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Recommendation

ITU-T Y.3122 (05/2023)

SERIES Y: Global information infrastructure, Internet protocol aspects, next-generation networks, Internet of Things and smart cities

Future networks

Quality of service assurance requirements and framework for smart grid supported by IMT-2020 and beyond

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Recommendation ITU-T Y.3122

Quality of service assurance requirements and framework for smart grid supported by IMT-2020 and beyond

Summary

Recommendation ITU-T Y.3122 specifies the quality of service (QoS) assurance aspects for the smart grid supported by the international mobile telecommunications 2020 (IMT-2020) and beyond.

It first provides an overview of the smart grid supported by IMT2020 and beyond. It then identifies a number of QoS considerations and the QoS assurance requirements and framework based on the QoS considerations are specified. |Finally, smart grid application scenarios with detailed QoS requirements supported by IMT2020 and beyond are described in Appendix I.

History *

Edition	Recommendation	Approval	Study Group	Unique ID
1.0	ITU-T Y.3122	2023-05-14	13	11.1002/1000/15531

Keywords

Framework, IMT-2020, QoS assurance, requirements, smart grid.

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Quality of service assurance requirements and framework for smart grid supported by IMT-2020 and beyond

1 Scope

This Recommendation specifies the quality of service (QoS) assurance aspects for smart grid supported by IMT-2020 and beyond. The scope of this Recommendation is as follows:

- QoS considerations;
- Requirements;
- Framework;
- Application scenarios.

This Recommendation specifies the QoS assurance aspects from a networking viewpoint for the smart grid supported by the IMT-2020 and beyond. Therefore non-networking aspects of QoS assurance for the smart grid are out of the scope of this Recommendation.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T Y.3102] Recommendation ITU-T Y.3102 (2018), *Framework of the IMT-2020 network*.

[ITU-T Y.3104] Recommendation ITU-T Y.3104 (2018), *Architecture of the IMT-2020 network.*

[ITU-T Y.3106] Recommendation ITU-T Y.3106 (2019), *Quality of service functional requirements for the IMT-2020 network.*

[ITU-T Y.3107] Recommendation ITU-T Y.3107 (2019), *Functional architecture for QoS assurance management in the IMT-2020 network.*

[ITU-T Y.3108] Recommendation ITU-T Y.3108 (2019), *Capability exposure function in the IMT-2020 networks.*

[ITU-T Y.3109] Recommendation ITU-T Y.3109 (2021), *Quality of service assurance-related requirements and framework for virtual reality delivery using mobile edge computing supported by IMT-2020.*

[ITU-T Y.3112] Recommendation ITU-T Y.3112 (2018), *Framework for the support of network slicing in the IMT-2020 network.*

[ITU-T Y.3113] Recommendation ITU-T Y.3113 (2021), *Requirements and framework for latency guarantee in large-scale networks including the IMT-2020 network.*

[ITU-T Y.3118] Recommendation ITU-T Y.3118 (2022), *Requirements and framework for jitter guarantee in large scale networks including IMT-2020 and beyond.*

[ITU-T Y.3120] Recommendation ITU-T Y.3120 (2023), *Functional architecture for latency guarantee in large scale networks including IMT-2020 and beyond.*

[ITU-T Y.3121] Recommendation ITU-T Y.3121 (2023), *Quality of service requirements and framework for supporting deterministic communication services in local area networks for IMT-2020*.

[ITU-T Y.3130] Recommendation ITU-T Y.3130 (2018), *Requirements of IMT-2020 fixed mobile convergence*.

[ITU-T Y.3153] Recommendation ITU-T Y.3153 (2019), *Network slice orchestration and management for providing network services to 3rd party in the IMT-2020 network.*

[ITU-T Y.3158] Recommendation ITU-T Y.3158 (2022), *Local shunting for multi-access edge computing in IMT-2020 networks.*

[ITU-T Y.3170] Recommendation ITU-T Y.3170 (2018), *Requirements for machine learning-based quality of service assurance for the IMT-2020 network.*

[ITU-T Y.3172] Recommendation ITU-T Y.3172 (2019), *Architectural framework for machine learning in future networks including IMT-2020.*

[ITU-T Y.3175] Recommendation ITU-T Y.3175 (2020), *Functional architecture of machine learning-based quality of service assurance for the IMT-2020 network.*

[ITU-T Y.4000] Recommendation ITU-T Y.4000/Y.2060 (2012), *Overview of the Internet of things.*

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 IMT-2020 [b-ITU-T Y.3100]: Systems, system components, and related aspects that support to provide far more enhanced capabilities than those described in [b-ITU-R M.1645].

