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TECHNICAL SPECIFICATION

Virtual Power Plants-
Part 2: Use Cases

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Part 2: Use Cases

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CONTENTS

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VIRTUAL POWER PLANTS –

Part 2: Use cases

FOREWORD

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IEC TS 63189-2 has been prepared by subcommittee 8B: Decentralized electrical energy systems, of IEC technical committee 8: System aspects of electrical energy supply. It is a Technical Specification.

The text of this Technical Specification is based on the following documents:

Draft	Report on voting
8B/136/DTS	8B/198/RVDTS

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this Technical Specification is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

A list of all parts in the IEC 63189 series, published under the general title *Virtual power plants*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn, or
- revised.

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INTRODUCTION

The virtual power plants use cases are developed to facilitate the standardization in this area from a system perspective. The use cases capture the basic information, business roles, actors, scenarios, and processes from practical business applications, pilot projects, and academic researches of virtual power plants in different countries. This document is developed to capture the requirements in the form of use cases that contain the scenarios and steps in a logical sequence so that it cannot only be understood by interested parties to obtain their related requirements, develop a virtual power plant, or operate a virtual power plant, but also establish a nomenclature for the functions, roles, etc. Meanwhile, the use cases in the document apply to any types of DER aggregation (physical, virtual, small and large), and also to microgrids.

Interested parties for this document include, but are not limited to:

- virtual power plant operator
- distributed generation operator
- demand response service operator
- electrical energy storage operator
- electric vehicle operator
- electric vehicle charging station with storage
- power system operator
- electricity market operator
- transmission and/or distribution company
- energy service company
- energy information provider
- regulator

The major objectives of this document include:

- to build common understanding of the business, system and functional requirements and thus to facilitate further development of VPPs;
- to investigate future standardization needs, in order to ensure the easy implementation, performance and interoperability of VPPs;
- to serve as an input to the IEC Use Case management repository, the purpose of which is to collect, administer, maintain, and analyze generic use cases.

VIRTUAL POWER PLANTS –

Part 2: Use cases

1 Scope

This document is applicable to virtual power plants (VPPs) that consist of distributed generation, controllable loads, and electrical energy storages.

This part of IEC 63189 is to provide VPPs use cases that capture the basic information, business roles, actors, scenarios, and processes.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC SRD 62913-1:2019[1], *Generic smart grid requirements – Part 1: Specific application of the Use Case methodology for defining generic smart grid requirements according to the IEC systems approach*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1
aggregator
party who contracts with a number of other network users (e.g. energy consumers) in order to combine the effect of smaller loads or distributed energy resources for actions such as demand response or ancillary services

[SOURCE: IEC 60050-617:2017, 617-02-18]

3.2
controllable load
CL
load of particular consumers which under contract shall be reduced, for a limited period of time, at the request of the distribution supply undertaking

Note 1 to entry: Controllable load can be increased as well as reduced, according to the request of the distribution supply undertaking.

1 This publication was withdrawn.

[SOURCE: IEC 60050-603:1986, 603-04-42, modified — Addition of a Note 1 to entry.]

3.3
demand response
DR
action resulting from management of the electricity demand in response to supply conditions

[SOURCE: IEC 60050-617:2011, 617-04-16]

3.4
distributed energy resources
DER
generators (with their auxiliaries, protection and connection equipment), including load having a generating mode (such as electrical energy storage systems), connected to a low-voltage or a medium-voltage network

[SOURCE: IEC 60050-617:2017, 617-04-20]

3.5
distributed generation
DG
generation of electric energy by multiple resources which are connected to the power distribution system

Note 1 to entry: Distributed generation in VPPs are usually in the form of renewable energy generation, such as wind power, photovoltaic generation.

[SOURCE: IEC 60050-617:2009, 617-04-09, modified — Addition of a Note 1 to entry.]

3.6
electrical energy storage
EES
installation able to absorb electrical energy, to store it for a certain amount of time and to release electrical energy during which energy conversion processes may be included

Note 1 to entry: The term "electrical energy storage" may also be used to indicate the activity that an apparatus, described in the definition, carries out when performing its own functionality.

Note 2 to entry: The term "electrical energy storage" should not be used to designate a grid-connected installation, "electrical energy storage system" is the appropriate term.

[SOURCE: IEC 62933-1:2018, 3.1, modified — The example was deleted.]

3.7
prosumer
network user that consumes and produces electrical energy

[SOURCE: IEC 60050-617:2017, 617-02-16]

3.8
use case
specification of a set of actions performed by a system, which yields an observable result that is, typically, of value for one or more actors or other stakeholders of the system

[SOURCE: ISO/IEC 19505-2:2012, 16.3.6]

3.9
virtual power plant
VPP
party or system that realizes aggregation, optimization and control of distributed generation, energy storage devices and controllable loads

Note 1 to entry: The aggregated distributed generation, energy storage devices and controllable loads are not necessarily within the same geographical area.

Note 2 to entry: The party or system is to facilitate the activities in power system operations and electricity market.

4 System requirements

4.1 General considerations

VPPs aim to effectively aggregate DG, EESs and CLs as one dispatchable and tradable unit by utilizing technologies in areas such as information, communication and control technologies. VPPs provide capacity and ancillary services to the power system operation and sell energy to electricity markets. VPPs enhance the overall system economics and reliability, promote efficient optimization in resources, and facilitate renewable energy consumption.

The general objective of this document is to collect actual business applications, pilot projects, and academic researches, and develop use cases that capture VPPs basic information, business requirements, actors and roles, scenarios, and processes. VPPs use cases help participants to understand an existing function or process, engineers to develop system and functional requirements, and stakeholders to reach common consensus on best practice processes.

Use cases in this document can also provide guidance to development teams on user's needs related to cyber security and data privacy.

4.2 Basic requirements

4.2.1 General

The system should be capable of aggregating, forecasting, optimizing, coordinating, and controlling distributed generation, energy storage systems, and controllable loads, as one dispatchable unit in power system operations and one tradable unit in electricity markets. Meanwhile, it should be capable of providing ancillary services, such as reserve to guarantee promised delivery, and communicating with the power system operator directly to provide the support in operators' tasks.

4.2.2 Privacy

The system should comply with applicable laws and regulations to ensure the integrity, security and privacy of related data acquired during the VPPs operation process.

4.2.3 Cyber security

VPPs' operation depends on cyber security to a large extent. The system should consider preventive measures to ensure cyber security and minimize risks that could cause network communication breakdowns in system failures.

4.2.4 Adaptability, flexibility and interoperability

The system should be adaptable to various software and hardware conditions, as well as flexible to incorporate customer needs, and interoperable among related equipment to realize coordinated operation.

4.2.5 Communication and information

The system should utilize the information and communication technologies to ensure the secure, reliable and effective communication to satisfy the technical and commercial needs.

4.2.6 Reliability

The reliability and security of the system should be ensured.

4.3 Operational risks of VPPs

4.3.1 General

Potential operational risks caused by the failure of a VPP equipment or system are classified into three levels, depending on the severity of potential damages to grid operations and electricity market.

4.3.2 Major

A failure in a VPP equipment or system is considered as major, if it could result in serious impacts or damages to grid operations and/or the market, including but not limited to:

– blackout;
– complete or large-scale loss of data acquisition and transmission;
– complete or large-scale failure of communication network;
– database crashes;
– application program outage;
– unable to cover the reserves.

4.3.3 Moderate

Abnormal operation of DER dispatch and control could result in moderate impacts or damages to grid operations and/or the market, including but not limited to:

– brownout or frequency drift;
– partial loss of stored data;
– failure of system upgrade;
– abnormal of software and/or hardware operation environment.

4.3.4 Minor

Abnormal operation of DER dispatch and control could result in minor impacts or damages to operations or the market, including but not limited to:

– redistribution of load or short-term unavailability of backup systems;
– terminal data collection deviation;
– failure of database backup;
– failure of data processing and calculation;
– interruption of access to network.

5 Business roles

5.1 VPP participant

A VPP participant can be an aggregator or VPP operator to group distinct agents in a power system (i.e. consumers, producers, prosumers, etc.) to act as a single entity when interacting with various market operator or providing services to system operator.

5.2 DER owner

A DER owner is a party who owns physical assets of the distributed resources to participate in VPP, including DG, EES, CL and electric vehicle (EV) charging station.

5.3 System operator

The system operator is responsible for the safe and reliable operation of a part of the power system in certain area and for connection to other parts of the power system.

5.4 Electricity market operator

The electricity market operator is responsible for operation of the electricity market through managing the selling and buying prices with the objective of maximizing profit while ensuring satisfaction of customers' needs.

6 Actors

An actor can be a person, an equipment, or an organization that plays a role in use cases developed in this document.

Common actors derived from stakeholders are listed as follows.

- VPP service provider
- DG operator
- demand response service operator
- EES operator
- electric vehicle operator
- EV charging station with storage
- system operator
- electricity market operator
- transmission and/or distribution company
- energy service company
- energy information provider
- regulator

7 Application scenarios and functions

7.1 Overview

Primary application scenarios and functions of VPP are categorized into five types:

1) aggregation and optimization;
2) analysis and forecast;
3) energy system management;

4) trading and settlements;
5) communication.

7.2 Functions

– Aggregation and optimization

Aggregation refers to the function that multiple distributed resources, such as DG, electrical energy storage and CLs are grouped together to act as one operating unit that is dispatchable and tradable.

Optimization refers to the function that improves the VPP system's operational and economic performance through maximizing or minimizing certain parameters.

– Analysis and forecast

Analysis refers to the functions conducted via quantitative calculations. The results can be provided to VPP stakeholders for investigation, inspection and survey purposes.

Forecast refers to the function that predicts DG's output, CL's consumption, etc.

– Energy system management

Energy system management refers to the function that VPP decomposes power system's dispatchments and send controls to individual DER based on interaction with power system operator.

– Trading and settlements

Trading refers to the function that realizes VPP buys or sells in electricity market.

Settlements refer to the function that performs financial settlements between VPP and the market, as well as financial settlements between a VPP service provider and an individual VPP component.

– Communication

Communication refers to the function that realizes information transfers and data exchanges (such as dispatch order, schedules, bids and offers, etc.) between VPP and system operator, VPP and electricity market, a VPP service provider and an individual VPP component.

8 VPP use case

8.1 Overview

This clause is to present the use case template and use case matrix applied in the development process of VPP use cases.

8.2 Use case template

The use case template provided in IEC SRD 62913-1 shall be adopted to facilitate the collection of relevant information and ensure the consistency of all use cases.

8.3 Use case matrix

A use case matrix is developed to fully cover the application scenarios, functions, business roles, as illustrated in Figure 1.

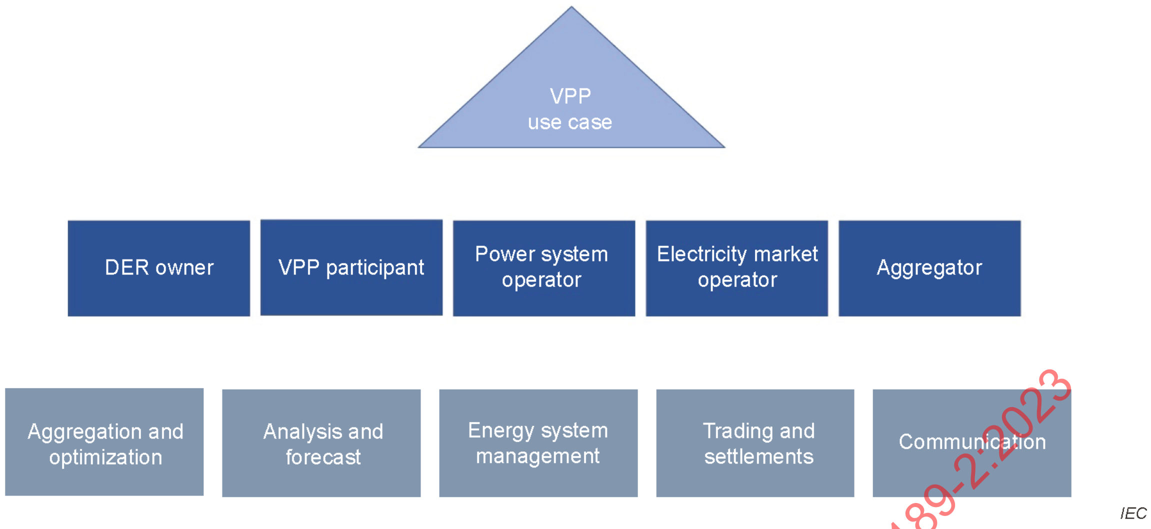


Figure 1 – Use case matrix development methodology

8.4 Use case development

8.4.1 General

VPPs use cases are developed to cover each application scenarios and functions listed in use case matrix defined in 8.3, using the provided use case template required in 8.2.

8.4.2 Description of the use case

8.4.2.1 Use case list

Table 1 lists all use cases described in this document.

