ISO/TC 268/SC 1
Smart community infrastructures

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ISO CD 37160 for ballot

Document type:	CD ballot
Date of document:	2018-07-30
Expected action:	INFO
Background:	Dear Members of ISO/TC268/SC1 The CD ballot for ISO 37160 is launched via eBalloting system. At our last plenary meeting in Zhuhai, ISO/TC268/SC1 took following resolution for ISO 37160 (SC1/WG5) ***Resolution -118(Zhuhai -08/2018)*** ***Approval of the report from ISO/TC 268/SC1/WG5*** *ISO/TC 268/SC 1 approves the report from ISO/TC 268/SC 1/WG5 as presented by Mr. Chiba, and also decided that ISO 37160 should proceed to CD stage provided that IEC TC5, IEC SyC Smart Cities and ISO TC301 agree that no contradictions are found between their work and ISO 37160.* Based on this resolution, ISO/TC268/SC1 chair and secretary have been contacting those committees (after the meeting, we found that ISO TC192 also has relevance to this project), and as you can find their responses on the N302 we can conclude that ISO 37160 does NOT contradict to any projects under these relevant committees. TC268/SC1 secretary, therefore, launch the CD ballot as agreed at plenary meeting. Please check the eBalloting Portal and cast your national ballot. Best regards, Yusuke Chiba (Secretary of ISO/TC268/SC1)
Committee URL:	https://isotc.iso.org/livelink/livelink/open/tc268sc1

ISO 37160 (E)

ISO TC 268/SC 1

Secretariat: JISC

Smart community infrastructure - Electric power infrastructure - Measurement method for quality of thermal power infrastructure and requirement for plant operations and management

CD stage

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Contents

Foreword

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This document was prepared by Technical Committee 268, *Sustainable cities and communities*, Subcommittee 1, *Smart community infrastructure*.

Introduction

This document describes the method for measuring the quality of thermal power infrastructure during the operation phase and the requirements for operations and management activities for the purpose of maintaining and improving the quality of thermal power infrastructure in the medium and long term.

Considering the importance of a sufficient and stable electric power supply to the standard of living and economic activities, electric power shortages or frequent outages are serious risks to society. Therefore, maintaining and improving the quality of the thermal power infrastructure is an important concern for all regions, and is especially one of the most urgent and important issues to regions in the process of rapid economic growth. It is possible to achieve a sufficient and stable electric power supply by starting the operation of a thermal power infrastructure as scheduled, operating it stably, and performing effective O&M throughout the duration of the service.

Also, the reduction of environmental burdens, such as greenhouse gas emissions, is a pressing global issue, and it is recommended to reduce the environmental burdens attributable to the thermal power infrastructure while carefully considering factors such as the social costs of the environmental impact, the costs required for environmental protection measures, and the effectiveness of these measures.

From these viewpoints, it is expected that efforts to maintain and improve the quality of the thermal power infrastructure by applying appropriate O&M will make society more sustainable. For example, this document is directly relevant to SDG Goal 7 (affordable and clean energy), Goal 11 (sustainable cities and communities), Goal 13 (climate action), Goal 14 (life below water) and Goal 15 (life on land).

Smart community infrastructure - Measurement method for quality of thermal power infrastructure and requirement for plant operations and management

1. Scope

This document is applicable to any organizations involved in operations and management (hereinafter referred to as O&M) that intends to maintain and improve the quality of thermal power infrastructure (hereinafter referred to as QTPI), and specifies the method for measuring QTPI during the operation phase and the requirements for high-quality O&M activities.

Note: This document is applicable to electric power providers, including public utilities and independent power producers (IPPs), and relevant stakeholders. The selection and importance of evaluation indices, however, resulting from the application of this document and will vary depending on the electric power provider and its characteristics

2 Normative references

There are no normative references in this document.

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 https://www.iso.org/obp

3.1
thermal power infrastructure
station generating electric power utilizing oil, gas, coal or biomass as fuel, excluding nuclear and geothermal energy.

3.2
Net maximum capacity
NMC
output calculated by subtracting the power of the auxiliary system used by the equipment from the total maximum output

Note 1 to entry: Depending on the objective of using NMC, either of the following two calculation methods can be applied.

(1) Station NMC
Output is calculated by subtracting TICP used within the station from the GMC

(2) Unit NMC
Output is calculated by subtracting power consumption of the auxiliary system of the particular unit from the GMC

3.3
total internal consumption of the plant (TICP)
summation of the power consumption of the auxiliary systems and general power consumption

Note 1 to entry: General power consumption includes energy consumption of administration office such as lighting, air conditioning, etc.

