>
<td><strong>Energy Storage Systems</strong></td>
<td>Financial benefits of utilising off-peak energy stored and used during peak periods</td>
</tr>
<tr>
<td></td>
<td>Enabling smooth RE power output for submitting generation bids</td>
</tr>
<tr>
<td><strong>EV Charging Asset</strong></td>
<td>Peak shaving using energy stored in fully charged EVs</td>
</tr>
<tr>
<td></td>
<td>Financial benefits for EV users to feed energy to the grid</td>
</tr>
<tr>
<td><strong>RE Generation</strong></td>
<td>Grid independence Energy trading for both peak power and base load generation</td>
</tr>
<tr>
<td></td>
<td>Energy trading as a response to the demand for energy in the VPP</td>
</tr>
</tbody>
</table>

Table 5.1: Benefits and Points to be Validated upon POC Project Completion

04 Scale Up Implementation

Replication and expansion

The last step of the process focuses on scaling up results achieved during the POC project for broader implementation across several local VPPs, controlled by a Master VPP.

The system works for the pilot set of sensors and assets, the next phase involves extending the set-up to cover more assets and larger geographical areas. While ensuring the capability to handle increased complexity, it is also important that the interlinked assets and sensors are compatible with the VPP software platform.

First, the VPP software platform needs to have a trusted partner, such as a DR aggregator, VPP Operator, ESS OEM or System Integrator. The partner should work with VPP stakeholders to implement the POC across a large set of assets in stages. The initial POC project may work well with dozens of connected assets; however, will this be sustainable if the implementation expands to include hundreds or thousands of sensors and assets? The types of data collected may also evolve from basic meter readings and energy flow to sophisticated data such as location, light, wind speed, and energy usage patterns.

Data and security

As the number of assets increase, the data collected from sensors and meters will grow exponentially, signalling the need for cloud deployments to interconnect VPPs covering a larger geographical area. The access to data collected from a large set of assets enables the VPP operator to understand the customer demand profile, RE generation pattern, demand response dispatch frequency, and EV charging needs. This information is crucial to facilitate predictive generation, optimal energy management, and maximise financial gains.

Ability to sense the “big picture”

The access to data collected from a large set of assets enables the VPP operator to understand the customer demand profile, RE generation pattern, demand response dispatch frequency, and EV charging needs. This information is crucial to facilitate predictive generation, optimal energy management, and maximise financial gains.

Process improvement

The consolidation of several small VPPs under a Master VPP; implementation of protocols or directions by a local VPP for efficient operation can also be easily analysed, shared, and implemented into other local VPPs. Similarly, problem-solving measures to overcome issues can also be shared and implemented.

Improve business outcomes by working with a partner

The VPP platform is a single consolidated system that will connect various assets, collate data and send control signals for energy management in a VPP. An experienced channel partner installs the VPP platform to implement a VPP. Key channel partners include:

- VPP Operators
- ESS OEMs
- Demand Response Aggregators
- Smart District Managers
- Renewable Energy Operators

The consolidation of several small VPPs under a Master VPP; implementation of protocols or directions by a local VPP for efficient operation can also be easily analysed, shared, and implemented into other local VPPs. Similarly, problem-solving measures to overcome issues can also be shared and implemented.
The future of VPP functionalities ranges from a super VPP encompassing the entire value chain to many small VPPs at different hierarchy levels.

The advancements in Artificial Intelligence Self Learning are projected to stimulate the evolution of an Intelligent and Predictive platform.

Developments in smart appliances that optimise energy consumption based on weather and market prices, could also lead to real-time VPP functionalities and services.

VPPs in the future need to understand and incorporate customer behaviour to provide personalised smart energy services.

Eventually, the overall VPP architecture will need to scale up to millions of devices, processing trillions of data points.

With such an extensive range of customers and millions of assets, an agile plug-and-play model is essential to adapt to the evolving open standards to allow customers to add new assets and devices to the network.

Self Learning & Intelligent

Real time - Integrate Weather data and market prices

Predictive - events of the future

Single Platform for entire power value chain.

Personalized

Modular

Scalable
VPP Use Cases

Use Case 1: Energy Storage Management

In this model, the VPP platform acts as an Energy Storage Aggregator performing the essential functionality of control and management of energy storage systems such as battery storage, heat pump or air conditioners. Other functionalities of the platform include monitoring of assets such as ESS, analysing data from smart meters, and uniting all resources.