Table 1 – Use case list

Use case identification		
ID	**Area/Domain(s)/Zone(s)**	**Name of use case**
BUC-1	Area: Energy systems Domains: VPP, DER Zone: Energy market, operation	Virtual power plant operation in peak shaving and regulation energy market in China
BUC-2	Area: Energy systems Domains: VPP, DER, customers Zone: Frequency control market, operation	Virtual power plant operation in providing frequency control ancillary services in China
BUC-3	Area: Energy systems Domains: VPP, DER, Customers Zones: Energy services, business operation	Virtual power plant operation in providing comprehensive energy services in China
BUC-4	Area: Energy systems Domains: VPP, DER Zone: Energy market, operation	Virtual power plant operation platform and its practice in Japan
BUC-5	Area: Energy systems Domains: DER, VPP Zones: Energy market, frequency control market, operation	Virtual power plant demonstrations in the Australian National Electricity Market (NEM)
BUC-6	VPP, DER	Generic commercial use case of virtual power plants in Australia
BUC-7	Area: Energy systems, Domains: DER, VPP Zones: Energy market, frequency control market, operation	Virtual power plant for Power Supply Co., Ltd. in Germany

Use case identification		
ID	**Area/Domain(s)/Zone(s)**	**Name of use case**
SUC-1-a	VPP, DER	Normal mode of participating in power system operation
SUC-1-b	VPP, DER	Emergency mode of alleviating power system contingencies
SUC-1-c	VPP, DER	Participating in peak shaving and regulation energy market
SUC-1-d	VPP, DER	Local energy management and coordinated control of distributed energy resources
SUC-2-a	VPP, DER	Virtual power plant participating in primary frequency control
SUC-2-b	VPP, DER	Virtual power plant participating in secondary frequency control
SUC-7-a	VPP, DER	Virtual power plant participating in system frequency control
SUC-7-b	VPP, DER	Virtual power plant participating in voltage optimization

8.4.2.2 Scope and objectives of use case

Table 2 lists scope and objectives of all use cases in this document.

Table 2 – Scope and objectives of use case

Scope and objectives of use case	
Scope	BUC-1, SUC-1-a, SUC-1-b, SUC-1-c & SUC-1-d: These use cases are applicable to the VPPs that integrate industrial and commercial facilities, electric vehicles and charging stations, smart homes and buildings, electric heating devices, air conditioning and cooling systems, distributed photovoltaic systems, etc. These VPPs participate in the normal/emergent modes of power system operation and valley filling energy market via local energy management. BUC-2, SUC-2-a & SUC-2-b: These use cases describe the VPPs providing primary frequency control services and participating in secondary frequency control ancillary service market. BUC-3: This use case describes VPPs providing comprehensive energy services for DER, including energy utilization optimizations, economic analysis to increase incomes, and comprehensive analysis to maximum social benefits. BUC-4: This use case describes VPPs that consist of DG, CL and EES, which are integrated to the VPP operation platform. BUC-5: To explore the capabilities of aggregated DER/VPPs to deliver frequency control following contingencies (in the NEM frequency control ancillary service market), and better understand how VPPs respond to market price signals. BUC-6: This use case describes business/commercial, low voltage, "behind the meter" VPPs in Australia as of 2020, consisting of distributed solar PV generation and EES. BUC-7, SUC-7-a & SUC-7-b: To explore the capabilities of aggregated DER/VPPs to increase the grid stability.
Objective	BUC-1: This VPP pilot project has a total capacity of 357,6 MW including both 256,7 MW CL, 106 kW DG and 800 kW EES, where CL includes 73,2 MW industrial and commercial loads, 259,7 MW electric heating devices, and 23,8 MW other types of CL. The project covers multiple regions in Jibei power system including Zhangjiakou, Langfang and Qinhuangdao cities. The objectives of the use case mainly include: – to investigate and develop key technologies of VPPs This use case is supposed to take on new roles as market intermediaries between power system operators and local DER. This use case aims to investigate and develop the key technologies of VPPs including operation framework, communication architecture, market mechanism, etc. – to provide regulation services for power system operation This use case aims to provide regulation services for power system during peak/valley periods of load profiles. With the dispatchable resources provided by VPPs, thermal power plants can reduce the needs for peak shaving and thus save operational costs. Local DER can be utilized to balance renewable generation and load. In addition, this VPP project in China is able to provide 154-MW capacity for regulation. – to test and verify the emerging technologies applied in energy industries This use case provides an opportunity to apply emerging technologies, such as 5G, Artificial Intelligence, Internet of Things, etc. These technologies can be verified and used to accelerate the innovations in energy industries and support the development of business models and economies of VPPs. – to provide policy suggestions for the development of VPPs This use case aims to provide operation and regulatory approaches/policy suggestions for the development of VPPs. It can also promote the transition of China's regulated electric power industry toward the deregulated electricity market.

	– to support 100 % Green Winter Olympics in 2022 This use case will help to fulfil the promise on "100 % Green Olympic" made for 2022 Beijing Winter Olympics. By integrating and controlling DGs, EESs and controllable loads in Olympic zones, the VPP pilot project can dynamically balance renewable generation and load in Olympic stadium through day-ahead and real-time energy markets. – to accelerate energy transition toward a clean and sustainable system This use case is developed to verify the operation architecture, technology, and mechanism of VPPs. The VPP pilot project can reduce renewable energy curtailment and operation costs for generators, explore the regulation capability and the cost savings on electricity bills for customers, and defer the investment in utility infrastructures. This use case provides an effective solution to accelerate a clean and sustainable energy transition. BUC-2: This use case includes two types of VPPs. The first type is VPPs that are mainly composed of DG, EES, etc. This type of VPPs has the capability and task to provide primary frequency control service. Therefore, they should meet the requirements of grid code and provide primary frequency control capability. Besides, this type of VPPs can participate in the secondary frequency control ancillary service market. The second type is VPPs that only participate in the second frequency control. The objectives of the VPP project mainly include the following aspects: – VPPs mainly composed of DGs provide primary frequency control service. – VPPs participate in secondary frequency control ancillary service market. BUC-3: The objectives of the VPPs providing comprehensive energy services mainly include: – the operational process of VPPs that provide comprehensive energy services for DER VPPs collect, and analyse real-time and historical energy utilization data of DER. VPPs provide diversified and targeted comprehensive energy services for DER. – the business mechanisms for three types of energy services including energy utilization optimization, increasing revenue of DER, and maximizing social benefits of DER BUC-4: The objectives and importance of VPP use cases in Japan are as follows: – enhance economic efficiency of power system By using VPPs to decrease the peak demand, it can reduce maintenance costs and capital investment for power generation equipment, also to suppress the increase in output of thermal power plants with high fuel costs. These measures can reduce power generation costs, leading to more economical use of energy. – higher penetration of renewable energy With the penetration of renewable generation such as solar and wind generation increasing, the amount of generated power may exceed demand during the day. In such cases, it is necessary to maintain the balance between supply and demand by suppressing renewable energy. But if VPPs can control energy resources such as EES to increase the demand, it is possible to effectively use the generated power. These measures will contribute to the introduction of more renewable energy. – reduction of power system stabilization cost Conventionally, power generation for peak demand such as thermal power and pumped-storage hydro power have been utilized in order to supply electricity stably. Since VPPs use the DER on the demand side for purposes different from the original one, it is expected to reduce the capital cost and stabilize the power system at lower cost.

	BUC-5: The objectives of the demonstration are intended to allow the system operator to explore: – the operational capability for market participation This relates to the VPPs' reliability to deliver contingency frequency control ancillary services (FCAS). In the Australian National Electricity Market Contingency FCAS is facilitated through a market that is co-optimised with the energy market. The purpose of the contingency FCAS market is to assist in correcting supply unbalances following a major contingency event, such as a loss of a generating unit/major load or large transmission element. The contingency FCAS market consists of several markets, relating to response timeframes to the frequency event (e.g. 6 seconds, 60 seconds, 5 minutes). The VPP demonstrations explore the capability of VPPs to deliver contingency FCAS, such as whether they can deliver the frequency response they are enabled for and what may be a typical extra fleet capacity VPP operators dispatch over and above their enabled contribution to reliably meet that target. – gain operational visibility of aggregated DER To understand VPPs' impact on power system security, local power quality, and how they interact with the market. A series of application programming interfaces (APIs) are established for participants to submit operational forecasts and actual performance data, this is necessary because the VPP demonstration participants operate un-scheduled in the energy market. – operational and policy ongoing arrangements In addition, the demonstrations will assist determining appropriate operational and regulatory arrangements for DER to participate in FCAS and energy markets on an ongoing basis (following the demonstrations). This will be done by assessing the suitability of a new approach for FCAS DER specifications and will inform required changes to regulatory frameworks and operational process to ensure VPPs are better integrated in the NEM electricity markets. – market dynamics and planning This aspect explores the extent that VPPs' response to energy market price signals. If this can be extrapolated to very large VPPs, what impacts could this have on energy markets and how much reliance should be placed on VPPs responding to energy market signals for planning studies. BUC-6: The first objective of Australian VPPs is to demonstrate the role of virtual power plants in enabling higher penetrations of distributed renewable generation in the grid, and help further understanding of the role of distributed "smart" storage in supporting grid resilience and reliability. The second objective is to address growing "prosumer" interest and demand for greater control over their electricity bills as well as to achieve greater energy independence against a backdrop of high retail energy costs. Thirdly, the VPP would also enable VPP retailers/aggregators to derive additional value streams during specific network and wholesale market events, through coordinated/orchestrated VPP dispatch. Collectively, the 2nd and 3rd objectives can ultimately reduce the cost of the system to the end customer, while reducing the energy costs going forward. Lastly, this document is a contribution to the IEC use case management repository, the purpose of which is to collect, administer, maintain, and analyse use cases.

	BUC-7: The objectives of the VPP are intended to allow DER to response to – demand-response signals based on the current availability/flexibility of each asset – cold load pickup support based on the current availability/flexibility of each asset – system frequency control signals based on the predefined reserve band – voltage optimization signals to improve the reliability and power quality of distribution network operation
Related business case(s)	– energy management system use case – microgrid use case – TBC

8.4.2.3 Narrative of use case

Table 3 lists narrative of all use cases in this document.

Table 3 – Narrative of use case

Narrative of use case
Short description
BUC-1, SUC-1-a, SUC-1-b, SUC-1-c and SUC-1-d: These use cases are developed from the VPP project in China which has been put into operation since December 2019. Involved activities include: • participating in power system operation in normal or emergency mode • participating in electricity market enabling purchases, through bids to buy, and sales, through offers to sell • providing peak shaving and regulation services and participating in energy market • local energy management and coordinated control of DER BUC-2, SUC-2-a and SUC-2-b: These use cases describe application scenarios which include: • providing primary frequency capability and making the VPPs meet the requirements of grid code • participating in frequency control ancillary service market BUC-3: This use case describes application scenarios where VPP provides comprehensive energy services including energy utilization optimization, increasing revenue of DER, and maximizing social benefits. BUC-4: This use case describes application scenarios in which VPPs can achieve commercial goals of both residential customers as well as the VPP retailers/aggregators while supporting power system reliability and security.

Narrative of use case

BUC-5: This use case is opened for a period of at least 12 months from July 2019 (with a possible extension). This involved:

- enrol in the VPP demonstration as a trial participant.
- enrol/register their VPP demonstration in the contingency frequency control ancillary services markets
- participate in contingency frequency control market and responding to energy price signals as non-scheduled resources
- analyze response to frequency deviations in accordance with bids/enablement in the frequency control markets
- analyze response to energy market price signals as non-scheduled resources

BUC-6: This use case describes application scenarios in which VPPs can achieve commercial goals of both residential customers as well as the VPP retailers/aggregators while supporting power system reliability and security.

BUC-7, SUC-7-a & SUC-7-b: These use cases involve:

- participate in electricity market, including peak shaving service, valley filling service, etc.
- participate in system frequency regulation
- participate in voltage optimization

Complete description

BUC-1, SUC-1-a, SUC-1-b, SUC-1-c and SUC-1-d: These use cases are developed from the VPP pilot project in State Grid Jibei in China. The first phase of the VPP pilot project has a total capacity of 160 MW with 11 kinds of DER integrated. The VPP aggregates 80-MW DER to participate in the valley filling energy market in North China. From the perspective of operational performance, the VPP can actively respond to real-time dispatch orders sent by power system. The VPP can effectively reduce peak load and shift load at night hours when reserve capacity is insufficient. The VPP pilot project demonstrates that the revenue is increased and the wind power curtailment rate is reduced.

BUC-2, SUC-2-a and SUC-2-b: These use cases are developed from the VPP pilot project in China, including DG, EESs and CLs.

- providing primary frequency control capability, which helps to meet the requirements of integration and reduce the frequency deviation of the whole system
- participating in the secondary frequency control market, which can help to maintain the frequency balance of the power system

BUC-3: The business use case covers VPPs providing comprehensive energy services for DER. There are three types of comprehensive energy services involving energy utilization optimization, increasing revenue of DER, and maximizing social benefits. Two scenarios of enrolment in VPPs, and providing comprehensive energy services for DER are included.

BUC-4: Due to the tight supply-demand balance of electricity caused by the Great East Japan Earthquake in 2011, it was strongly recognized that it is important not only to promote the conventional energy saving but also to perform energy management. In addition, after the earthquake, the introduction of renewable energy such as solar power and wind power generation has greatly expanded.

On the other hands, the introduction of distributed energy resources on the consumer side such as cogeneration systems consisting of residential PV panels and fuel cells, storage batteries, electric vehicles have been promoted.

From this background, the traditional power supply system relying on centralized large-scale power plants has begun to be reconsidered, and a mechanism to utilize energy resources on the consumer side for the power system is being developed.