NOTE 1 – [b-ITU-R M.1645] defines the framework and overall objectives of the future development of IMT-2000 and systems beyond IMT-2000 for the radio access network.

NOTE 2 – This definition is based on [b-ITU-R M.2083-0].

3.1.2 Internet of things (IoT) [ITU-T Y.4000]: A global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies.

3.1.3 multi-access edge computing (MEC) [b-ETSI GS MEC 001]: System which provides an IT service environment and cloud-computing capabilities at the edge of an access network which contains one or more type of access technology, and in close proximity to its users.

3.1.4 quality of service (QoS) [b-ITU-T P.10]: The totality of characteristics of a telecommunications service that bear on its ability to satisfy stated and implied needs of the user of the service (see [b-ITU-T E.800]).

3.1.5 quality of service assurance [ITU-T Y.3109]: Functionalities or mechanisms that enable service providers to make statements with a degree of confidence that the service meets the quality characteristics or objectives specified elsewhere.

3.2 Terms defined in this Recommendation

None.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

AF Application Function

AI Artificial Intelligence

AN Access Network

AR Augmented Reality

CN Core Network

CP Control Plane

DN Data Network

E2E End-to-End

eMBB enhanced Mobile Broadband

FMC Fixed Mobile Convergence

GCS Ground Control Station

HD High Definition

IoT Internet of Things

IMT International Mobile Telecommunications

MEC Multi-access Edge Computing

ML Machine Learning

mMTC massive Machine Type Communication

PCF Policy Control Function

QoS Quality of Service

SG Smart Grid

UAV Unmanned Aerial Vehicle

UE User Equipment

UP User Plane

UPF User Plane Function

URLLC Ultra-Reliable Low Latency Communication

VR Virtual Reality

5 Conventions

This Recommendation uses the following conventions:

The term "**is required to**" indicates a requirement which must be strictly followed, and from which no deviation is permitted, if conformance to this Recommendation is to be claimed.

The keywords "**is recommended**" indicate a requirement which is recommended but which is not absolutely required. Thus this requirement need not be present to claim conformance.

6 Overview

A power grid consists of five phases: power generation, power transmission, power transformation, power distribution, and power consumption. A smart grid (SG) is a modernized power grid which uses advanced information and communication technologies to monitor and control the production and distribution of electricity in order to save energy, reduce losses, and enhance the reliability of the power grid [b-GSMA-SG].

Advanced information and communication technologies such as Internet, Internet of things (IoT) [ITU-T Y.4000], IMT-2020 [b-ITU-T Y.3100], cloud, big data, artificial intelligence (AI) and new control methods are used to build reliable, economical, and efficient power grids. Smart grid is built based on the advanced information and communications technologies. Such technologies represented by the IMT-2020 and beyond, enabling the capabilities of high coverage, network slicing, high bandwidth, low latency, and massive connectivity can be used across all five phases of smart gird.

It is important to identify the network quality of service (QoS) [b-ITU-T P.10] requirements and framework to realize a smart grid system with the advanced technologies supported by IMT-2020 and beyond. Clauses 7, 8, and 9 describe the requirements and framework respectively. Application scenarios with the detailed QoS requirements are described in Appendix I.

7 QoS considerations

The IMT-2020 and beyond is expected to provide customized QoS support for a variety of different smart grid application scenarios (e.g., power generation, power transmission, power transformation, power distribution and power consumption) described in Appendix I. Some representative customized QoS requirements include: deterministic precise control, massive information collection, high bandwidth, and high isolation, etc.

Deterministic precise control: Intelligent distribution automation in power distribution is one of the most representative application examples for deterministic precise control type. Many advanced technology digital devices require zero interruption of power supplies. In order to improve the reliability of electricity power supply, it is required to achieve uninterrupted power supply in power supply areas by reducing power supply accident isolation time to milliseconds. To achieve the improved reliability, intelligent distribution automation technology integrates monitoring, protection, control, and measurement of distribution power capabilities. It should monitor the current status of the power distribution network to provide a continuous power supply and ensure that the accident isolation time does not exceed the deterministic timing criteria.