3.4
Gross maximum capacity (GMC)
maximum output that a unit can generate in a specific period

3.5
Equivalent unit derated hours
EUNDH
value calculated by dividing the product of the limited output amount and the limited output time by the net maximum output (NMC)

3.6
Available Hours
AH
the time, in hours, during which the unit is available for service

3.7
Period Hours
PH
all intended time excluding unintended shutdown time resulting from natural disasters

3.8
Service Hours
SH
time that the power generation facility is electrically connected to an electric power system and generating electric power

3. 9
The equivalent availability factor (EAF) excluding seasonal deratings.
EAFxs

$$EAFxs = \frac{(AH - EUNDH)}{PH} \times 100$$

3.10
Heat consumption Ratio
HR
value calculated by dividing the fuel input I [MJ] to the power generation facility by the generated power P [MWh]

$$\mathrm{HR} = \frac{\mathrm{I}}{\mathrm{P}}$$

3.11
Forced Outage Hours
FOH
time that a device or main equipment did not operate due to a forced outage

3.12
Forced Outage Rate
FOR

$$\text{FOR} = \frac{\text{FOH}}{\text{FOH} + \text{SH}} \times 100$$

3.13
Demand Supply Adjustment
ability of the power generation facility to change the output according to changes in supply and demand

3.14
Demand Supply Adjustment not available
time that the function of the ability to adjust power supply and demand is not available

Note 1 to entry: The total time of the following (1) and (2) are included.

(1) The time that the use of Auto Frequency Control (AFC) or Load Frequency Control (LFC) was restricted due to unplanned causes.

(2) The time that the power generation of the facility was constant due to unplanned causes.

Note 2 to entry: AFC is defined as the adjustment of power output using AFC devices to maintain the frequency of the electric system within a standard value.

Note 3 to entry: LFC is defined as detecting frequency variations and interconnected power variations caused by load variations and controlling the output to maintain the frequency and power flow within standard values during the normal operation

3.15
Discharge rate
emissions per unit of amount of economic activities (e.g. the value calculated by dividing the annual emissions [g or kg] by the annual power generation [kWh])

3.16
Industrial safety accident Rate
coefficient considering the number of people who became unable to work, the number of people whose work was restricted, and the number of fatalities due to an accident per 200,000 or 1,000,000-man-hours worked

4 Evaluation indices of the quality of thermal power infrastructure during the operation phase

4.1 Quality of thermal power infrastructure (QTPI)

QTPI specifies the degree to which thermal power infrastructure consistently meets or exceeds customer requirements or expectations regarding initial operation capability, supply stability, reliable operation and fast recovery, environmental and social consideration, safety and economic efficiency.

Note 1: The 3E & S is used to represent quality of thermal power infrastructure: energy security, environmental conservation, economic efficiency, and safety.

Note 2: The three sub-components of energy security which is specific to thermal power infrastructure are initial operation capability, supply stability, and reliable operation and fast recovery.

Note 3: Environmental and social considerations and environmental conservation are both used to indicate aspects of general quality of infrastructure.