Narrative of use case
Each distributed energy resource introduced in factories and households is small in scale and has only a limited impact on the power system. But with advanced energy management technology utilizing Internet of Things, if these are aggregated and remotely controlled as a VPP system, it can be contributed to realize stable and flexible power systems. Therefore, VPP is expected to play an important role in power systems as functions including peak shaving, avoidances of the renewable energy curtailment, supply in case of power shortage, etc. BUC-5 & BUC-6: The business case covers VPP demonstrations that include aggregated portfolios of controllable assets at various points on the network (for assets <5 MW at each individual connection point), to deliver frequency response and/or respond to energy market signals. For VPPs that will participate in frequency control trials, they can be provided by either proportional/variable or switched style response. The proportional control is proportional to the size of frequency deviation (such as through a droop controller) and switched style involve an on/off switch to the frequency deviation (e.g. switching off a pool pump). Once enrolled to participate in the VPP demonstrations and set up to interact with and be included in appropriate market systems, the VPP will participate in contingency frequency control markets (six in total). The VPP demonstrations exclude grid scale generation and grid scale energy storage. VPPs responding to energy market signals are not scheduled and do not (at this stage) submit bids specifying their generation intentions. However, forecasting data is required so that an understanding can be gained for possible future scheduling and energy market participation. The system operator will observe and monitor the various VPP demonstrations for their responses to frequency deviations (where participating in this area) and responses to the energy market. The demonstrations have been opened for a minimum 12-month period and are used to determine overall efficacy of the VPPs to meet the use case objectives. BUC-7, SUC-7-a & SUC-7-b: The business case covers VPP demonstrations that include aggregated portfolios of controllable assets, like solar, batteries, HVACs and a charging station, at various points on the grid to participate in load pickup support, demand response and/or voltage optimization. Once enrolled to participate in the VPP demonstrations and set up to interact with and be included in appropriate market systems, the VPP will participate in contingency frequency control markets. The VPP demonstrations exclude grid scale generation, grid scale energy storage and controllable loads. The system operator will observe and monitor the various VPP demonstrations for their responses to the system calls.

8.4.2.4 Key performance indicators (KPIs)

Table 4 lists KPIs of all use cases in this document.

Table 4 – Key performance indicators

Key performance indicators			
ID	**Name**	**Description**	**Reference to mentioned use case objectives**
BUC-1-KPI1	Response Availability of VPP	The deviation between the actual provided peak shaving and regulation energy and the dispatched energy of system operators.	Objectives 1, 3 and 4
BUC-1-KPI2	Regulation Capacity	The regulation energy measured in MWh provided by VPP for upstream system operators.	Objectives 2, 4 and 6
BUC-1-KPI3	Response Rate of Peak Shaving	The response rate of the VPP providing peak shaving services for power system.	Objectives 2 and 4
BUC-1-KPI4	Mileage of Peak Shaving	The absolute value of the total peak shaving capacity during a period.	Objectives 2 and 5
BUC-2-KPI1	Response Rate of Frequency Control	Response rate of set point command	Objectives 1 and 2
BUC-2-KPI2	Adjustment Accuracy of Frequency Control	The difference between the actual output and the set point output when the response is stable.	Objectives 1 and 2
BUC-2-KPI3	Response Time of Frequency Control	After the EMS system issues a command, the time it takes for the VPP to step out of the adjustment dead zone consistent with the adjustment direction.	Objectives 1 and 2
BUC-2-KPI4	Available Time of Frequency Control	The percentage of time that the frequency control can be called to the total time	Objectives 1 and 2
BUC-3-KPI1	Energy Efficiency Improvement	The weighted average of energy utilization and comprehensive supply of a DER	Objectives 3
BUC-3-KPI2	Energy-saving Benefits	The benefits of DER when the energy service of energy utilization optimization is provided by VPP operators.	Objectives 3
BUC-3-KPI3	Income Increment	The amount of income increment of DER in the energy service of increasing revenue of DER.	Objectives 3
BUC-4-KPI	VPP Demonstration Projects in Japan	Through demonstration projects from 2016 to 2020, the aim is to establish VPP technology for controlling energy resources, including storage batteries and electric vehicles with a total capacity of 50 MW or more, and to promote the introduction of renewable energy, peak shaving, etc.	

Key performance indicators			
ID	**Name**	**Description**	**Reference to mentioned use case objectives**
BUC-5-KPI1	Frequency Control Delivery	The VPP performance based on aggregated response of VPP devices to deliver contingency frequency control during a frequency disturbance.	
BUC-6-KPI1	Reduction in Consumer Cost of Electricity	Consumer effective/net electricity cost savings through ability to store and self-consume low cost electricity from onsite solar PV generation	Objectives 2
BUC-6-KPI2	VPP Capital Cost Minimisation	Total capital cost of the VPP covered by the consumer	Objectives 2 and 3
BUC-6-KPI3	Supply Reliability	Increased consumer electricity supply reliability, i.e. reduction of instances of unserved energy through the VPP microgrid islanding features	Objectives 1 and 2
BUC-6-KPI4	Provision of Grid Support Services	Services provided by the VPP to support grid reliability and security, in particular system frequency and local voltage support	Objectives 1 and 3
BUC-7-KPI1	Demand Response	The VPP performance based on aggregated response of VPP devices to deliver demand response	
BUC-7-KPI2	System frequency regulation Delivery	The VPP performance based on aggregated response of VPP devices to deliver system frequency regulation	
BUC-7-KPI3	Voltage Optimization	At the level of distribution network, the voltage fluctuation caused by overload of some distribution lines can be solved	

8.4.2.5 Use case conditions

Table 5 lists conditions of all use cases in this document.

Table 5 – Use case conditions

Use case conditions	
Assumptions	
Prerequisites	
BUC-1-P1	DER enrolled in the VPP demonstration and authorize the VPP to be the agent to bid in energy market.
BUC-1-P2	Minimum aggregated capacity 2,5 MW.
BUC-1-P3	Communication mechanism and application interfaces among internal system (VPP platform, DER) and external system (Power System Operator, Electricity Market Operator) are required. The exchanged information includes system/DER operational data, system/DER predicted data, and system or VPP platform needs/request/order etc.
BUC-1-P4	Testing to validate the resource hosting capacity, charging/discharging rate and communication data accuracy to meet the requirements of power system operator.
BUC-2-P1	DER enrol in the VPP demonstration and authorize the VPP to be the agent to bid in secondary frequency control electricity market.
BUC-2-P2	Minimum aggregated capacity 0,5 MW.
BUC-2-P3	Interaction capability and application interface with power system operator and DER owners are required. The interactive information and data include system/DER operational data, system/DER forecast data, and system or VPP platform needs/request/order etc. Terminology: Interface, information change, internal/external system, communication channel
BUC-2-P4	Communications, measurement, smart meter and other intelligent sensing terminals are required, and meet time-sharing measurement requirements of power and energy.
BUC-2-P5	Testing to demonstrate capability, regulation rate and communication data accuracy is required via technical test of power system operators.
BUC-3-P1	Monitoring and recording requirements are met (including installation of relevant equipment) to monitor and record the energy utilization of DER, including 5-minute resolution samples of active power flow for DER and device level telemetry (5-minute resolution, uploaded once per day).
BUC-3-P2	Application interface (API) setup to submit device data and interface with VPP operators, including operational data (aggregated forecast of power).
BUC-3-P3	Communications and telemetry facilities to VPPs.
BUC-3-P4	The DER have enrolled in in the VPPs providing comprehensive energy services for the trial.
BUC-5-P1	A minimum of 1 MW aggregated capacity is required.
BUC-5-P2	Testing to demonstrate capability via a frequency injection test, lab test and VPP wide test.

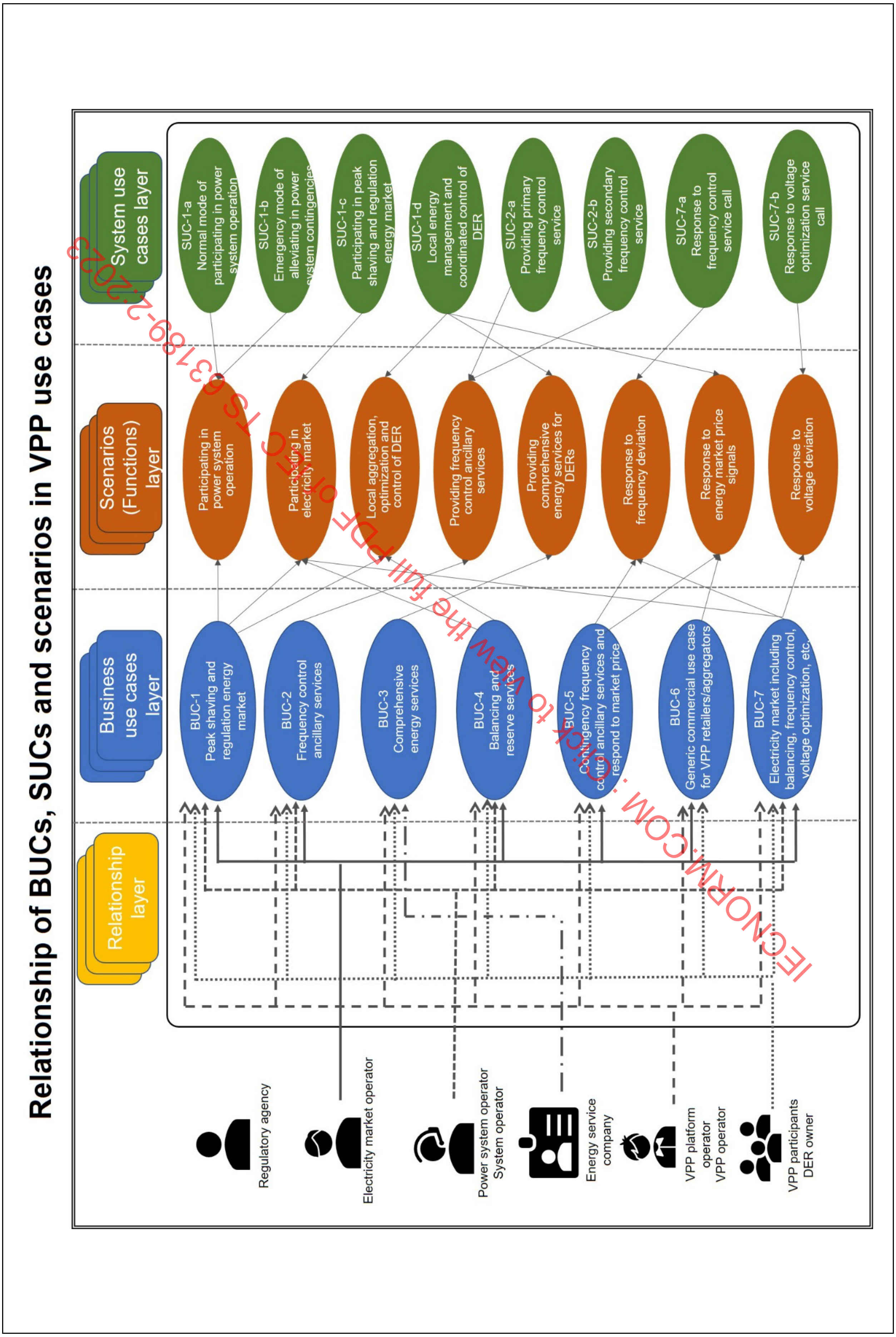
Use case conditions	
BUC-5-P3	Monitoring and recording requirements met (including installation of relevant equipment) to monitor and record the response to changes in frequency of the power system. This includes 1 second resolution samples of active power flow and local frequency for contingency events. Participants also submit operational forecasts, aggregated performance data near real time (5-minute resolution, 5 minutes after the fact) and device level telemetry (5-minute resolution, uploaded once per day).
BUC-5-P4	Application interface (API) setup to submit device data and interface with system operator systems, including operational data (aggregated forecast of active power flows and actual power flows) and frequency assessment data.
BUC-5-P5	Communications and telemetry facilities to system operator systems.
BUC-5-P6	The VPP participant (VPP aggregator/retailer) has enrolled in the VPP demonstration and within the markets for the trial.
BUC-6-P1	Qualifying VPP sites shall be connected to the main electricity network and market
BUC-6-P2	Each VPP site includes on-site solar PV generation of at least 3 kW
BUC-6-P3	Specific inverter solutions shall meet monitoring, communications, and control requirements for coordinated remote control/dispatch/ orchestration
BUC-7-P1	5 MW of aggregate capacity required to be eligible.
BUC-7-P2	Testing to demonstrate capability via a hardware in the loop test.
BUC-7-P3	Monitoring and recording requirements met (including installation of relevant equipment) to monitor and record the response to changes in frequency of the power system. This includes 1 second resolution samples of active power flow and local frequency for contingency events. Participants also submit operational forecasts, aggregated performance data near real time (5-minute resolution, 5 minutes after the fact) and device level telemetry (5-minute resolution, uploaded once per day).
BUC-7-P4	Application interface (API) setup to submit device data and interface with system operator systems. The flexibility of the VPP will be updated to the system operator and service calls will be sent by the system operator in real time.
BUC-7-P5	Communications and telemetry facilities to system operator systems.
BUC-7-P6	The VPP participant (VPP aggregator/retailer) has enrolled in in the VPP Demonstration and within the markets for the trial.
BUC-7-P7	Monitoring and recording requirements met to monitor and record the dispatch order from the system operator and the response of the VPP and also the response of each DER.
SUC-7-P8	VPP estimates the capacity of the VPP to increase or decrease the MW and send to the system operator for reference.
SUC-7-P9	Communication between VPP and the DER was tested based on standardized communication protocols.