The key QoS requirements of deterministic precise control in communications networks for smart grid are as follows: latency (less than 10 ms), bandwidth (200 kbit/s-2.5 Mbit/s), isolation (high), and reliability (99.999%). Ultra-reliable and low-latency communication (URLLC) slice of IMT-2020 with deterministic capabilities is a typical choice for these types of smart grid applications. Furthermore, multi-access edge computing (MEC) [ITU-T Y.3158], [b-ETSI GS MEC 001] technology, which enables distributed gateway deployment to implement local traffic processing and logical computing, can also be used to save bandwidth and reduce latency. Large scale and local area deterministic technologies [ITU-T Y.3113], [ITU-T Y.3118], [ITU-T Y.3120], [ITU-T Y.3121] can also be used to enable deterministic precise control requirements of smart grid.

Massive information collection: Monitoring of power generation, transmission, transformation and distribution require collection of massive real-time equipment status information. Advanced metering infrastructure enables various functions including automatic power consumption information collection, distributed energy monitoring, power consumption analysis and management. Based on the advanced metering infrastructure, the real-time demand of power load can be understood, fast accommodation of distributed clean energy can be achieved, and more effective usage based price policy can be provided.

The key QoS requirements of the massive information collection in communications networks for smart grid are as follows: access (tens of millions of terminals), frequency and concurrency (second-level to quasi-real-time data collection), latency (less then 200 ms), bandwidth (4 Mbit/s), isolation (middle), and reliability (99.999%). Massive machine type communication (mMTC), which supports a very large number of connected devices transmitting a relatively low volume of non-delay-sensitive data, is a typical choice for these types of smart grid applications.

High bandwidth: Video based monitoring, virtual reality (VR)/augmented reality (AR) inspection and unmanned aerial vehicle (UAV) based inspection, are examples of high bandwidth smart grid applications. Video based monitoring provides capability of status monitoring during the phases of power generation, transmission, transformation, and distribution. It enables high definition (HD) video transmission of remote images and enhances on-site management capabilities for emergency applications. It also improves risk identification for lines and power supply equipment. VR/AR based interactive maintenance and inspection can be used during the phases of power generation and power transformation. Operators can wear VR/AR smart glasses to inspect grid equipment and to interact with a VR/AR inspection service platform. Under the guidance of a control centre, the VR/AR inspection service platform can confirm the accurate target area through intelligent identification. It then clearly lists the contents to inspect and sets up standardized guidance for inspecting the content (graphics, video) to assist inspectors. This will greatly improve the inspection accuracy and safety. UAV based inspection can also monitor and cruise along a power line or tunnel to find any potential hazards or faults [b-ITU-T F.749.10]. If any, the location of hazards and fault information will be transported back to the ground control station (GCS).

The key requirements of supporting high bandwidth smart grid applications are as follows: bandwidth (10-80 Mbit/s), latency (20 ms-1s), isolation (middle), reliability (99.9%) and mobility (120 km/h). Enhanced mobile broadband (eMBB) is a typical choice for these types of smart grid applications.

High isolation: It is required to support different service isolation levels for different smart grid applications (see details in Appendix I). For example, intelligent distribution automation is an application in the power production area of the power grid and must be completely isolated from other applications in power management areas.

Based on the high level QoS considerations described above, IMT-2020 network slicing combined with other enabling technologies can be designed to handle specific smart grid application requirements, meet differentiated service level agreement (SLA) requirements, and build isolated network instances automatically on demand. Clause 8 specifies quality of service assurance requirements for smart grid supported by IMT-2020 and beyond (SG-IMT2020). To fulfil the requirements, a framework of quality of service assurance [ITU-T Y.3109] for SG-IMT2020 is specified in clause 9.

8 QoS assurance requirements

8.1 Network slicing for SG

– SG-IMT2020 is required to support network slicing (URLLC, mMTC, eMBB, etc.) for different smart gird applications;

– SG-IMT2020 is recommended to support URLLC slice with large scale and local area networks deterministic communication capabilities [ITU-T Y.3113], [ITU-T Y.3118], [ITU-T Y.3120], [ITU-T Y.3121];

– SG-IMT2020 is required to translate customer's service requirements to a network slice template (e.g., charging, policy control, security, mobility, performance) [ITU-T Y.3112];

– SG-IMT2020 is required to have capabilities to create and deploy network slice over cross-domain (access network, core network and transport network, etc.);

– SG-IMT2020 is required to have capabilities to guarantee that network slices are isolated and one slice instance has no impact on other slices during its runtime;
– SG-IMT2020 is required to have capabilities to monitor, modify and delete network slices with no or minimal impact on the existing network services [ITU-T Y.3153].