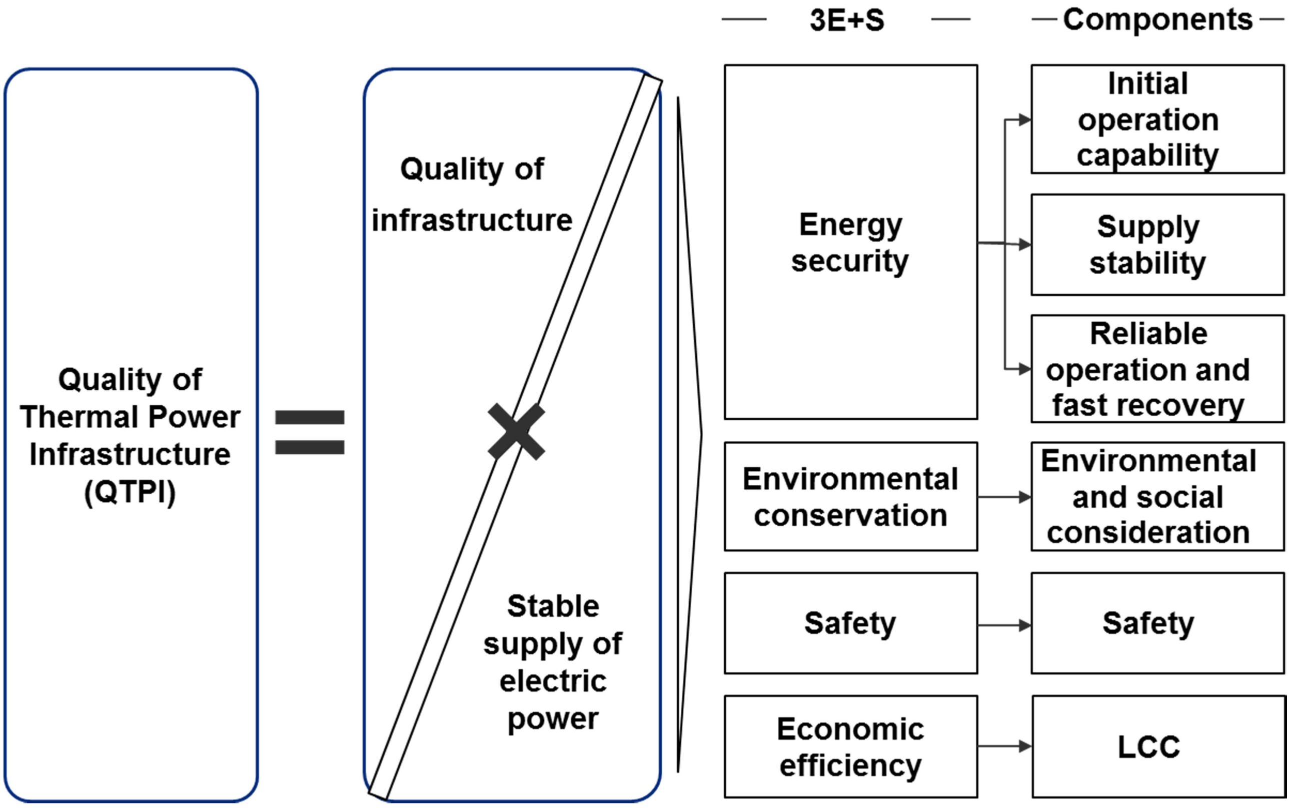

Figure 1 --- Components of quality of thermal power infrastructure

4.2 Components of the quality of thermal power infrastructure (see figure 1)

4.2.1 General

O&M operators shall consider the following components in order to maintain and continuously improve the quality of thermal power infrastructure during the operation phase:

4.2.2 Initial operation capability

Initial operation capability means the ability to start operation of each unit of thermal power infrastructure as planned and scheduled

Note: Initial operation capability includes the ability to start operation on planned start time in conformance to relevant specifications and unit specific conditions.

4.2.3 Supply stability

Supply stability means the ability of thermal power infrastructure to consistently supply electric power without fail

4.2.4 Reliable operation and fast recovery

Reliable operation means to minimize internal forced outages of the thermal power infrastructure to the extent practical and to safely deactivate the infrastructure without damaging the equipment. Fast recovery means to recover from a forced outage as soon as practical.

Note: Internal forced outage refers to a shutdown or output suppression that is within the control of the power station. They can be caused by external and internal incidents, excluding shutting down or limiting output due to events such as planned maintenance.

4.2.5 Environmental and social considerations

Environmental and social considerations means the attention on prevention or control of environmental impacts attributable to the thermal power infrastructure and coexistence with the local community

Note 1: The factors that need to be considered from the viewpoint of reducing adverse environmental impacts can include the control of air pollutants, waste water, heated effluents, other wastes as well as Green House Gas (GHG) emissions.

Note 2: The factors that need to be considered from the viewpoint of addressing social aspects can include community engagement, transparency and disclosure of operations. For details of social considerations, see ISO 26000.

4.2.6 Safety

Safety in the context of thermal power infrastructure means the state of no danger by prevention or control of damage except for environmental impact

Note: Safety consideration is primarily classified into disaster prevention, information security and crime prevention.

4.2.7 Life Cycle Cost (LCC)

Life cycle cost in the context of thermal power infrastructure means the summation of the costs throughout the life cycle of the thermal power infrastructure, provided that the thermal power infrastructure satisfies all requirements of the components of the above mentioned QTPI

Note: LCC can be roughly classified into EPC costs and operation costs including disposal costs. In the case of a thermal power infrastructure, fuel costs account for a large portion of running costs. The LCC also includes several other factors, such as O&M costs and additional costs caused by forced outages or costs of compensation for local residents caused by such as environmental pollution.

4.2.8 Performance indicators and evaluation of the QTPI

O&M operators shall collect the required data for evaluation by evaluators as specified in Table 1 to Table 10. Evaluators can include stakeholders such as insurance organizations, government, power providers, NGOs and environmental organizations. Evaluators can utilize the indices as shown in 4.3 for appropriate measurement of QTPI during the operation phase of the thermal power infrastructure. The evaluation methods and formulas shall be reviewed, as appropriate, by reflecting the improvement of the function, performance, etc. of equipment so that it can be kept up-to-date with changes in the social environment and the market situation.

4.3 Evaluation indices

4.3.1 Supply stability

4.3.1.1 Availability

Table 1 shows the evaluation method, formula, evaluation period, unit, and scope of evaluation to assess, at planned intervals, O&M capability of the thermal power infrastructure and the quality of unit.

Table 1. Evaluation index of supply stability: Availability

Evaluation method	Compute the equivalent availability factor excluding seasonal deratings of the power equipment concerned.
Formula	$F_{EAF,XS} = (t_{AH} - t_{EUNDH}) / t_{PH} \times 100$ where $F_{EAF,XS}$: equivalent availability factor excluding seasonal deratings t_{AH} : available hours t_{EUNDH} : equivalent unit derated hours t_{PH} : period hours
Evaluation period	period determined by evaluator (e.g. 5 years)
Unit	%
Scope of evaluation	Power unit

4.3.1.2 Increase of heat rate

Table 2 shows the evaluation method, formula, evaluation period, unit, and scope of evaluation to assess adequacy of the O&M of the power equipment.