8.4.3 Diagrams of use case

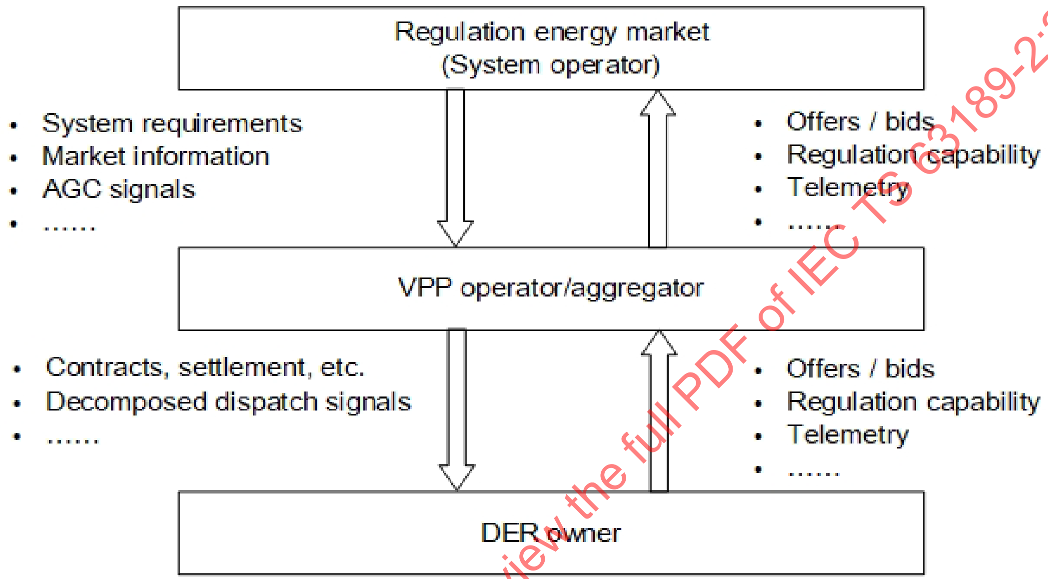
Table 6 lists diagrams of the relationship of BUCs, SUCs and scenarios in VPPs use cases, and SUCs.

Table 6 – Diagrams of use case

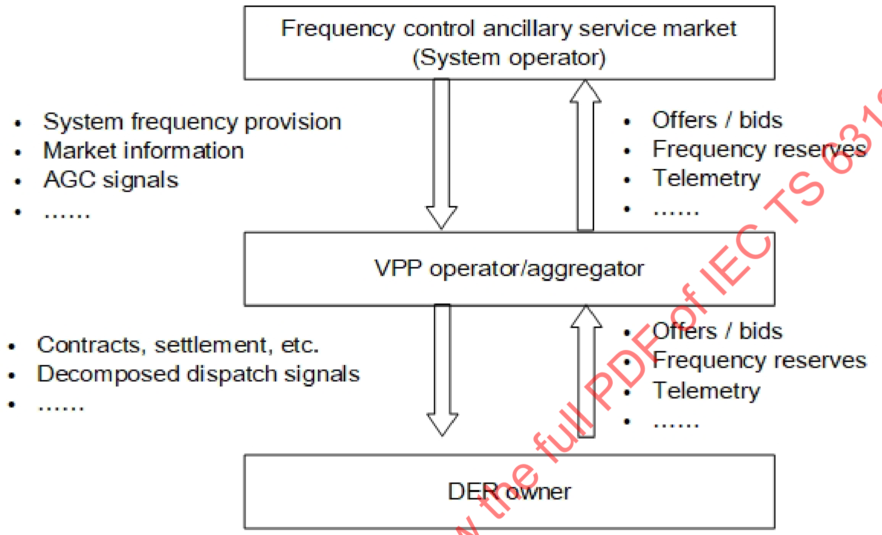
Diagram(s) of use case	
No.	**Flowchart name**
UC-1	Relationship of BUCs, SUCs and scenarios in VPP use cases


Relationship of BUCs, SUCs and scenarios in VPP use cases
Relationship layer
Business use cases layer
Scenarios (Functions) layer
System use cases layer
Regulatory agency
Electricity market operator
Power system operator
System operator
Energy service company
VPP platform operator
VPP operator
VPP participants
DER owner
BUC-1 Peak shaving and regulation energy market
BUC-2 Frequency control ancillary services
BUC-3 Comprehensive energy services
BUC-4 Balancing and reserve services
BUC-5 Contingency frequency control ancillary services and respond to market price
BUC-6 Generic commercial use case for VPP retailers/aggregators
BUC-7 Electricity market including balancing, frequency control, voltage optimization, etc.
Participating in power system operation
Participating in electricity market
Local aggregation, optimization and control of DER
Providing frequency control ancillary services
Providing comprehensive energy services for DERs
Response to frequency deviation
Response to energy market price signals
Response to voltage deviation
SUC-1-a Normal mode of participating in power system operation
SUC-1-b Emergency mode of alleviating in power system contingencies
SUC-1-c Participating in peak shaving and regulation energy market
SUC-1-d Local energy management and coordinated control of DER
SUC-2-a Providing primary frequency control service
SUC-2-b Providing secondary frequency control service
SUC-7-a Response to frequency control service call
SUC-7-b Response to voltage optimization service call

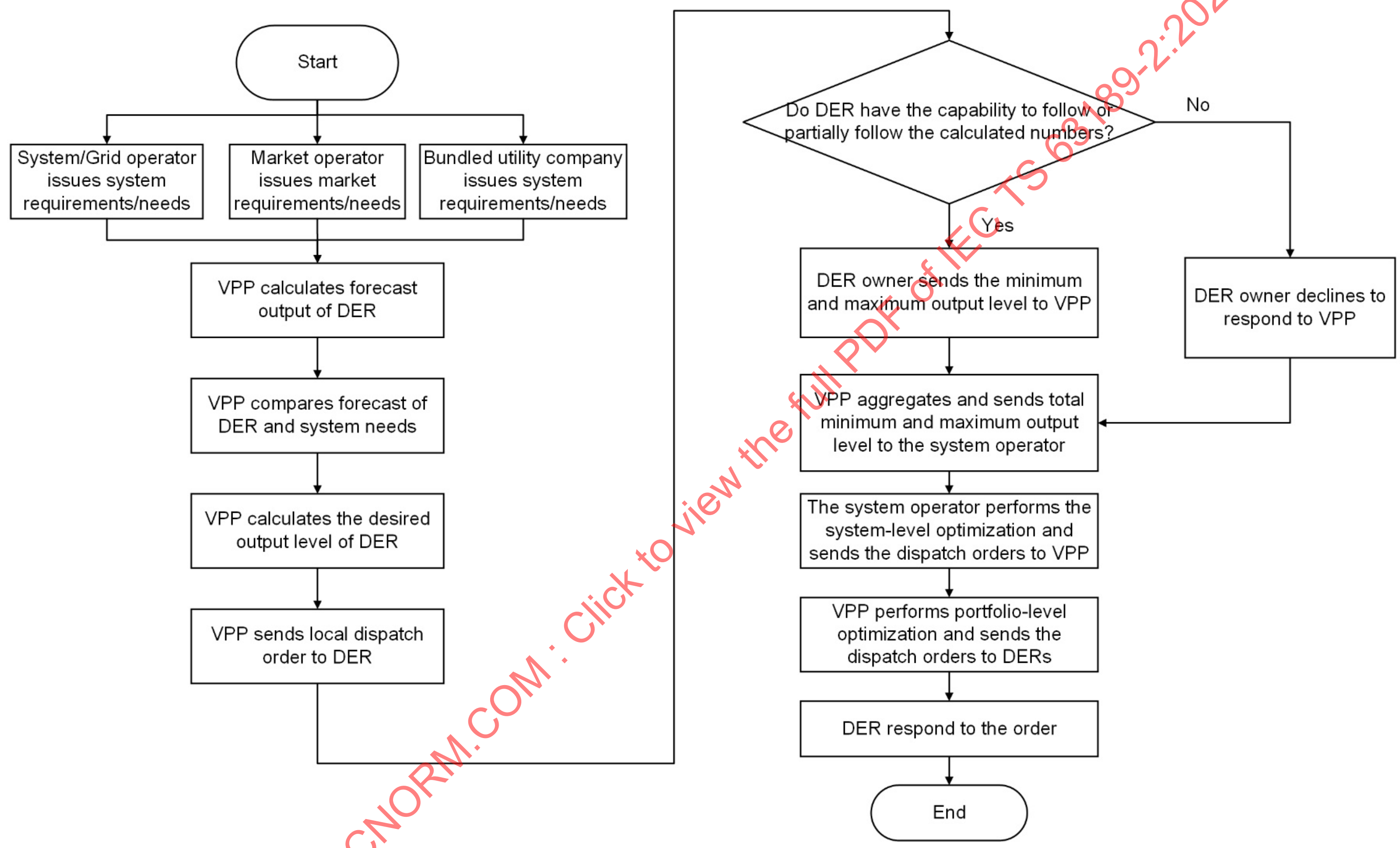
Diagram(s) of use case	
No.	**Flowchart name**
BUC-1-F1	Participating in regulation energy market



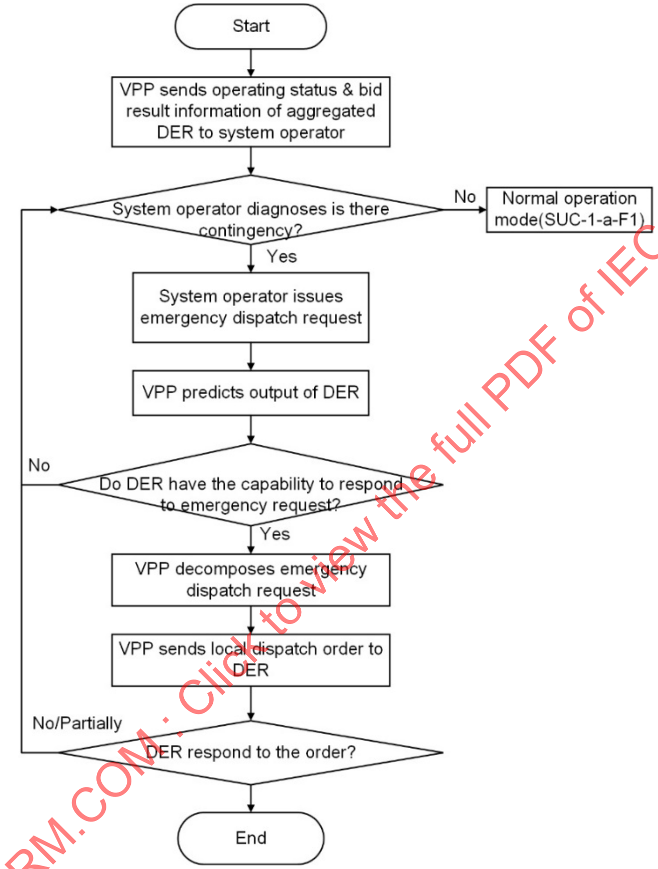
Diagram(s) of use case	
No.	**Flowchart name**
BUC-2-F1	Providing frequency control services



Diagram(s) of use case	
No.	**Flowchart name**
SUC-1-a-F1	Normal mode of participating in power system operation

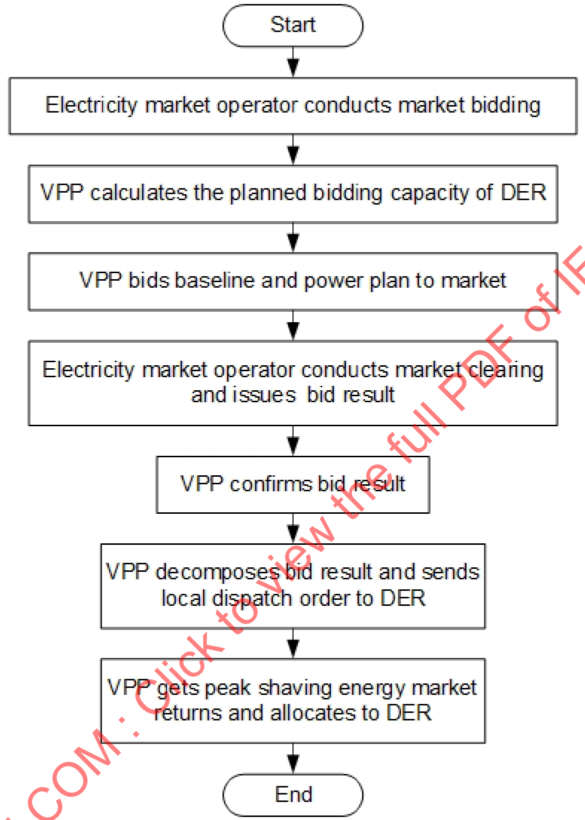


Diagram(s) of use case	
No.	**Flowchart name**
SUC-1-b-F1	Emergency mode of alleviating power system contingencies

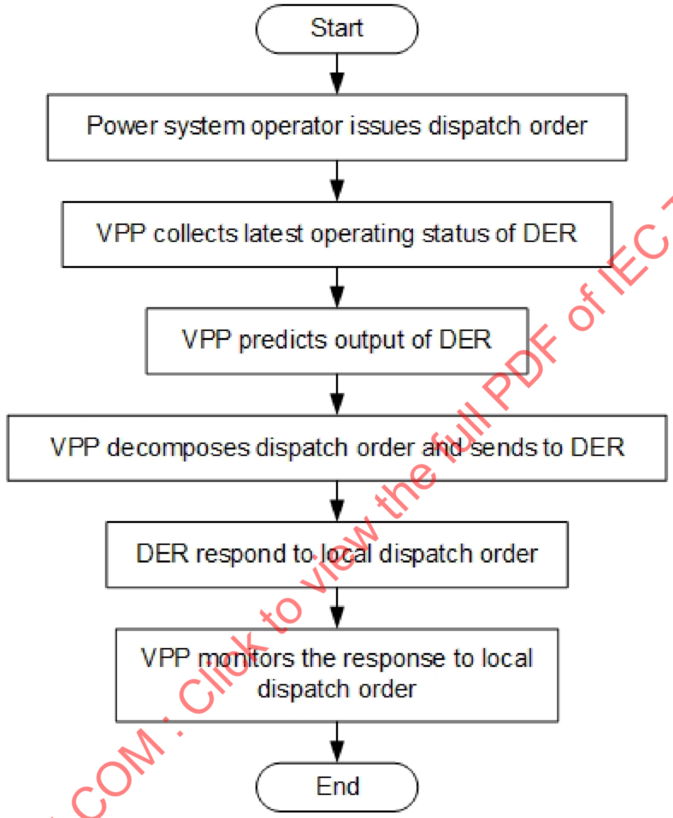


NOTE The SUC applied for VPP in bundled transmission and distribution power system operations. It also applied for VPP in unbundled power system, seeing details in German Redispatch 2.0.