8.2 QoS planning for SG-IMT2020 slices

– SG-IMT2020 is required to support slice QoS planning before creation of a network slice;
– SG-IMT2020 is required to support capabilities to estimate network coverage, capacity, bandwidth, and delay for network slice planning;
– SG-IMT2020 is required to support slice QoS policy design for a specific smart grid service;
– SG-IMT2020 is required to support slice topology design and evaluation for a specific smart grid service;
– SG-IMT2020 is required to support slice route design and evaluation for a specific smart grid service.

8.3 QoS provisioning for SG-IMT2020 slices

– SG-IMT2020 is required to support end-to-end (E2E) QoS provisioning for network slice over cross-domain (access network, core network and transport network, etc.);
– SG-IMT2020 is recommended to support autonomic smart grid slice management and orchestration;
– SG-IMT2020 is required to support service specific QoS enforcements enabled by flow classification, marking, congestion avoidance, queue shaping and queue scheduling;
– SG-IMT2020 is required to support QoS interworking and mapping among smart grid user equipment (UE), access network (AN), transport network and core network (CN) in a smart grid slice.

8.4 QoS monitoring for SG-IMT2020 slices

– SG-IMT2020 is required to support E2E QoS parameters monitoring of a smart grid network slice (e.g., capacity, uplink/downlink bandwidth, loss rate, jitter, delay, etc.);
– SG-IMT2020 is required to support smart grid network slice QoS parameters associated anomaly detection;
– SG-IMT2020is required to report QoS events upon detecting QoS parameters associated anomalies that violate the SLA.

8.5 QoS optimization for SG-IMT2020 slices

– SG-IMT2020 is recommended to support smart grid network slice QoS optimization enabled by MEC [ITU-T Y.3158], [b-ETSI GS MEC 001] and machine learning (ML)/artificial intelligence (AI) [ITU-T Y.3170], [ITU-T Y.3172], [ITU-T Y.3175] technologies;
– SG-IMT2020 is recommended to support traffic prediction based on the analysis of collected slice QoS data;
– SG-IMT2020 is recommended to support routing optimization based on the current smart grid traffic status;
– SG-IMT2020 is recommended to support QoS anomaly prediction based on the analysis of slice QoS data.

9 Framework

A framework of QoS assurance for smart grid supported by IMT-2020 and beyond is shown in Figure 1.