Table 2. Evaluation index of supply stability: Increase of heat rate

Evaluation method	Compute the difference between the heat rate of the most recent year and the designed heat rate. Since a performance test is generally performed at periodic maintenance, once every several years, the values measured in the performance tests conducted in the last five years (optional) shall be adopted.
Formula	$D_{HR} = H_{R,PEV} - H_{R,DSP}$ where D_{HR}: increase of heat rate $H_{R,PEV}$: heat rate at the time of the performance test (performance evaluation) in the evaluation period $H_{R,DSP}$: heat rate at the time of initial performance test.
Evaluation period	Most recent evaluation result
Unit	MJ/MWh
Scope of evaluation	Power unit

4.3.1.3 Ability to adjust power supply and demand

Table 3 shows the evaluation method, formula, evaluation period, unit, and scope of evaluation to assess the ability of the power equipment to change output in response to changes of power supply and demand.

Table 3. Evaluation index of supply stability: Ability to adjust power supply and demand

Evaluation method	Compute the percentage of the time that the ability to adjust the power supply and demand is functioning to the total time of parallel operation of the power equipment concerned.
Formula	$R_{DSA} = (1 - t_{DSA,NA} / t_{SH}) \times 100$ where R_{DSA} : ratio of demand and supply adjustment [%] $t_{DSA,NA}$: restricted time of the ability to adjust power supply and demand t_{SH} : service hours
Evaluation period	period determined by evaluator (e.g. 5 years)
Unit	%
Scope of evaluation	Power unit

4.3.2 Reliable operation and fast recovery (Forced Outage Rate (FOR))

Table 4 shows the evaluation method, formula, evaluation period, unit, and scope of evaluation to assess the reliability of the power equipment and the ability to recover by O&M.

Table 4. Evaluation index of reliable operation and fast recovery: Forced Outage Rate (FOR)

Evaluation method	Compute the Forced Outage Rate (FOR) of the power equipment concerned.
Formula	$R_{FOR} = t_{FOH} /(t_{SH} + t_{FOH}) \times 100$ where R_{FOR} : Forced Outage Rate (FOR) t_{FOH} : forced outage hours t_{SH} : service hours
Evaluation period	period determined by evaluator (e.g. 5 years)
Unit	%
Scope of evaluation	Power unit

4.3.3 Environmental and social considerations

4.3.3.1 Unit requirements for SO_X, NOx and PM emissions

Table 5 shows the evaluation method, formula, evaluation period, unit, and scope of evaluation to assess the quality of environmental considerations in view of operation data on impacts on the atmospheric environment.

Table 5. Evaluation index of environmental and social considerations: Unit requirements for SOx , NOx and PM emissions

Evaluation method	Evaluate initiatives other than those for the effectiveness of the exhaust gas treatment facility (e.g. adoption of low NOx burners, low-sulfur/nitrogen fuel) by computing the discharge rate. The evaluation can be based on NMC, but GMC is recommended if available. SOx will be either computed based on the sulfur concentration of the fuel or measured by SOx emission monitoring. NOx will be computed based on the results of regular gas exhaust measurement. If the measurement is conducted multiple times a year, the average will be computed. Particulate matter (PM) will be computed based on the results of regular gas exhaust measurement. If the measurement is conducted multiple times a year, the average will be computed Load frequency may have an impact, but this will not be considered as the impact could be considered minimal. NOTE: For comparison between other facilities, it is noted that value of the ratio differs depending on auxiliary power.
Formula	(1) $U_{SOx} = M_{SOx,AEM} / P_{g,A}$ (2) $U_{NOx} = M_{NOx,AEM} / P_{g,A}$ (3) $U_{PM} = M_{PM,AEM} / P_{g,A}$ U_{SOx}, U_{NOx}, U_{PM} : Unit requirement for SOx, NOx and PM emissions $M_{SOx,AEM}, M_{NOx,AEM}, M_{PM,AEM}$: annual SOx, NOx and PM emissions [g] $P_{g,A}$: annual power generation [kWh]
Evaluation period	period determined by evaluator (e.g. 5 years)
Unit	g / kWh
Scope of evaluation	Power unit

4.3.3.2 Unit requirement for CO_2 emissions

Table 6 shows the evaluation method, formula, evaluation period, unit, and scope of evaluation to assess the quality of environmental considerations in view of operation data on impacts of CO_2 emissions.

Table 6. Evaluation index of environmental and social considerations: Unit requirement for CO_2 emissions

Evaluation method	The evaluation can be based on NMC, but GMC is recommended if available. Compute annual CO_2 emissions from the annual fuel consumption etc. according to each economy's computation methodology.
Formula	$U_{CO2} = M_{CO2,AEM} / P_{g,A}$ where U_{CO2} : unit requirement for CO_2 emissions $M_{CO2,AEM}$: annual CO_2 emissions [kg] $P_{g,A}$: annual power generation [kWh]
Evaluation period	period determined by evaluator (e.g. 5 years)
Unit	Kg- CO_2/kWh
Scope of evaluation	Power unit

4.3.3.3 Water quality

Table 7 shows the evaluation method, formula, evaluation period, unit, and scope of evaluation to assess the impacts on water quality.