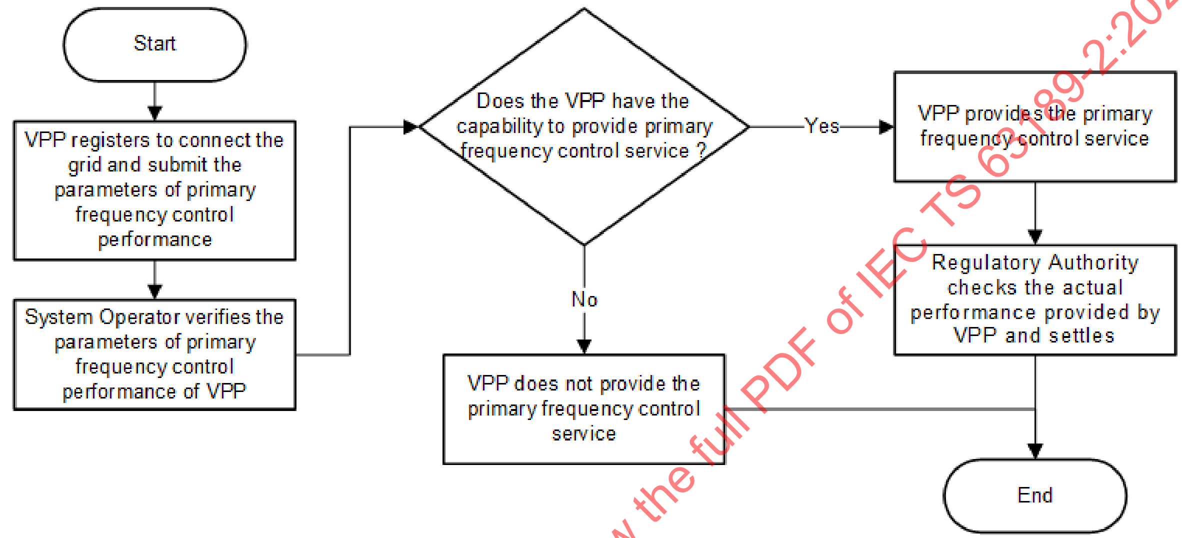
Diagram(s) of use case	
No.	**Flowchart name**
SUC-1-c-F1	Participating in valley filling energy market



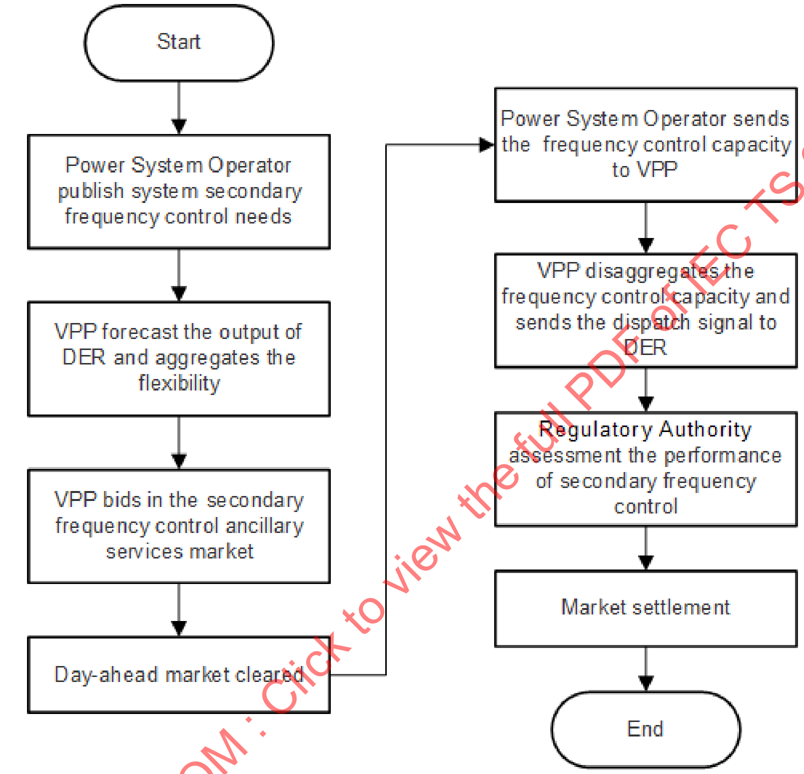
Diagram(s) of use case	
No.	**Flowchart name**
SUC-1-d-F1	Local energy management and coordinated control of distributed energy resources



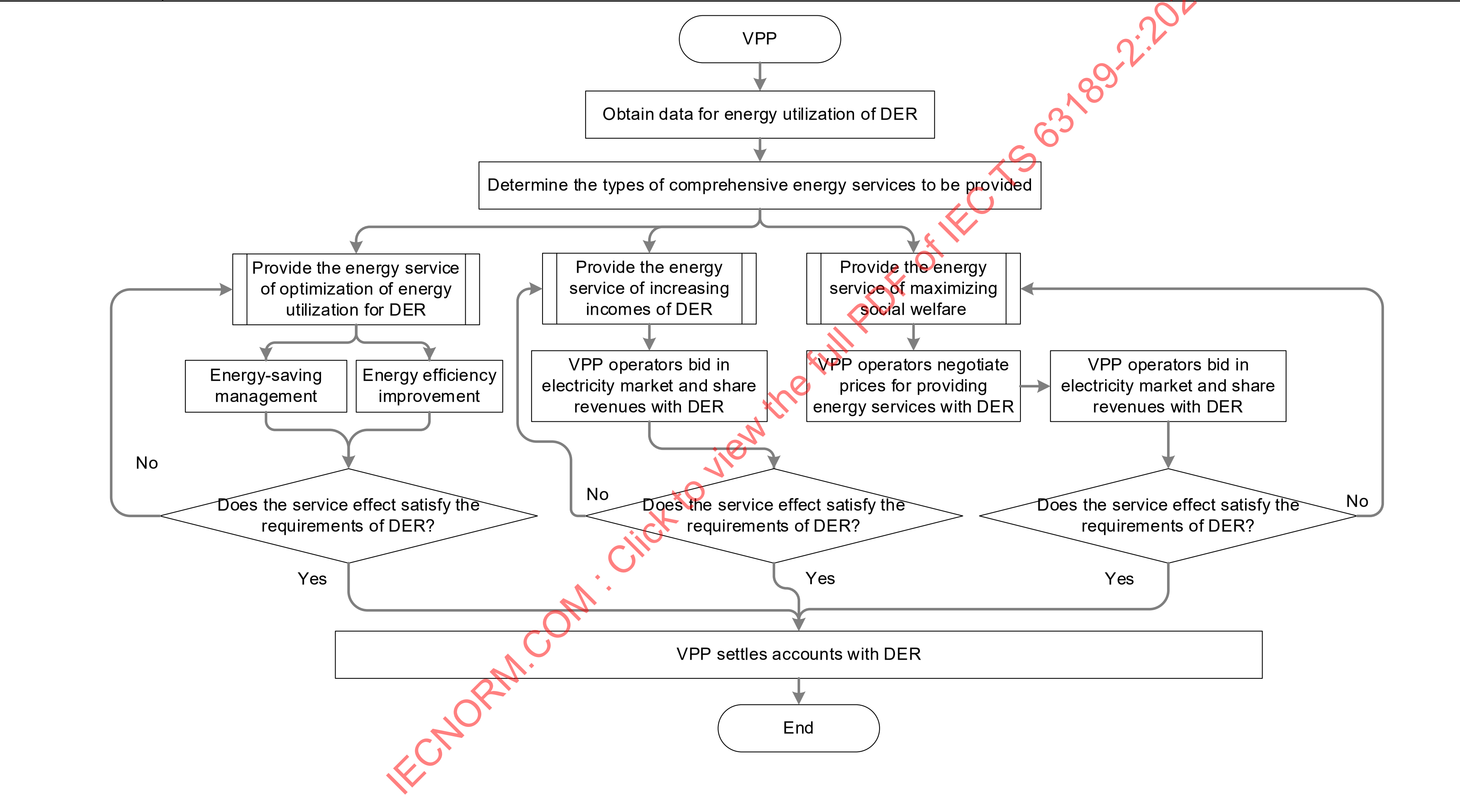
Diagram(s) of use case	
No.	**Flowchart name**
SUC-2-a-F1	Providing the primary frequency control service



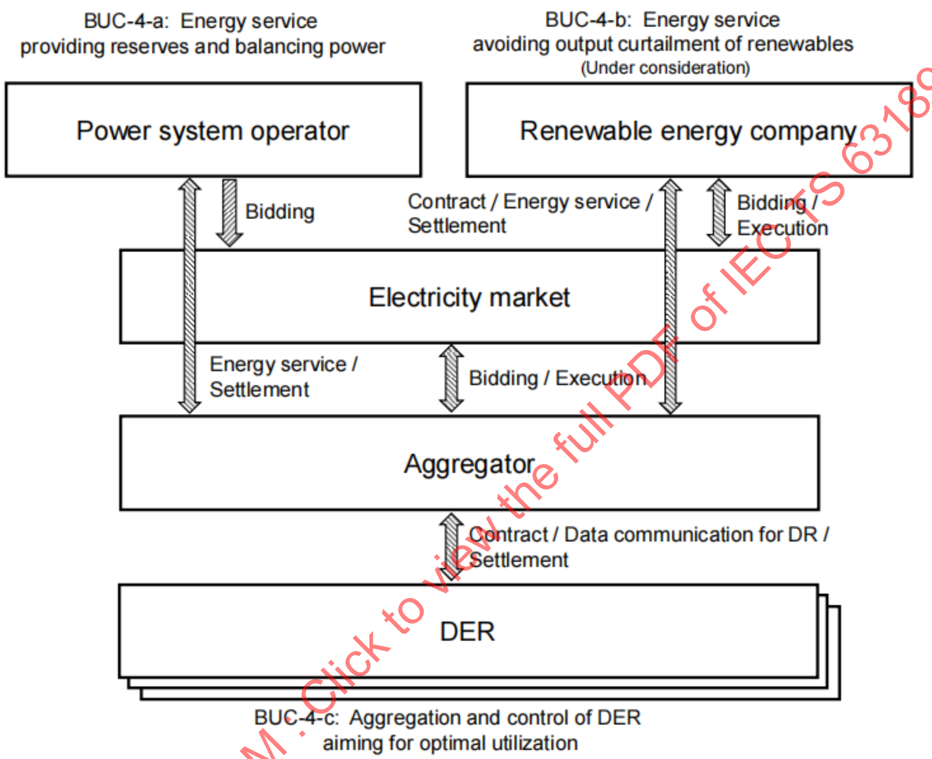
Diagram(s) of use case	
No.	**Flowchart name**
SUC-2-b-F1	Participating in the secondary frequency control ancillary service market



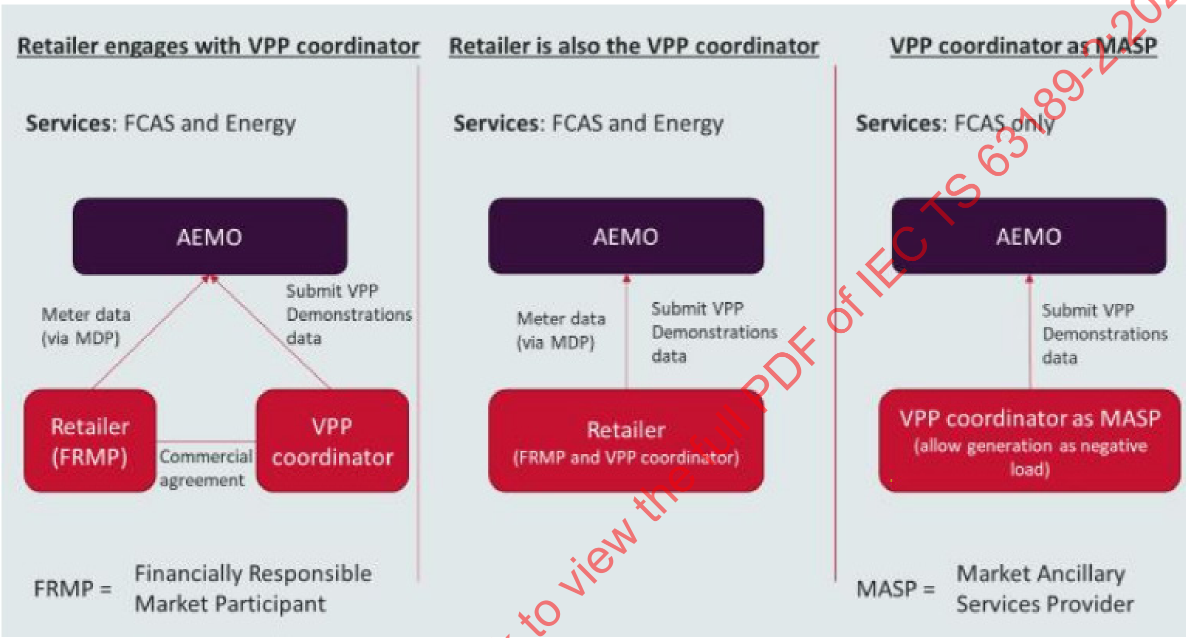
Diagram(s) of use case	
No.	**Flowchart name**
BUC-3-F1	Providing comprehensive energy services