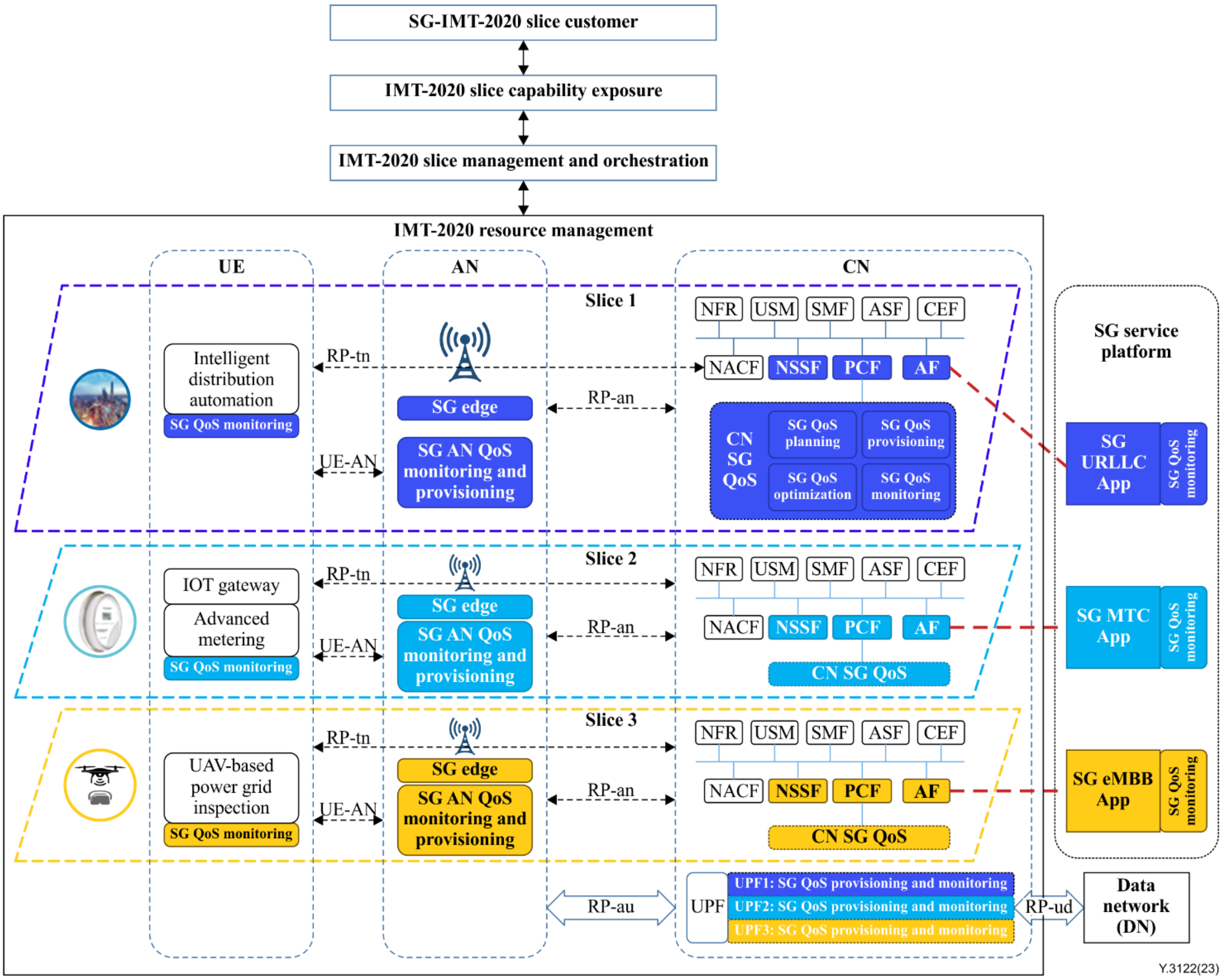

Figure 1 – A framework of QoS assurance for smart grid by IMT-2020 and beyond

The framework of QoS assurance for smart grid is built over the IMT-2020 slicing network technology [ITU-T Y.3153], [ITU-T Y.3112]. The QoS assurance capabilities for smart grid are distributed among UEs, AN, SG edge, CN and SG service platform. Multiple heterogeneous smart grid user equipment connect to the AN and different types of smart grid applications are supported by the SG service platform as shown in Figure 1.

The description of the role of each component is as follows:

– SG service platform plays two roles: SG-IMT2020 slice customer and an instance of AF of the SG slice. As a SG slice customer, it interacts with IMT-2020 slice management and orchestration functional entity (FE) through IMT-2020 slice capability exposure FE [ITU-T Y.3108].

– Once the slice capability exposure FE accepts a network slice requirement from a SG customer, then the requirement is sent to the slice management and orchestration FE to instantiate, modify or release a network slice instance.

– The slice management and orchestration FE is responsible for service management and resource management of an E2E network slice. Based on the slice requirements, it performs slice design, slice configuration, slice life cycle management and interacts with other

IMT-2020 functionalities, e.g., policy control function (PCF), through service-based interfaces [ITU-T Y.3102], [ITU-T Y.3104].