Table 7. Evaluation index of environmental and social considerations: Water quality

Evaluation method	The evaluation will be based on the measurement of water quality (discharge concentration) from the thermal power infrastructure. If water quality is measured multiple times a year, the average of the measured values shall be adopted.
Formula	Examples of the items to be measured are pH, BOD, COD, N-hexane, total nitrogen, total phosphorus, SS, Escherichia coli, and temperature difference between water intake and water discharge.
Evaluation period	period determined by evaluator (e.g. 5 years)
Unit	pH: (-) BOD, COD, N-hexane, total nitrogen, to phosphorus, SS: (mg/l) Escherichia coli : (number of cells /cm^3) Temperature difference between water intake and water discharge: (t)
Scope of evaluation	Power station

4.3.3.4 Waste recycling rate

Table 8 shows the evaluation method, formula, evaluation period, unit, and scope of evaluation to assess the quality of environmental considerations for waste.

Table 8. Evaluation index of environmental and social considerations: Waste recycling rate

Evaluation method	The recycle rate of waste that the O&M operator is responsible for disposing of (e.g. fly

	ash, desulfurized gypsum, sludge from waste water) should be computed per power unit. Recycle includes material recycle, thermal recycle, and sales of recycled items.
Formula	$R_{recycle} = \sum W_{waste,recycle} / \sum W_{waste} \times 100$ where $R_{recycle}$: waste recycling rate $W_{waste,recycle}$: recycled amount of waste generated by the power plant [t] W_{waste} : amount of waste generated by the power plant [t]
Evaluation period	period determined by evaluator (e.g. 5 years)
Unit	%
Scope of evaluation	Power station

4.3.4 Safety (number of casualties caused by occupational accidents)

Table 9 shows the evaluation method, formula, evaluation period, unit, and scope of evaluation to assess the adequacy of measures to prevent occupational accidents to workers in relation to natural disasters, equipment problems, and occupational accidents to workers involved in operations in the thermal power infrastructure.

Table 9. Evaluation index of safety: Number of casualties caused by industrial safety accidents

Evaluation method	Evaluate the number of casualties caused by industrial safety accidents by calculating the occupational accident rate from the number of employees, who were unable to work or subjected to some restriction on work for one or more days following the day of an occupational accident, among all employees working for the thermal power infrastructure.
Formula	$R_{ISA} = \left[\frac{N_{olt} + N_{orta} + N_{of}}{t_{nsmhw}} \right] \times t_{omh}$ where R_{ISA} : industrial safety accident rate N_{olt} : number of workers who were unable to work for one or more days following the day of an industrial accident (number of lost time) N_{orta} : number of workers who were subjected to restriction on work for one or more days following the day of an industrial accident (restricted time accidents) N_{of} : number of deaths from industrial accidents (fatalities) t_{nsmhw} : total man-hours worked within the power plant (number of station man-hours worked)

	t_{omh} : 200,000 man-hours worked or 1,000,000 man-hours worked
Evaluation period	period determined by evaluator (e.g. 5 years)
Unit	Number of people
Scope of evaluation	Power station

4.3.5 LCC (LCC considering all 5 other components)

Table 10 shows the evaluation method, formula, evaluation period, unit, and scope of evaluation to assess the balance of the total benefit (total power generation) and total costs (sum of total power generation costs and social costs) of the power equipment during the operation phase.

Table 10. Evaluation index of LCC reduction: LCC considering all 5 other components

Evaluation method	Evaluate the adequacy and economic efficiency of both equipment and O&M by considering the total power generation and social cost (environmental impact) in the indicator.
Formula	$C_{lcc} = \sum(C_{tpg} + C_s) / \sum(P_{tpg})$ where C_{lcc} : life cycle cost of thermal power infrastructure C_{tpg} : total power generation costs, EPC costs, fuel costs, O&M costs, and decommissioning costs C_s : social costs based on which external costs, such as CO_2 emission costs, are quantitatively evaluated P_{tpg} : Net Actual power generation will be used for operations carried out in the past. In case of evaluating only the operations carried out in the future, the total operation period from the present moment to the future shall be used, and past EPC, fuel costs, O&M costs and social costs shall be excluded.
Evaluation period	From the time of evaluation till decommissioning
Unit	(US$ or local currency) / kWh
Scope of evaluation	Power unit or power station

Example

The LCC can be calculated by the service-year levelized cost of electricity (LCOE) adopted by the Organization for Economic Cooperation and Development (OECD).

Annex A shows an example of an LCC formula.