In the VPP platform, the following services are offered:
- Energy Storage Management
  - ESS current status – Charged, No Charge, Currently Charging
  - Charging statistics – Voltage, Amperage, Temperature
  - Energy data – Smart Meter and power data
  - Sensor Data – Temperature, Humidity, IL luminance
  - Grid power data
  - Generation values
- Ancillary Services
  - Energy Supply-Demand Planning (supply-demand balancing through battery chargers and discharges)
  - Energy Storage Management – batteries, heat pumps, air-conditioners
  - Demand Forecast (short-term & long-term)
  - Demand Control (peak cut, peak shift)
  - Energy Usage Optimisation
  - ESS Aggregation Plan: - Battery usage control - Charging of battery during off-peak hours or from renewable sources of power - Optimisation of battery charging and discharging
- Energy Trading
  - Energy  Supply-Demand Planning (supply-demand balancing through battery charges and discharges)
  - Demand Forecast (short-term & long-term)

The platform analyses the data and maintains power demand-supply balance. The platform also assists the VPP operator to participate in the power market using customer energy storage resources, and contribute to reducing power costs through market mechanisms.

Use Case 2: Demand Response Management

In a VPP operating as a Demand Response Aggregator, the platform procures data on supply, demand, and generation. The demand forecast is formulated and based on the stipulated demand and supply plan.

In a VPP operating as a Demand Response Aggregator, the platform procures data on supply, demand, and generation. The demand forecast is formulated and based on the stipulated demand and supply plan. The next step is DR calculation. All DR participants are pre-notified and based on their response, the DR is scheduled and executed. Upon completion of the DR schedule, DR bids can be submitted for ancillary services such as reserve margin.

<table>
<thead>
<tr>
<th>Input Signals to VPP Platform</th>
<th>VPP Platform Processes</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESS current status – Charged, No Charge, Currently Charging</td>
<td>- Energy Storage Management – batteries, heat pumps, air-conditioners</td>
<td>- Demand Response load schedule of each participating customer –</td>
</tr>
<tr>
<td>Charging statistics – Voltage, Amperage, Temperature</td>
<td>- Energy Supply-Demand Planning (supply-demand balancing through battery chargers and discharges)</td>
<td>- Dispatch Load, Time, and Duration Energy data –</td>
</tr>
<tr>
<td>Energy data – Smart Meter and power data</td>
<td>- Energy Storage Management – batteries, heat pumps, air-conditioners</td>
<td>- Smart Meter and power data</td>
</tr>
<tr>
<td>Sensor Data – Temperature, Humidity, IL luminance</td>
<td>- Demand Forecast (short-term &amp; long-term)</td>
<td>- Sensor data – temperature, humidity, IL luminance</td>
</tr>
<tr>
<td>Grid power data</td>
<td>- Demand Control (peak cut, peak shift)</td>
<td>- Equipment data – status data</td>
</tr>
<tr>
<td>Generation values</td>
<td>- Energy Usage Optimisation</td>
<td>- Grid power data</td>
</tr>
<tr>
<td>Energy Management</td>
<td>ESS Aggregation Plan: - Battery usage control - Charging of battery during off-peak hours or from renewable sources of power - Optimisation of battery charging and discharging</td>
<td>Generation values</td>
</tr>
<tr>
<td>Ancillary Services</td>
<td>Energy Storage Management</td>
<td>- Energy Supply-Demand Planning (supply-demand balancing through battery charges and discharges)</td>
</tr>
<tr>
<td>Ancillary Services</td>
<td>Demand Forecast (short-term &amp; long-term)</td>
<td>- Demand Response Program – DR Capacity Management, DR Execution</td>
</tr>
<tr>
<td>Energy Trading</td>
<td>Demand Control (peak cut, peak shift)</td>
<td>- Demand Forecast (short-term &amp; long-term)</td>
</tr>
<tr>
<td>Energy Usage Optimisation</td>
<td>Energy Usage Optimisation</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Input Signals to VPP Platform</th>
<th>VPP Platform Processes</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demand Response load schedule of each participating customer –</td>
<td>- Energy Supply-Demand Planning (supply-demand balancing through battery chargers and discharges)</td>
<td>- Dispatch Load, Time, and Duration Energy data –</td>
</tr>
<tr>
<td>Dispatch Load, Time, and Duration Energy data –</td>
<td>- Energy Storage Management – batteries, heat pumps, air-conditioners</td>
<td>- Smart Meter and power data</td>
</tr>
<tr>
<td>Smart Meter and power data</td>
<td>- Demand Forecast (short-term &amp; long-term)</td>
<td>- Sensor data – temperature, humidity, IL luminance</td>
</tr>
<tr>
<td>Sensor data – status data</td>
<td>- Demand Control (peak cut, peak shift)</td>
<td>- Equipment data –</td>
</tr>
<tr>
<td>Grid power data</td>
<td>- Energy Usage Optimisation</td>
<td>- Grid power data</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Services Offered by VPP Platform</th>
<th>Customers</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy Storage Management</td>
<td>ESS Service Providers</td>
<td>Minimising the costs related to battery charging and discharging. Balancing of supply and demand.</td>
</tr>
<tr>
<td>Ancillary Services</td>
<td>T&amp;D Company</td>
<td>Providing reserve capacity, voltage support through reactive power control.</td>
</tr>
<tr>
<td>Energy Trading</td>
<td>Wholesale Electricity Market</td>
<td>Facilitating power generation bids.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Services Offered by VPP Platform</th>
<th>Customers</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy Management</td>
<td>Consumers, RE Resource Providers</td>
<td>Minimising the costs related to battery charging and discharging. Balancing of supply and demand.</td>
</tr>
<tr>
<td>Ancillary Services</td>
<td>T&amp;D Company</td>
<td>Providing reserve capacity, voltage support through reactive power control.</td>
</tr>
</tbody>
</table>
**Use Case 3: Renewable Energy management**

The distributed energy resources in a community or region can be conveniently aggregated using a VPP platform, to operate as a single large source of power.