– SG-IMT2020 network slice is a tenant-oriented virtual network. SG-IMT2020 network slice is designed to handle specific SG application requirements, meet differentiated SLA requirements, and automatically build isolated network instances on demand. Large scale and local area network deterministic communications technologies [ITU-T Y.3113], [ITU-T Y.3118], [ITU-T Y.3120], [ITU-T Y.3121] can be used to enable deterministic communications requirements of smart grid.
– Resource management is responsible for cross-domain resource management for AN, core network and transport network. A network slice instance is instantiated by resource management according to the network slice template generated in slice management and orchestration. Resource management assigns necessary resources to the network slice instance.
– Once an SG slice is provisioned and activated supported by the above FEs, as an instance of AF, the SG service platform initiates the requested SG service through AF in the slice. E2E smart grid slice QoS control is further supported by the SG-IMT2020 core network (CN). The QoS functionalities (planning, provisioning, monitoring and optimization) [ITU-T Y.3106], [ITU-T Y.3107] are distributed in both control plane (CP) and user plane (UP) in different network slices. The machine learning based AI technologies [ITU-T Y.3170], [ITU-T Y.3172], [ITU-T Y.3175] can be used for smart grid QoS optimization.
– The smart grid access network supports various smart grid terminals and applications based on its fixed mobile convergence (FMC) [ITU-T Y.3130] capabilities. Smart grid QoS provisioning and monitoring for QoS enforcement and QoS data collection is supported in the access network.
– The SG edge is located near to the smart grid UEs. The SG edge support QoS optimization enabled by MEC [ITU-T Y.3158], [b-ETSI GS MEC 001]. Thanks to the local access, computing, storage and bandwidth provided by the smart grid edge, a one-stop solution is available for efficient data delivery. Furthermore, the traffic cost of the SG service platform can be reduced.
– There are many different types of smart grid terminals (smart grid power equipment, electricity meters VR/AR terminals and UAVs, etc.) which have different QoS requirements. These terminals are connected to the IMT-2020 FMC [ITU-T Y.3130] network directly. Internet of thing (IoT) devices for smart grid can be connected through a smart grid IoT gateway [ITU-T Y.4000].

10 Security considerations

This Recommendation describes the QoS assurance requirements and framework for smart grid supported by IMT-2020 and beyond, therefore, general network security requirements and mechanisms in IP-based networks and IMT-2020 network should be applied [b-ITU-T Y.2701], [b-ITU-T Y.3101]. The security mechanisms such as authentication, authority, accounting and encryption should be adopted to ensure security of smart grid and IMT-2020 system.

Appendix I

Application scenarios of smart grid support by IMT-2020 and beyond

(This appendix does not form an integral part of this Recommendation.)

I.1 Power generation

Electric power generation generally includes traditional hydro power generation, thermal power generation, and nuclear power generation, as well as emerging clean energy power generation, such as wind power generation, solar power generation, etc. Power generation equipment generally includes generators, transformers, turbines, boilers, electrical switches, and various other control equipment and safety protection equipment. IMT-2020 and beyond can be deployed to support dynamic monitoring of power generation equipment, intelligent power generation control and video based inspection of power plants.

Based on dynamic monitoring of power generation equipment and the power plant environment, it can display the current status of power generation equipment and the power plant environment (such as real time video, the load of the unit, rotor speed, temperature, vibration, pressure, and humidity, etc.). This can assist the staff of the power plant to understand the status of power generation, find hidden dangers of accidents, and avoid non-planned electricity suspension.

Intelligent power generation control is a new generation of safe, efficient and environmentally friendly power generation control system formed by introducing new technologies. Intelligent power control provides functions such as intelligent control, VR/AR based interactive maintenance, and dynamic adjustment and adaptation for the full life cycle management of the power generation system.

By introducing intelligent inspection methods such as inspection robots or power inspection drones, it will help discover the hidden dangers of faults of power generation equipment in time and play an important guarantee for the safety production of power generation places.

The key QoS requirements for power generation supported by IMT-2020 and beyond are illustrated in Table I.1 [ITU-T Y.3109], [b-CCSA-Grid].

Table I.1 – Power generation

Application scenario		Latency	Bandwidth	Reliability	Mobility	Isolation
Dynamic monitoring of power generation	Equipment status collection	≤100 ms	≥200 kbit/s	≥99.9%	-	High
	Video based environment monitoring	≤1s	≥10 Mbit/s (1080 P)	≥99.9%	-	Middle
Intelligent power generation control	Control information collection	≤100 ms	≥200 kbit/s	≥99.9%	-	High
	AR/VR based maintenance	≤20 ms	≥80 Mbit/s	≥99.99%	-	High
Smart inspection of power generation plants	Status and control information collection	≤30 ms	≥2 Mbit/s	≥99.99%	0-10 km/h	Middle
	Video based inspection	≤100 ms	≥10 Mbit/s (1080P)	≥99.9%	0-10 km/h	Middle

I.2 Power transmission

Based on IMT-2020 and beyond, operators can monitor the status of the power transmission line. The monitored data are transmitted to the main station through online monitoring devices to realize the qualitative or quantitative analysis of the operating conditions of the power transmission line. The monitored parameters include: the tilted angle of the rod tower, transmission line vibration, frequency, amplitude, temperature, humidity, wind speed, wind direction, rainfall, atmospheric pressure, and images of the transmission rod tower, etc. Interactive UAV- based inspection can also be deployed. UAV can monitor and cruise along the power transmission line to find whether there are any hazards or faults [b-ITU-T F.749.10]. The UAV is required to transmit payload information such as audio, video, image and other sensor information to the GCS for power grid inspection. UAV-based power grid inspection may be widely deployed in power transmission phase which includes: power line inspection and power tunnel inspection [b-GSMA-SG].