5 Operation of thermal power infrastructure

5.1 General

The application of "Self-Elevating Mechanism for Sustainable Operation and Management" by O&M operators is the determinant factor of maintaining and further improving QTPI during the operation phase of a thermal power infrastructure (see figure 2).

In order to maintain and further improve QTPI by taking into account internal and external context, O&M operators shall establish, implement, and maintain processes for measurement, data control, analysis, response to risks, operational control, and integrated management as shown below.

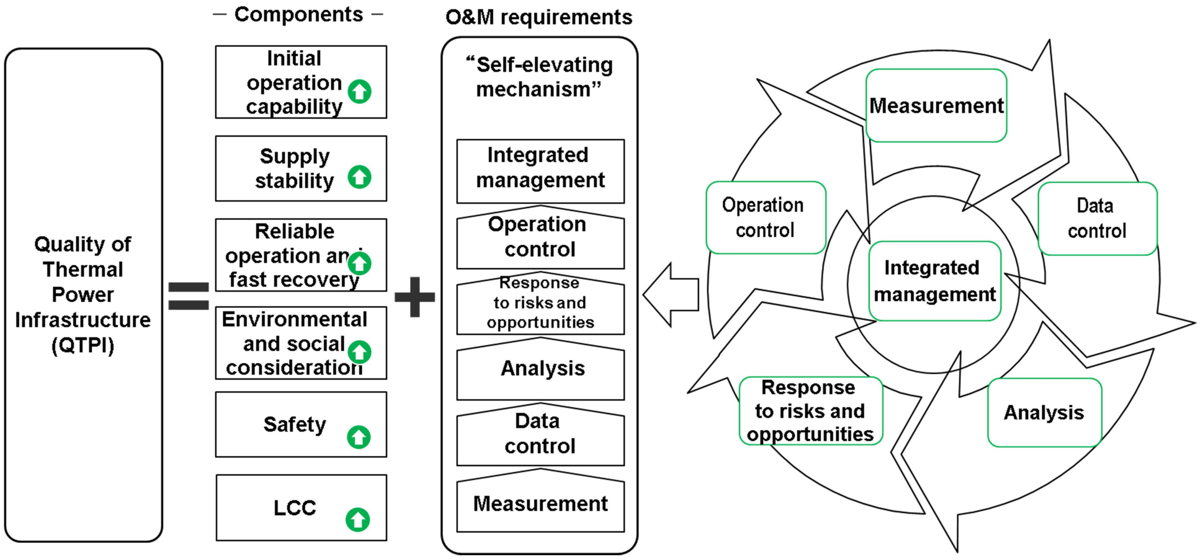

Figure 2 Self-Elevating Mechanism for Sustainable Operation and Management

5.2 Measurement

O&M operators shall determine and adopt the following, as needed:

a) what needs to be monitored and measured;

b) frequency of measurement;

c) the methods for monitoring and measurement;

d) devices or systems for monitoring and measurement;

e) appointment of personnel responsible for measurement.

When determining what needs to be measured, they shall be monitored and recorded taking into account on the necessity of O&M operations and of the provision of information to stakeholders. When determining the measurement method, the necessary accuracy shall be taken into account.

When introducing a device or system, capability to perform appropriate measurement or monitoring shall be taken into account.

5.3 Data control

O&M operators shall implement the following, as applicable:

a) adopting a general-purpose format and automated recording and accumulation of data to ensure smooth data control;

Note 1: The data that needs to be automatically recorded in a general-purpose format are process data which result from measurements of the operating status of the equipment. Any formats and any types of media may be acceptable for other O&M operation data.

b) storing accumulated data for analysis for the necessary period;

c) making accumulated data suitable for use to ensure fast data analysis;

d) protecting data adequately (e.g. from loss of confidentiality, improper use, or loss of integrity, or implement necessary anti cybersecurity control measures).

e) providing data appropriate to be exchanged and shared in the community for multiple purposes, for example, demand and supply management, disaster management

Note 2: ISO 37156 addresses principle of data sharing and exchange.

5.4 Analysis

O&M operators shall implement the following, as applicable:

a) analyzing the measured results of the evaluation indices in 4.2 comprehensively and identifying problems.

   Analyzing the measured results of the evaluation indices in 4.2 comprehensively and identifying problems by benchmarking the results against other plants. When benchmarking, consider the following:

   1) Ensuring security of the data
   2) Assuring sufficient quality of the sharing data
   3) Managing the sharing data responsibly

b) appointing personnel with required skills for data analysis and assigning appropriate work;

c) determining the format of the required information tool for data analysis.

5.5 Response to risks and opportunities

In order to maintain and further improve QTPI, it is necessary to make continuous efforts to identify and determine potential risks, reduce their adverse effects, resolve consequential problems and promote opportunities to improve QTPI. O&M operators shall implement, maintain, and improve a process to address potential and actual risks, including:

a) determining potential risks to the thermal power infrastructure based on the analysis results in a timely manner, establishing a scheme for dealing with them in advance and periodically carrying out a drill. Risks can include both internal risks and external risks:

Internal risks such as;

- equipment failures, electric and machinery breakdown (forced outages, output limitation, power grid failure.);

- deviation from controlled values;

- human errors;

- fire and explosion in the station;

- accidents causing injury and ill-health.