Diagram(s) of use case	
No.	**Flowchart name**
BUC-4-F1	Virtual power plant operation platform and its practice in Japan

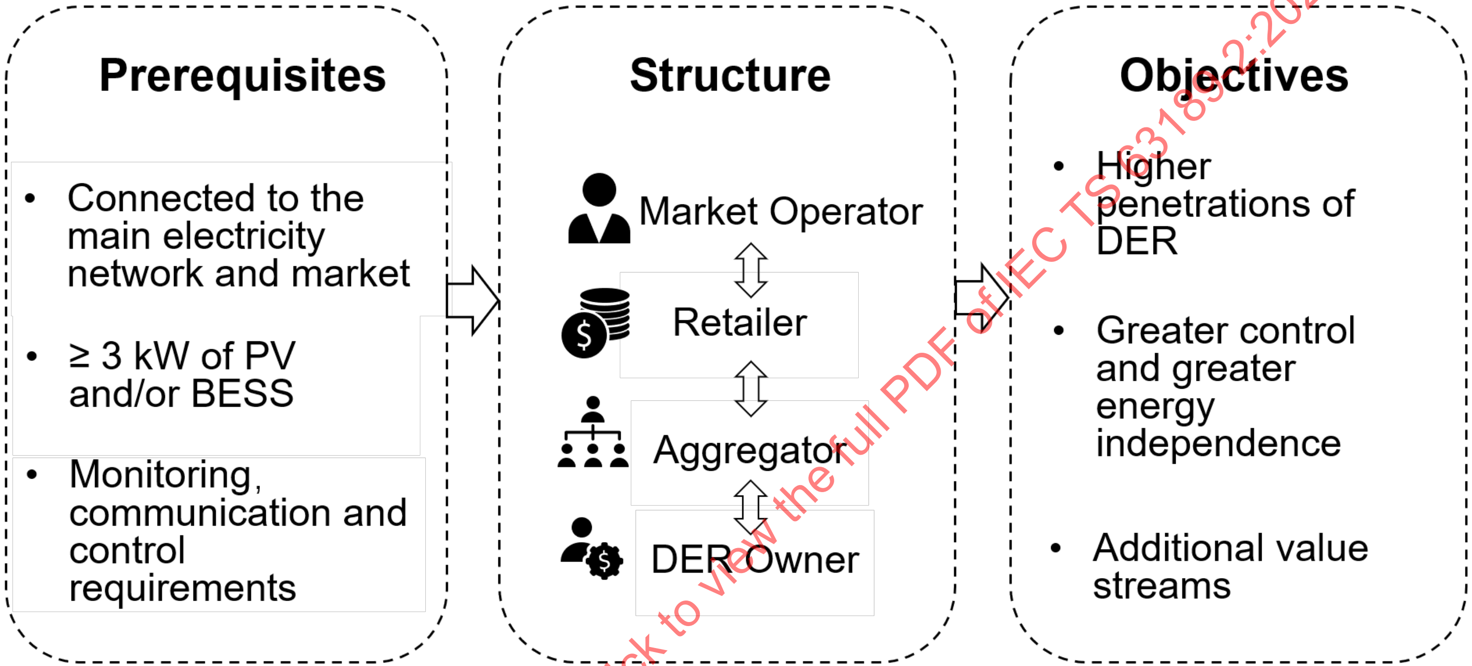


Diagram(s) of use case	
No.	**Flowchart name**
BUC-5-F1	Three models for participation in the NEM VPP demonstration

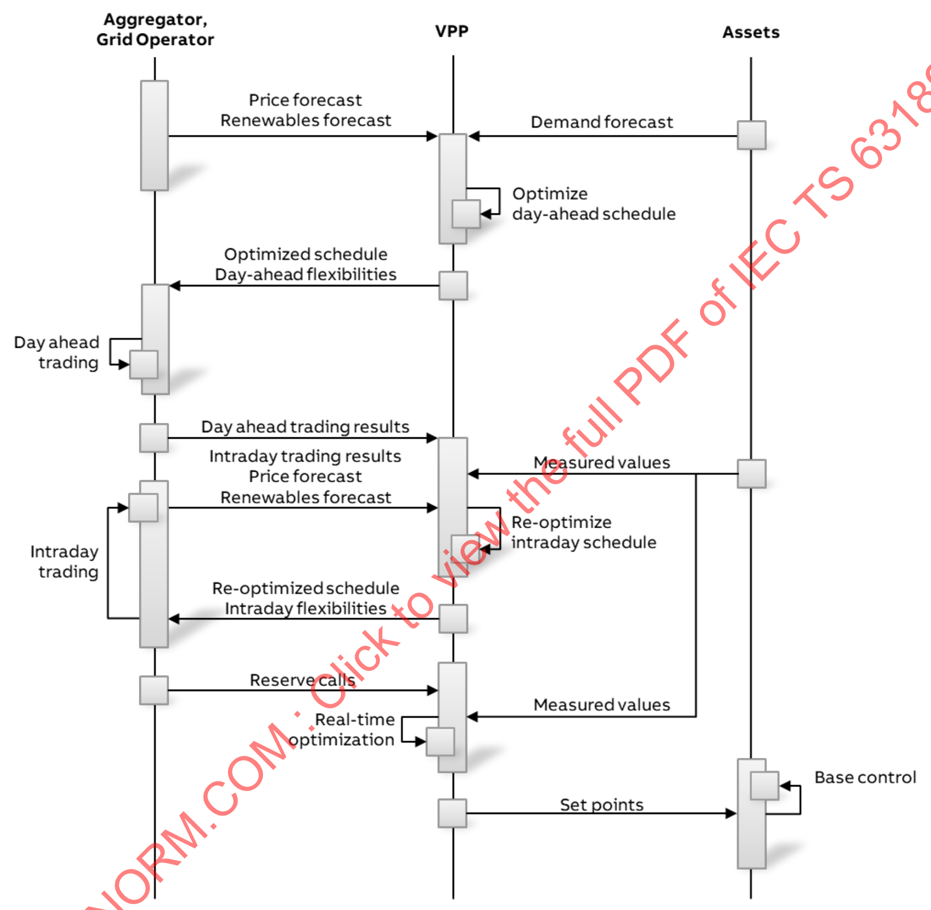


Source: https://aemo.com.au/-/media/files/electricity/der/2021/nem-vpp-demonstrations_final-design.pdf?la=en [viewed 2023-10-09]

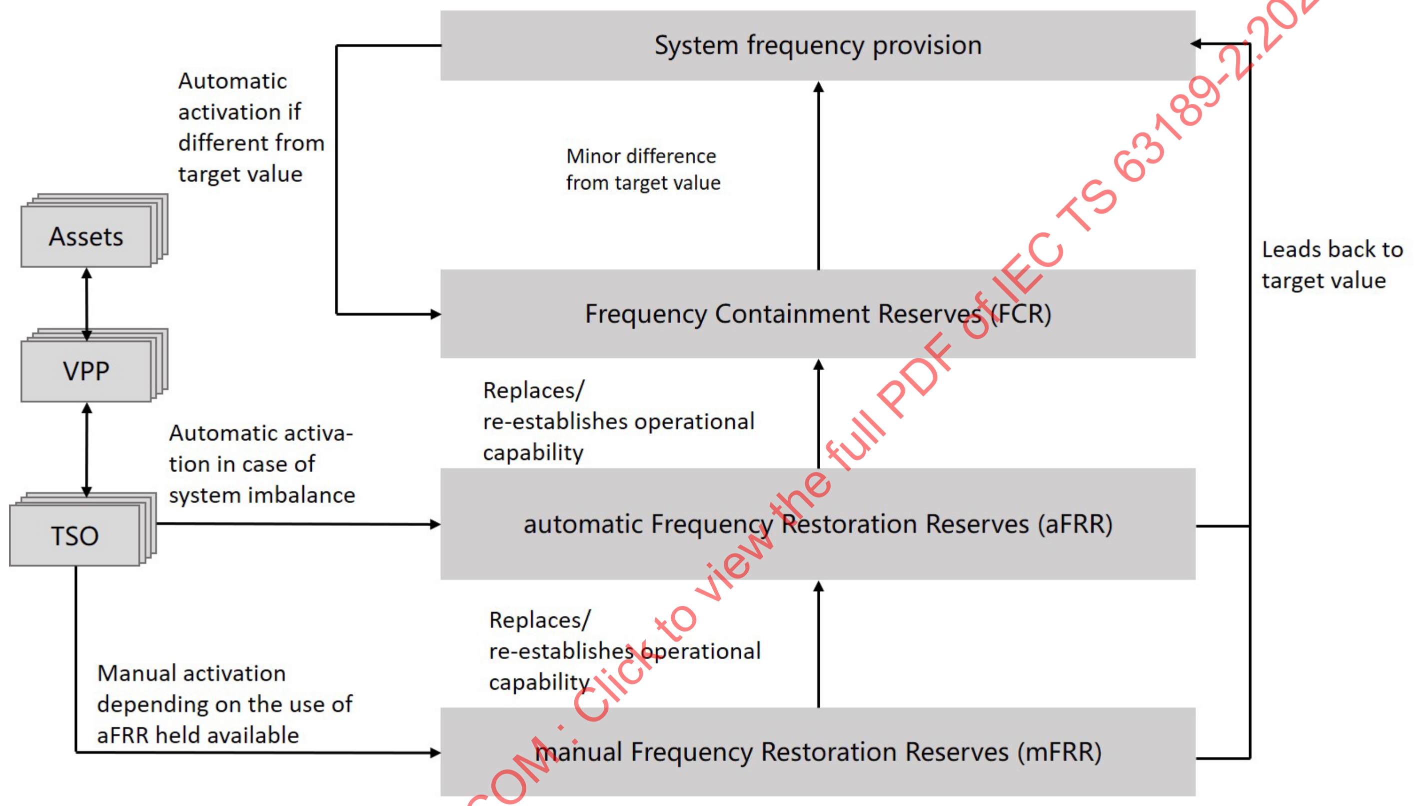
Diagram(s) of use case	
No.	**Flowchart name**
BUC-6-F1	Generic commercial use case of virtual power plants



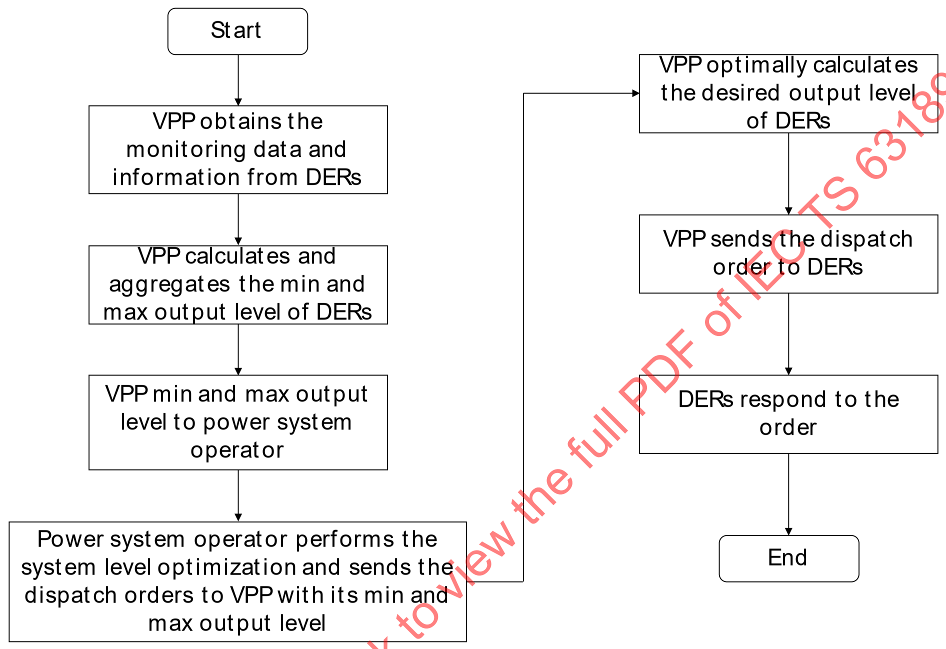
Diagram(s) of use case	
No.	**Flowchart name**
BUC-7-F1	Participating in the electricity market



Diagram(s) of use case	
No.	**Flowchart name**
SUC-7-a-F1	Participating in system frequency control



Diagram(s) of use case	
No.	**Flowchart name**
SUC-7-b-F1	Participating in voltage optimization in Shenzhen