**VPP Platform Processes**
- Grid power data
- Distributed energy resource generation data
- Consumer energy data – Smart Meter and power data
- Sensor data – Temperature, Humidity, IL luminance
- Equipment data – status data
- Generation values

**Services Offered by VPP Platform**

<table>
<thead>
<tr>
<th>Services Offered by VPP Platform</th>
<th>Customers</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy Management</td>
<td>Consumers, RE Resource Providers</td>
<td>Minimising the costs related to battery charging and discharging.</td>
</tr>
<tr>
<td>Ancillary Services</td>
<td>T&amp;D Company</td>
<td>Balancing of supply and demand. Providing reserve capacity, voltage support through reactive power control.</td>
</tr>
<tr>
<td>Energy Trading</td>
<td>Wholesale Electricity Market</td>
<td>Facilitating power generation bids.</td>
</tr>
</tbody>
</table>

**Output**
- Submit generation bids to wholesale electricity market
- Provide ancillary services to T&D company
- Can consider serving GENCOs
- Enable CO2 reduction
- Aid basic reduction of electricity prices during peak hours

**Control Signals Offered by VPP Platform**

<table>
<thead>
<tr>
<th>Control Signals Offered by VPP Platform</th>
<th>Customers</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy Management</td>
<td>Consumers, RE Resource Providers</td>
<td>Minimising the costs related to battery charging and discharging. Balancing of supply and demand.</td>
</tr>
<tr>
<td>Energy Storage Management</td>
<td>Energy Storage Service Providers/ Consumers</td>
<td>Minimising the costs related to battery charging and discharging. Balancing of supply and demand.</td>
</tr>
<tr>
<td>Demand Response Management</td>
<td>DR Participants</td>
<td>Enabling demand response dispatch signals to scheduled load.</td>
</tr>
<tr>
<td>Demand Control</td>
<td>Consumers</td>
<td>Sending signals to consumers to optimise energy usage, engage ESS charging/discharge as required.</td>
</tr>
</tbody>
</table>

**Use Case 4: Asset Remote Control**

The platform ensures supply-demand balance in the region, reduces grid power dependence, and utilises excess power for generation bid submissions in the electricity market or as ancillary services.

**VPP Platform Processes**
- Grid power data
- Distributed energy resource generation data
- Consumer energy data – Smart Meter and power data
- Sensor data – Temperature, Humidity, IL luminance
- Equipment data – status data
- Generation values

**Services Offered by VPP Platform**

<table>
<thead>
<tr>
<th>Services Offered by VPP Platform</th>
<th>Customers</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy Management</td>
<td>Consumers, RE Resource Providers</td>
<td>Minimising the costs related to battery charging and discharging. Balancing of supply and demand.</td>
</tr>
<tr>
<td>Energy Storage Management</td>
<td>Energy Storage Service Providers/ Consumers</td>
<td>Minimising the costs related to battery charging and discharging. Balancing of supply and demand.</td>
</tr>
<tr>
<td>Demand Response Management</td>
<td>DR Participants</td>
<td>Enabling demand response dispatch signals to scheduled load.</td>
</tr>
<tr>
<td>Demand Control</td>
<td>Consumers</td>
<td>Sending signals to consumers to optimise energy usage, engage ESS charging/discharge as required.</td>
</tr>
</tbody>
</table>

**Output**
- Grid power data
- Distributed energy resource generation data
- Consumer energy data – Smart Meter and power data
- Sensor data – Temperature, Humidity, IL luminance
- Equipment data – status data
- Generation values
- Energy Usage Optimisation

**Control Signals Offered by VPP Platform**

<table>
<thead>
<tr>
<th>Control Signals Offered by VPP Platform</th>
<th>Customers</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy Management</td>
<td>Consumers, RE Resource Providers</td>
<td>Minimising the costs related to battery charging and discharging. Balancing of supply and demand.</td>
</tr>
<tr>
<td>Energy Storage Management</td>
<td>Energy Storage Service Providers/ Consumers</td>
<td>Minimising the costs related to battery charging and discharging. Balancing of supply and demand.</td>
</tr>
<tr>
<td>Demand Response Management</td>
<td>DR Participants</td>
<td>Enabling demand response dispatch signals to scheduled load.</td>
</tr>
<tr>
<td>Demand Control</td>
<td>Consumers</td>
<td>Sending signals to consumers to optimise energy usage, engage ESS charging/discharge as required.</td>
</tr>
</tbody>
</table>