External risks such as;

- terrorist attack

- cyber attack

- natural disasters (earthquake, typhoon, tsunami, flood, forest fire, etc.)

b) investigating the causes of incidents, considering the degree of importance and taking actions to prevent them from recurring, and establishing a scheme for evaluating the adequacy of preventive actions.

c) developing a preventive maintenance program in order to minimize forced outages.

d) determining the necessary spare parts to allow for fast recovery in the event of a forced outage.

e) optimizing system control for less emission and higher performance.

f) introducing the latest technologies and practices for better operation flexibility.

g) optimizing the inspection interval and duration of power units for reducing LCC.

Note1: As far as cyber attacks are concerned, see IEC 62443 series,

Note 2: As far as natural disasters are concerned, see IEC 63152.

Note 3: Acts of terrorism are mitigated by the individual organizations or, if applicable, appropriate National Security Plan.

5.6 Operation Control

O&M operators shall establish a system for maintaining the management cycle of the process from measurement to response to risks and continually improve the process to ensure the following:

a) having in place an O&M program, keeping it updated as needed, and building a well-structured knowledge database to increase the reproducibility of the process from measurement to response to risks;

b) having in place well-structured systems for human resources development for acquisition of necessary O&M business skills, schematic evaluation of the development system and regular implementation of those trainings.

5.7 Integrated management

O&M operators shall establish processes to maintain and further improve QTPI by:

a) ensuring the management's commitment to the determination of important matters related to QTPI;

b) conducting periodic review about the following and establishing a scheme for taking necessary actions for improvement:

   1) results of previous reviews and the effectiveness of any actions taken;

   2) results of the evaluation indices described in 4.2;

   3) adequacy of operation control for maintaining effective operation;

   4) status of related communication with stakeholders;

   5) business environment (e.g. appropriateness of fuel procurement risk management (such as fuel stock));

   6) being adaptive to the latest technology and devices, such as Internet of Things;

   7) preparedness for response to changes of the social environment, etc.;

   8) preparedness for response to needs of stakeholders: (e.g. supply-and-demand adjustment due to increase in renewable energy, etc.);

c) being aware of social responsibilities including consideration of the following, determining a policy to achieve, and establishing a scheme to assume responsibilities:

   1) protection of human rights;

   2) rights of workers;

   3) environmental conservation (e.g. efforts to preserve and improve local and global environments);

   4) disaster planning (e.g. safety activities to prevent fire and/or work-related injuries) ;

d) communicating information to the local community relevant to any environmental pollution, for example, providing stakeholders with necessary information such as weather data, environmental data (i.e. SO_X, NO_X and PM emissions), etc. in real time;

e) ensuring that personnel with necessary competence for O&M operation are at work.

NOTE: Figure 3 illustrates relation among components of quality of thermal power infrastructure, requirements for operation to improve quality, and evaluation indices for components of quality.