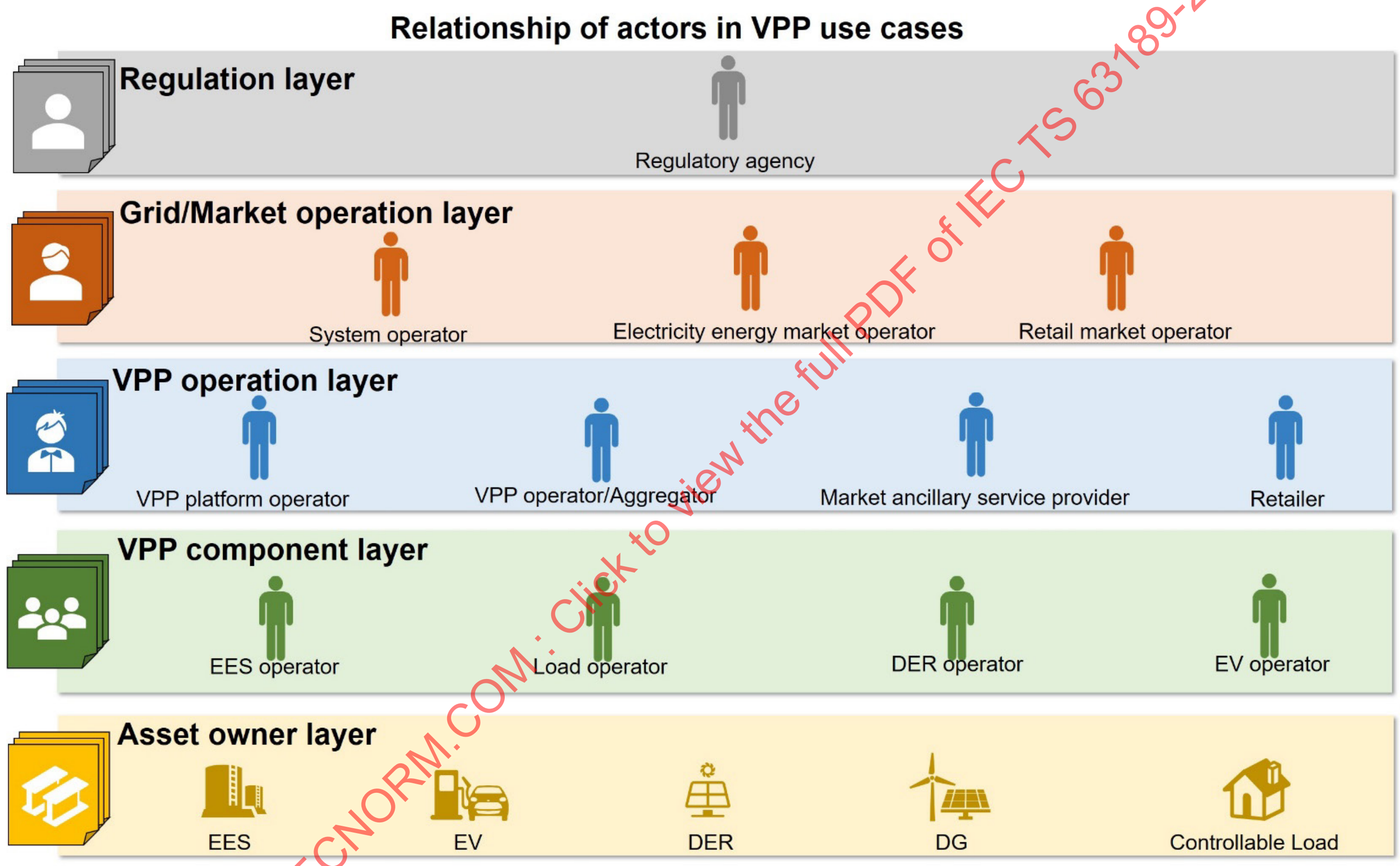
8.4.4 Technical details

8.4.4.1 Diagram(s) of actors

Table 7 lists diagram of actors in this document.

Table 7 – Diagram(s) of actors

Diagram(s) of actors	
No.	**Flowchart name**
Actor-F1	Relationship of actors in VPP use cases



8.4.4.2 Grouping of China

Table 8 lists actors grouping in VPPs of China in this document.

Table 8 – Grouping of China

Grouping		Group description	
VPP platform operator and stakeholders in China		This group includes operators and stakeholders related to the VPP platform in China.	
Actor name	**Actor type**	**Actor description**	**Further information specific to this use case**
DER Owner	Asset Owner	The DER owners manage the distributed energy resources to participate in VPP, including DG Operator, DR Service Operator, EES Operator and EV Charging Station Owner.	/
VPP Operator	Service provider	The VPP Operator is to group separate agents in a power system (i.e. consumers, producers, prosumers, etc.) to act as a single unit when interacting with electricity market operator or selling services to power system operator.	/
VPP Platform Operator	Service provider	The VPP platform operator is responsible to effectively aggregate, optimize, coordinate, and control VPPs and DER to provide services to the power system and electricity market.	/
Power System Operator	Operator	The power system operator is to effectively manage VPPs to provide ancillary services and capacity to the system.	/
Electricity Market Operator	Operator	The electricity market operator is to maximize social benefits as well as to increase market liquidity and transparency, including registration, transaction, settlement, etc.	/
Regulatory Authority	Government	The regulatory authority is responsible for market regulation.	/

8.4.4.3 Grouping of Japan

Table 9 lists actors grouping in VPPs of Japan in this document.

Table 9 – Grouping of Japan

Grouping		Group description	
VPP platform operator and stakeholders in Japan		This group includes operators and stakeholders related to the VPP platform in Japan	
Actor name	**Actor type**	**Actor description**	**Further information specific to this use case**
DER owner	Asset owner	The DER owners manage distributed energy resources such as electric vehicles, storage batteries, distributed generators and controllable loads and contracts with aggregators to participate in VPP.	/
Aggregator	Service supplier	The aggregators remotely monitor and control distributed energy resources. For example, electric vehicles, storage batteries, distributed generators and controllable loads on the consumer side can be controlled by advanced energy management technology utilizing Internet of Things. They work with power system operators, DER owners, etc. to provide VPP services.	/
Power system operator	Operator	The power system operators deliver electricity to consumers through transmission and distribution lines with balancing demand and supply. They manage VPPs effectively to provide VPP services to the system.	/
Renewable energy company	Electricity supplier	The renewable energy companies use renewable energy such as PV to generate electricity and provide it to the power system.	/
Electricity market operator	Operator	The electricity market operators are to maximize social benefits as well as to increase market liquidity and transparency, including registration, transaction, settlement, etc.	/

8.4.4.4 Grouping of Australia

Table 10 lists actors grouping in VPPs of Australia in this document.

Table 10 – Grouping of Australia

Grouping		**Group description**	
VPP platform operator and stakeholders in Australia		This group includes operators and stakeholders related to the VPP platform in Australia	
Actor name	**Actor type**	**Actor description**	**Further information specific to this use case**
Retailer	Role	Engages in the activity of selling electricity to consumers/end-users. In the VPP trial they are also financially responsible for each connection point. A retailer can also take on the role of a VPP coordinator.	
Market ancillary service provider (MASP)	Role	Delivers market ancillary services by offering a customer's load, or an aggregation of loads, into FCAS markets.	
System operator	Role	Manages electricity systems and markets	
VPP coordinator	Role	The entity that is coordinating the controllable assets to meet the VPP's operational objective	
VPP participant	Role	The party that interfaces with the system operator. The VPP participant can be the VPP coordinator or retailer and encompasses the entity that can make or accept payments to the system operator in respect of the frequency/energy markets.	

8.4.4.5 Grouping of Germany

Table 11 lists actors grouping in VPPs of Germany in this document.

Table 11 – Grouping of Germany

Grouping		Group description	
VPP platform operator and stakeholders in Germany		This group includes operators and stakeholders related to the VPP platform in Germany	
Actor name	**Actor type**	**Actor description**	**Further information specific to this use case**
Grid operator	Role	Manages electricity systems and markets	
VPP coordinator	Role	The entity that is coordinating the controllable assets to meet the VPP's operational objective	
Operator of assets within the VPP	Role	Operates assets(DER) within the VPP	

8.4.4.6 References

Table 12 lists references in this document.

Table 12 – References

References						
No.	**References type**	**Reference**	**Status**	**Impact on the use case**	**Originator / organisation**	**Link**
IEC SRD 62913-1	Standard	Generic Smart Grid Requirements	Published	Provide basic template	IEC	/
IEC 61850-7-42:2021	Standard	Communication networks and systems for power utility automation	Published		IEC	/
/	Website	Rules for VPP to participate in peak shaving and regulation energy market	Published		North China Energy Regulatory Bureau of National Energy Administration of the People's Republic of China	/

References						
No.	**References type**	**Reference**	**Status**	**Impact on the use case**	**Originator / organisation**	**Link**
/	Implementation rules	Implementation rules for ancillary service management of grid-connected power plants in North China	Published	Rules for this use case	North China Energy Regulatory Bureau of National Energy, Administration of the People's Republic of China	/
/	Implementation rules	Implementation rules for grid-connected operation management of power plants in North China	Published	Rules for this use case	North China Energy Regulatory Bureau of National Energy, Administration of the People's Republic of China	/
/	Website	AEMO VPP Demonstration website	Published	General VPP landing page for participants and interested parties	AEMO	https://aemo.com.au/en/initiatives/major-programs/nem-distributed-energy-resources-der-program/pilots-and-trials/virtual-power-plant-vpp-demonstrations
/	Website	VPP Final design	Published		AEMO	https://aemo.com.au/-/media/files/electricity/der/2021/nem-vpp-demonstrations_final-design.pdf?la=en
/	Website	VPP data specification	Published		AEMO	https://aemo.com.au/-/media/files/electricity/nem/der/2019/vpp-demonstrations/vpp-demonstrations-data-specification.pdf?la=en
/	Website	VPP FCAS specification	Published		AEMO	https://aemo.com.au/-/media/files/electricity/nem/der/2019/vpp-demonstrations/vpp-demonstrations-fcas-specification.pdf?la=en
AS/NZS 4777.2:2015	Standard	Australian Standards pertaining to LV technical grid connection requirements for inverters	Release version		Standards Australia	https://infostore.saiglobal.com/en-us/standards/as-nzs-4777-2-2015-101208_saig_as_as_212627//

References						
No.	References type	Reference	Status	Impact on the use case	Originator / organisation	Link
/	Enterprise standard	Technical guide for virtual power plant system construction	Published	Rules for this use case	China Southern Power Grid Shenzhen Power Supply Bureau Co. LTD	
/	Enterprise standard	Technical specification for hardware terminal of virtual power plant	Published	Rules for this use case	China Southern Power Grid Shenzhen Power Supply Bureau Co. LTD	

8.4.5 Step by step analysis of use case

8.4.5.1 Scenario conditions

Table 13 lists scenario conditions of all use cases in this document.

Table 13 – Scenario conditions

Scenario conditions						
No.	Scenario name	Scenario description	Primary actor	Triggering event	Pre-condition	Post-condition
BUC-1-a	Participating in power system operation	VPP participates in power system operation to provide regulation services	VPP, DER owners, VPP platform operator, power system operator, electricity market operator, regulatory authority	Power system needs issued by power system operator.	VPP reports power plan, baseline and response capability to power system operator.	VPP responds to the dispatch order of power system operator through the aggregated DER and meets power system needs.
BUC-1-b	Participating in energy market	VPP participates in electricity market to purchases, through bids to buy, and sell, through offers to sell.	VPP, DER owners, VPP platform operator, power system operator, electricity market operator, regulatory authority	Energy market opening noticed by electricity market operator.	VPP reports power plan and baseline to power system operator.	VPP participates in the energy market and DER respond to bid result.
BUC-1-c	Local aggregation, optimization and control of DER	VPP aggregates, optimizes and controls of DER locally to achieve a certain goal.	VPP, DER owners, VPP platform operator, power system operator, electricity market operator, regulatory authority	Dispatch order sent by power system operator.	VPP receives dispatch order from power system operator.	VPP provides an optimized control to DER.

Scenario conditions						
No.	**Scenario name**	**Scenario description**	**Primary actor**	**Triggering event**	**Pre-condition**	**Post-condition**
BUC-2	VPP provides frequency control service	VPP provides primary frequency control service and participates in the secondary frequency control ancillary service market	VPP, DER owners, VPP platform operator, power system operator, electricity market operator, regulatory authority	Power system frequency disturbance arises	VPP receives primary/secondary frequency control signal from power system operator	VPP responds to the frequency disturbance of power system
BUC-3-a	Enrolment in the VPP that provides comprehensive energy services	Action taken by DER to submit enrolment application of VPP for providing comprehensive energy services	DER	/	/	DER complete the enrolment.
BUC-3-b	Provide comprehensive energy services for DER	Action taken by VPP operator to provide comprehensive energy services for DER	VPP operator, DER	/	DER have enrolled in the VPP that provides comprehensive energy services.	VPP operator provides comprehensive energy services for DER.
BUC-4-a	Participating in power system operation <For power system operators>	VPP provides power system operators with the reserves and balancing power required to stabilize the grid such as regulating frequency and balancing electricity supply and demand, etc.	DER owner, aggregator, power system operator, electricity market operator	An established VPP intended to provide services to power system operator.	The VPP is technically capable to interact with the power system operator.	The power system operator has a better flexible capability to enhance the secure operation of power system.
BUC-4-b	Avoiding output curtailment of renewables <For renewable energy companies>	Renewable energy companies avoid PV output curtailment by increasing or shifting electricity demand with VPP. (Under consideration)	DER owner, aggregator, renewable energy company	An established VPP that has a desire to increase or shift electricity demand.	The VPP is technically viable to increase or shift electricity demand	The renewable energy companies can effectively utilize the generated electricity and eventually contribute to the further integration of renewables.
BUC-4-c	Aggregation and control of DER aiming for optimal utilization of their potentials <For DER owners>	VPP aggregates, optimizes and controls DER effectively to achieve a certain goal including energy management such as energy saving and shifting of peak demand.	DER owner, aggregator, power system operator, renewable energy company, electricity market operator	An established VPP that has a desire to aggregate, optimize and control DER effectively.	The VPP is technically viable to interact with DER.	VPP can provide an optimal solution for DER.