The key QoS requirements for power transmission supported by IMT-2020 and beyond are illustrated in Table I.2 [b-CCSA-Grid].

Table I.2 – Power transmission

Application scenario		Latency	Bandwidth	Reliability	Mobility	Isolation
Monitoring of power transmission	Equipment status collection	≤200 ms	≥2 Mbit/s	≥99.9%	–	Middle
	Image data	≤200 ms	≥20 Mbit/s	≥99.9%	–	Middle
	UAV-based monitoring	≤20 ms	≥50 Mbit/s	≥99.9%	10-120 km/h	Middles

I.3 Power transformation

Based on IMT-2020 and beyond, the operating environment of the power transformation station equipment can be controlled and monitored. The monitored information include: working environment of important equipment and the image of the station. Experts in the background of the substation can control the camera and support remote diagnosis for the status of the transformation station. Operators can wear VR/AR smart glasses to inspect deformation of the station and interact with the VR/AR inspection service platform. Under the guidance of the control centre, the VR/AR inspection service platform can confirm the accurate target area through intelligent identification. It then clearly lists the contents to inspect and sets up standardized guidance for inspecting the content (graphics, video) to assist inspectors.

The key QoS requirements for power transformation supported by IMT-2020 and beyond are illustrated in Table I.3 [b-CCSA-Grid].

Table I.3 – Power transformation

Application scenario		Latency	Bandwidth	Reliability	Mobility	Isolation
Monitoring of power transformation	Equipment status collection	≤200 ms	≥4 Mbit/s	≥99.9%	–	Middle
	Video based monitoring	≤100 ms	≥10 Mbit/s	≥99.9%	–	Middle
	AR/VR based inspection	≤20 ms	≥80 Mbit/s	≥99.99%	–	Middle

I.4 Power distribution

In order to improve the reliability of electricity power supply, it is required to achieve uninterrupted power supply in power supply areas by reducing power supply accident isolation time to milliseconds. To achieve the improved reliability, intelligent distribution automation is a combination of modern electronic technology, communication technology, and computer network technology with power system equipment. It integrates monitoring, protection, control, and measurement of distribution power technologies. It should monitor the current status of the power distribution network to provide a continuous power supply and ensure that the accident isolation time does not exceed the deterministic timing criteria. An intelligent power distribution station should support real-time monitoring of the equipment and environment, and carry out safety prevention and control to achieve intelligent power management.

The key QoS requirements for power distribution supported by IMT-2020 and beyond are illustrated in Table I.4 [b-smartgrid-5G].

Table I.4 – Power distribution

Application scenario	Latency	Bandwidth	Reliability	Isolation
Intelligent distribution automation	≤10 ms	≥2.5 Mbit/s	≥99.999%	High
Intelligent power distribution station	≤50 ms	≥10 Mbit/s	≥99.9%	Middle

I.5 Power consumption

A deep integration of advanced metering and IMT-2020 technologies enables electricity companies to understand the real-time demand of power load by their customers. It helps to transform the information interaction between electricity companies and their customers from one-way measurement to two-way interactions. New services will bring requirements for real-time and quasi-real-time reporting of power consumption data. In addition, the number of terminals will be further increased. In the future, the collection of power consumption information will be further extended to families to obtain the load information of all electric terminals. This will ensure a more refined balance between supply and demand and guide reasonable off peak power consumption [b-GSMA-SG].

Advanced metering infrastructure enables various functions including automatic power consumption information collection, distributed energy monitoring, power consumption analysis and management. Based on the advanced metering infrastructure, the real-time demand of power load can be understood, fast accommodation of distributed clean energy can be achieved, and more effective usage based pricing policy can be provided.

The key QoS requirements for power consumption supported by IMT-2020 and beyond are illustrated in Table I.5 [b-smartgrid-5G].

Table I.5 – Power consumption

Application scenario	Terminal number	Latency	Bandwidth	Reliability	Isolation
Advanced metering infrastructure	Tens of millions	≤200 ms	≥2 Mbit/s	≥99.999%	Middle

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