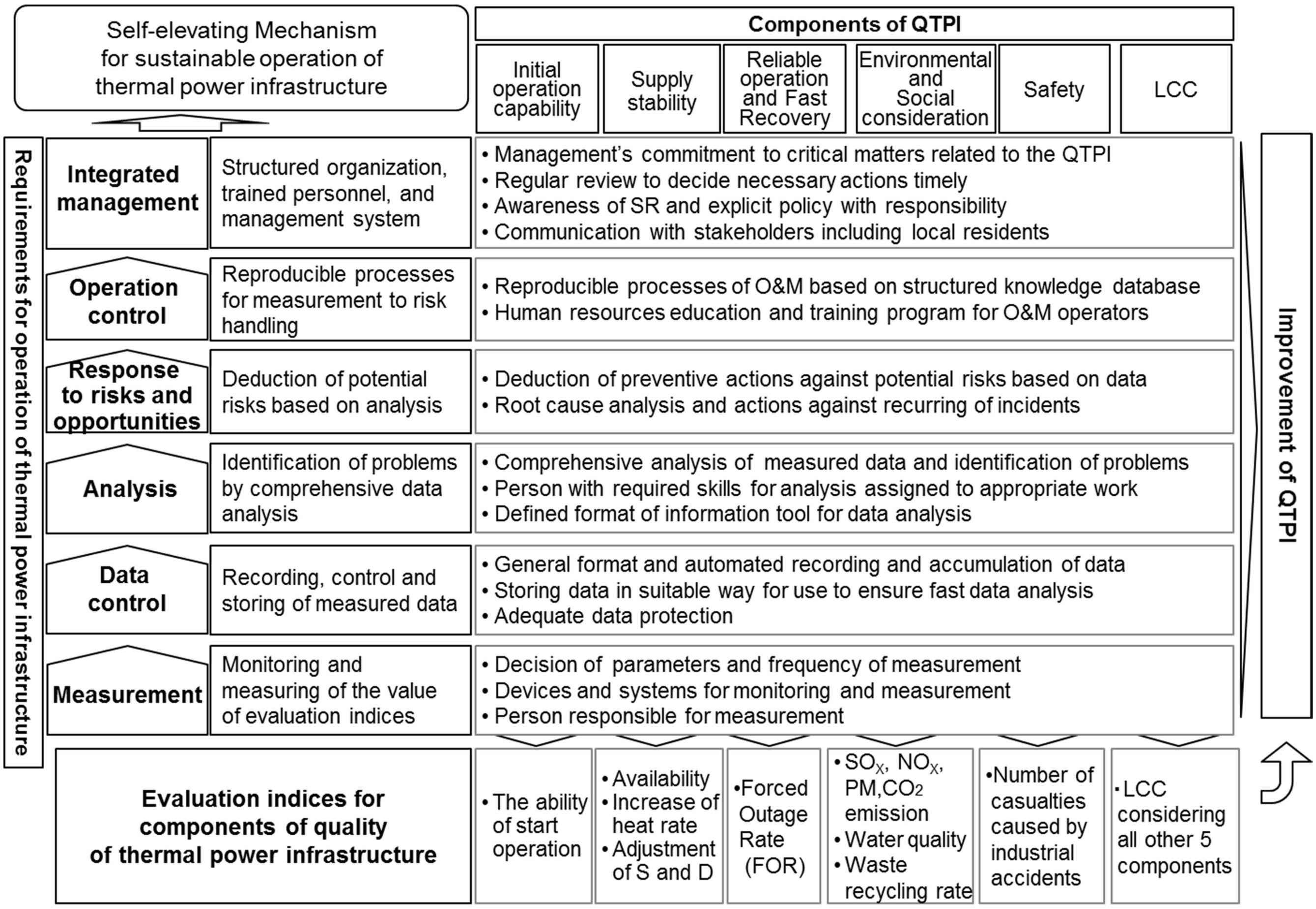

Figure 3 Components of quality of thermal power infrastructure, requirements for operation to improve quality and evaluation indices for components of quality

Annex A
(informative)

An example of LCC formula

A.1 Example of LCC formula considering all 5 other components

An example of LCC of the thermal power infrastructure can be calculated by the following formula.

$$C_{lcc} = (C_{past} + C_{future})/(P_{past} + P_{future})$$

where

C_{lcc} life cycle cost of thermal power infrastructure

C_{past} sum total of actual costs combining EPC costs, fuel costs, O&M costs, and social costs

C_{future} sum total of future costs combining fuel costs, O&M costs, social costs, and decommissioning costs

P_{past} sum total of actual power generation from the commencement of operation to the present

P_{future} sum of power generation from present onwards

Note 1: Convert the future C_{future} and P_{future} into current value.

Note 2: The past C_{past} and P_{past} are accumulated actual values, so do not adjust them like price correction.

Note 3: Calculate social costs by setting appropriate unit prices and coefficients.

(1) Calculation example of C_{future} (sum total from the present to *y* years later converted into current value)

$$C_{future} = \sum_{y} \left\{ (C_{f,y} + C_{O\&M,y} + C_{s,y} + C_{disp}) \times (1+r)^{-y} \right\}$$

where

$C_{f,y}$: fuel costs y years later

$$C_{f,y} = F_y \times P_{fuel}$$

where

F_y : fuel consumption y years later [MJ]

$$F_y = P \times (8760 \times A_{av} - t_{aFOH}) \times (R_{HCR} + D_{HCRY} \times y)$$

P: rated output [MW]

A_{av}: actual annual average availability [%]

R_{HCR}: current heat rate [MJ]

D_{HCRY} : actual annual average increase in heat rate [MJ/(MWh・year)]

t_{aFOH}: actual annual average forced outage time [h/year]

P_{fuel}: unit price of fuel [$/MJ]

$C_{O\&M,y}$: O&M costs y years later

$$C_{O\&M,y} = P_{g,y} \times C_{O\&M/P}$$

where

$P_{g,y}$: power generation y years later [MWh]

$C_{O\&M/P}$: O&M costs per unit power generation [$/MWh)]

$C_{s,y}$: social costs y years later

$$C_{s,y} = F_y \times C_{CO2}$$

where

C_{CO2}: CO2 emission costs per unit fuel consumption [$/MJ]

C_{disp} : disposal cost

r : discount rate (to be determined based on the interest rate on government bonds and other risk factors, such as currency exchange)

(2) Calculation example of P_{future} (sum total from the present to y years later converted into current value)

$$P_{future} = \sum_{y} \left\{ P \times (8760 \times A_{av} - t_{aFOH}) \times (1+r)^{-y} \right\}$$

where

P rated output [kW]

A_{av} actual average availability [%]

t_{aFOH} actual annual average forced outage time [h/year]

r discount rate (to be determined based on the interest rate on government bonds and other risk factors, such as currency exchange)

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