Scenario conditions						
No.	**Scenario name**	**Scenario description**	**Primary actor**	**Triggering event**	**Pre-condition**	**Post-condition**
BUC-5-a	Enrolment in VPP demonstration	Action taken by VPP participant to participate in the VPP demonstration for contingency frequency control	VPP participant and system operator	System operator has opened VPP demonstrations.		VPP is enrolled to participate in the demonstrations for frequency control in the NEM.
BUC-5-b	Response to frequency deviation	Action taken by VPP devices during a power system frequency disturbance.	VPP participant	Power system frequency disturbance	VPP has successfully enrolled in the demonstrations (see previous scenario). Additionally, the VPP has devices or mechanisms setup to respond to frequency changes (either through a frequency controller or switchable devices)	VPP has responded to the frequency disturbance by changing the aggregated active power flow via a frequency controller or through an on/off switch to participating switchable devices.
BUC-5-c	Response to energy market price signals	Action taken by VPP participant in response to an energy market signal.	VPP participant	Response to energy market signals	VPP has successfully enrolled in the demonstrations (see previous scenario) and is registered to participate in NEM energy market and can interface with market systems.	VPP participant changes aggregated active power flow in response to energy market spot prices.
BUC-7	Participating in the electricity market	Action taken by VPP participant to participate in the electricity market.	VPP participant	Market opening noticed by electricity market operator	The participants send the mode signal to demonstrate their willingness to participate in the electricity market.	VPP distributes the power demand to the participants based on the operation costs
SUC-1-a	Normal mode of participating in power system operation	In normal mode, the VPP aggregates DER and sends the power plan to the power system operator. Then VPP can receive the dispatch order, and provide optimized control of DER.	VPP, DER owners, VPP platform operator, power system operator, electricity market operator, regulatory authority	Power system needs issued by power system operator.	The VPP agents DER owners to report baseline and power plan to power system operator.	VPP responds to the dispatch order of power system operator.

Scenario conditions						
No.	**Scenario name**	**Scenario description**	**Primary actor**	**Triggering event**	**Pre-condition**	**Post-condition**
SUC-1-b	Emergency mode of alleviating power system contingencies	In emergency mode, the VPP can receive emergency dispatch request from power system operator against contingencies. Then VPP aggregates and optimizes DER to response to emergency request.	VPP, DER owners, VPP platform operator, power system operator, electricity market operator, regulatory authority	Emergency dispatch request sent by power system operator.	VPP reports response capability of aggregated DER to power system operator.	VPP responds to the emergency dispatch request.
SUC-1-c	Participating in peak shaving and regulation energy market	The VPP servers as agent for the DER to participate in the peak shaving and regulation energy market. VPP is responsible for bid, benefit allocation and coordinated control. The DER are responsible for the response to bid result.	VPP, DER owners, VPP platform operator, power system operator, electricity market operator, regulatory authority	Energy market opening noticed by electricity market operator.	VPP agents DER owners to report baseline and power plan to electricity market operator.	VPP agents DER to participate in peak shaving and regulation energy market and responds to bid result.
SUC-1-d	Local energy management and coordinated control of DER	The VPP receives dispatch order. The dispatch order can be generated from electricity market transaction or system ancillary/emergency service request. Then VPP collects the operational information of DER and decomposes the order. Through the coordinated control of DER, the VPP meets dispatch needs and enhances its flexibility and economy.	VPP, DER owners, VPP platform operator, power system operator, electricity market operator, regulatory authority	Dispatch order sent by power system operator	VPP receives dispatch order from power system operator.	VPP decomposes the dispatch order and provides optimized control to DER.

Scenario conditions						
No.	**Scenario name**	**Scenario description**	**Primary actor**	**Triggering event**	**Pre-condition**	**Post-condition**
SUC-2-a	VPP provides the primary frequency control service	The VPPs dominated by renewable energy should provide the primary frequency control service. This scenario involves the standard of primary frequency control service that the VPPs need to provide during registration and the assessment of performance.	VPP, DER owners, VPP platform operator, power system operator, electricity market operator, regulatory authority	Power system frequency disturbance arises	VPP receives primary frequency control signal from power system operator.	VPP has responded to the frequency disturbance and provided primary frequency control service.
SUC-2-b	VPP participates in the secondary frequency control ancillary service market	The process of VPP participating in the secondary frequency control ancillary service market, market clearance and final settlement.	VPP, DER owners, VPP platform operator, power system operator, electricity market operator, regulatory authority	Power system frequency disturbance arises	VPP receives secondary frequency control signal from power system operator.	VPP has provided secondary frequency control service according to the market clearing result
BUC-7	Response to the demand response/load pickup support signal	Action taken by VPP participant in response to demand response/load pickup support signal	VPP participant	Demand response signal sent by grid operator	The participants send the mode signal to demonstrate their willingness to participate in the demand response event.	VPP distributes the power demand to the participants based on the operation costs
SUC-7-a	Response to the system frequency regulation signal	Action taken by VPP participant in system frequency regulation	VPP participant	System frequency regulation signal sent by grid operator	The participants send the mode signal to demonstrate their willingness to participate in the system frequency regulation event.	VPP distributes the frequency regulation to the participants based on the operation costs
SUC-7-b	Response to the voltage regulation signal	Action taken by VPP devices during a power system voltage disturbance	VPP, DER owners, VPP platform operator, power system operator	Voltage regulation signal sent by grid operator	The participants send the mode signal to demonstrate their willingness to participate in the voltage control	VPP distributes the voltage control instruction to the participants based on the operation costs

8.4.5.2 Steps of scenarios

Table 14 lists steps of scenarios of all use cases in this document.

Table 14 – Steps of scenarios

Scenario								
Scenario name:		Normal mode to participate in power system operation						
Step No.	**Event**	**Name of process/ activity**	**Description of process/ activity**	**Service**	**Information producer (Actor)**	**Information receiver (Actor)**	**Information exchanged (IDs)**	**Requirements , R-ID**
SUC-1-a-s01	Power system needs issuance	Issuing system needs	Power system operator issues system request	Create, get, report	Power system operator	VPP, VPP platform operator, regulatory authority	SUC-1-a-InfEx01	/
SUC-1-a-s02	Forecast calculation of aggregated DER	Calculating forecast output	VPP calculates forecast output of aggregated DER	Create, get, report	DER owners	VPP, VPP platform operator	SUC-1-a-InfEx02	/
SUC-1-a-s03	Planned response capacity decomposition	Sending the planned local dispatch order	VPP calculates the desired output level of aggregated DER, decomposes the planned response capacity and sends planned local dispatch order to DER owners.	Create, get, report	VPP, VPP platform operator	DER owners	SUC-1-a-InfEx03	/
SUC-1-a-s04	Response capability determination	Determining the response capability	Do DER have the capability to follow or partially follow the planned local dispatch order? If yes, DER owners send the minimum and maximum output level to VPP. If no, DER owners decline to respond to VPP.	Create, get, report	DER owners	VPP, VPP platform operator	SUC-1-a-InfEx04	/
SUC-1-a-s05	Aggregation of DER response capacity	Sending the aggregated response capacity	VPP aggregates and sends total minimum and maximum output level to the power system operator.	Create, get, change, report	VPP, VPP platform operator	Power system operator	SUC-1-a-InfEx05	/

Scenario								
Scenario name:	Normal mode to participate in power system operation							
Step No.	**Event**	**Name of process/ activity**	**Description of process/ activity**	**Service**	**Information producer (Actor)**	**Information receiver (Actor)**	**Information exchanged (IDs)**	**Requirements , R-ID**
SUC-1-a-s06	Dispatch order issuance	Issuing dispatch order to VPP	The power system operator performs the system-level optimization and sends the dispatch order to VPP.	Create, get, change, execute	Power system operator	VPP, VPP platform operator, regulatory authority	SUC-1-a-InfEx06	/
SUC-1-a-s07	Dispatch order decomposition	Sending local dispatch orders to DER owners	VPP performs portfolio-level optimization and sends the local dispatch order to DER owners.	Create, get, change, execute	VPP, VPP platform operator	DER owners	SUC-1-a-InfEx07	/
SUC-1-a-s08	Response to local dispatch order	Responding to the local dispatch order	DER respond to the order	Create, get, report	DER owners	VPP, VPP platform operator	SUC-1-a-InfEx08	/

Scenario								
Scenario name:	Emergency mode of participating in power system contingencies							
Step No.	**Event**	**Name of process/ activity**	**Description of process/ activity**	**Service**	**Information producer (Actor)**	**Information receiver (Actor)**	**Information exchanged (IDs)**	**Requirements, R-ID**
SUC-1-b-s01	DER operational information reporting	Sending DER operating status and market bid result	VPP sends operating status and market bid result of aggregated DER to power system operator	Create, get, report	VPP, VPP platform operator	Power system operator	SUC-1-b-InfEx01	/

Scenario								
Scenario name:		Emergency mode of participating in power system contingencies						
Step No.	**Event**	**Name of process/ activity**	**Description of process/ activity**	**Service**	**Information producer (Actor)**	**Information receiver (Actor)**	**Information exchanged (IDs)**	**Requirements, R-ID**
SUC-1-b-s02	Emergency dispatch request issuance	Issuing emergency dispatch request	Power system operator determines if the system is in contingency? If yes, power system operator issues emergency dispatch request. If no, power system operator follows steps of normal mode	Create, get, change, execute	Power system operator	VPP, VPP platform operator, regulatory authority	SUC-1-b-InfEx02	
SUC-1-b-s03	Forecast calculation of aggregated DER	Calculating forecast output	VPP formulates output forecast of aggregated DER	Create, get, report	DER owners	VPP, VPP platform operator	SUC-1-a-InfEx02	
SUC-1-b-s04	Dispatch request decomposition	Decomposing emergency dispatch request	VPP determines if DER have the capability to response to emergency request? If yes, VPP allocates emergency dispatch request and sends to DER. If not, VPP refuses request.	Create, get, change, execute	VPP, VPP platform operator	DER owners	SUC-1-b-InfEx03	
SUC-1-b-s05	Response to local dispatch order	Responding to local dispatch order	DER respond to VPP local dispatch order	Create, get, report	DER owners	VPP, VPP platform operator	SUC-1-a-InfEx08	

Scenario								
Scenario name:		Participating in peak shaving and regulation energy market						
Step No.	**Event**	**Name of process/ activity**	**Description of process/ activity**	**Service**	**Information producer (Actor)**	**Information receiver (Actor)**	**Information exchanged(IDs)**	**Require-ments , R-ID**
SUC-1-c-s01	Market bidding opening	Conducting market bidding	Electricity market operator conducts market bidding	Create, get, report	Electricity market operator	VPP platform operator, regulatory authority	SUC-1-c-InfEx01	/
SUC-1-b-s02	Planned bidding capacity calculation	Calculating the planned bidding capacity	VPP calculates the planned bidding capacity of participating in the peak shaving and regulation energy market	Create, get, report	VPP, VPP platform operator	DER owners	SUC-1-c-InfEx02	
SUC-1-c-s03	Bidding to market	Bidding baseline and power plan	VPP represents DER owners to provide bid baseline and power plan to energy market	Create, get, change, report	VPP, VPP platform operator	Electricity market operator, regulatory authority	SUC-1-c-InfEx03	
SUC-1-c-s04	Market clearing and bid result issuance	Issuing bid result	Electricity market operator conducts market clearing and issues bid result.	Create, get, change, execute	Electricity market operator	VPP, VPP platform operator, regulatory authority	SUC-1-c-InfEx04	
SUC-1-c-s05	Bid result confirmation	Confirming bid result	VPP confirms the bid result	Create, get, change, report	VPP, VPP platform operator	Electricity market operator	SUC-1-c-InfEx05	
SUC-1-c-s06	Bid result decomposition	Decomposing bid result	The VPP sends the bid result and local dispatch order to DER.	Create, get, change, execute	VPP, VPP platform operator	DER owners	SUC-1-a-InfEx07	

Scenario								
Scenario name:	Participating in peak shaving and regulation energy market							
Step No.	**Event**	**Name of process/ activity**	**Description of process/ activity**	**Service**	**Information producer (Actor)**	**Information receiver (Actor)**	**Information exchanged(IDs)**	**Require-ments , R-ID**
SUC-1-c-s07	Market revenues allocation	Allocating market revenues	VPP receives peak shaving and regulation energy market revenues and allocates to DER owners	Create, get, change, report	VPP, VPP platform operator	DER owners	SUC-1-c-InfEx06	

Scenario								
Scenario name:	Local energy management and coordinated control of DER in VPP							
Step No.	**Event**	**Name of process/ activity**	**Description of process/ activity**	**Service**	**Information producer (Actor)**	**Information receiver (Actor)**	**Information exchanged(IDs)**	**Require-ments , R-ID**
SUC-1-d-s01	Dispatch order issuance	Issuing dispatch order	Power system operator issues dispatch order	Create, get, execute	Power system operator	VPP, VPP platform operator, regulatory authority	SUC-1-a-InfEx06	/
SUC-1-d-s02	DER operating status collection	Collecting operation status	VPP collects latest operating status of DER	Create, get, report	DER owners	VPP, VPP platform operator	SUC-1-d-InfEx01	
SUC-1-d-s03	DER output forecast	Predicting output	VPP collects the predicted generation and consumption data of DER	Create, get, report	DER owners	VPP, VPP platform operator	SUC-1-a-InfEx02	
SUC-1-d-s04	Dispatch order decomposition	Decomposing dispatch order	VPP decomposes the dispatch order and sends local dispatch order to DER	Create, get, change, execute	VPP, VPP platform operator	DER owners	SUC-1-a-InfEx07	
SUC-1-d-s05	Response to local dispatch order	Responding to local dispatch order	DER owners confirm local dispatch order and implement	Create, get, report	DER owners	VPP, VPP platform operator	SUC-1-a-InfEx08	