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Framework of climate change risk assessment for telecommunication and electrical facilities

Recommendation ITU-T L.1506

International
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ENVIRONMENT AND ICTS, CLIMATE CHANGE, E-WASTE, ENERGY EFFICIENCY; CONSTRUCTION, INSTALLATION AND PROTECTION OF CABLES AND OTHER ELEMENTS OF OUTSIDE PLANT

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Recommendation ITU-T L.1506

Framework of climate change risk assessment for telecommunication and electrical facilities

Summary

Recommendation ITU-T L.1506 describes the framework for assessing climate change risk to telecommunication and electrical facilities. The framework consists of a risk assessment methodology and considerations for applying the defined methodology. The methodology specified in this Recommendation provides a climate change risk assessment that integrates multiple climate change risk factors into a single metric and shows the assessment result from an overall perspective.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T L.1506	2018-01-13	5	11.1002/1000/13461

Keywords

Climate change, climate change adaptation, risk assessment.

* To access the Recommendation, type the URL http://handle.itu.int/ in the address field of your web browser, followed by the Recommendation's unique ID. For example, http://handle.itu.int/11.1002/1000/11830-en.

FOREWORD

The International Telecommunication Union (ITU) is the United Nations specialized agency in the field of telecommunications, information and communication technologies (ICTs). The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of ITU. ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

NOTE

In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

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As of the date of approval of this Recommendation, ITU had not received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementers are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database at http://www.itu.int/ITU-T/ipr/.

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Framework of climate change risk assessment for telecommunication and electrical facilities

1 Scope

This Recommendation describes a framework for assessing climate change risks to telecommunication and electrical facilities. This Recommendation includes an overview of climate change-related risks, requirements for climate change risk assessment methodology, risk assessment methodology and considerations for using the defined methodology.

Development of climate change risk factors or of a weighting scheme for an individual risk factor is outside the scope of this Recommendation, as is the development of interpretation criteria for assessment results.

It should be noted that the methodology defined in this Recommendation is not intended for comparison among different organizations, but is mainly targeted at self-assessment purposes.

2 References

None.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following term defined elsewhere:

3.1.1 spider web chart [b-ISO/IEC TR 20913]: Chart that consists of multiple performance indicators which are set in a circle like a spider web.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 climate change risk factor: An environmental factor (temperature, humidity, precipitation, etc.) or natural disaster (hurricane, earthquake, etc.) that can impact telecommunication and electrical facilities.

NOTE – The terms "climate change risk factor" and "risk factor" are used interchangeably throughout this Recommendation.

3.2.2 climate change risk indicator: A defined measure for a risk factor.

NOTE – The terms "climate change risk indicator" and "risk indicator" are used interchangeably throughout this Recommendation.

3.2.3 climate change risk metric: An overall climate change-related risk metric integrating individual risk indicators by using the weighted spider web chart methodology.

NOTE – The terms "climate change risk metric" and "risk metric" are used interchangeably throughout this Recommendation.

3.2.4 overall climate change risk: The value of the overall climate change risk as calculated through the climate change risk metric.

3.2.5 weighted spider web chart: An extended spider web chart that allows different relative weights among multiple performance indicators of a spider web chart.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

CPU Central Processing Unit

RBS Radio Base Station

SMOP Surface Measure Overall Performance

$SMOP_W$ Weighted Surface Measure Overall Performance

5 Conventions

None.

6 Overview of climate change risks to telecommunication and electrical facilities

That global climate changes are likely to profoundly affect the global energy sector, which powers the world's society, is gradually being recognized. The energy sector provides the electricity and fuels that propel society and economy, including commerce, manufacturing, transportation, communications, healthcare, water supply and treatment, and other critical infrastructure and systems. That climate changes have a potential for disrupting normal economic operations and quality of life is becoming clear. In addition to efforts to reduce greenhouse gas emissions that may cause climate change, it is recognized that adaptation to and preparation for climate impacts can no longer be avoided. Among the various energy sources, electrical infrastructure is indispensable to daily life and is vulnerable to many types of natural disaster, such as earthquakes, extreme heat, thunderstorms, high winds, ice storms and floods. These climate-related risk factors include average and peak temperature changes; average, seasonal and peak precipitation and hydrology changes; more intense hurricanes; sea level rises and storm surges; as well as changes to ecosystems. Some of these phenomena have already become more frequent or severe because of climate change and these trends are expected to continue. Figure 1 shows some examples of damage to electrical facilities caused by climate change risk factors [b-NPG].

Underground pipe (Flooding) | Telephone poles collapse (Hurricane) | Underground cable duct collapse (Heavy rain)

Figure 1 – Examples of damage to electrical facilities due to climate change risk factors

The effects of major climate change risk factors are summarized as follows [b-NPG].

– Temperature rise: Electrical current passing through electrical plant causes the equipment to heat up. The maximum current rating of electrical plant is generally governed by the equipment's maximum permissible operating temperature. This temperature is usually determined by the type of conductor or insulation material involved, but there may be other considerations. If the ambient temperature increases, the available temperature rise decreases and the maximum current rating is reduced. Reduced ratings can be a particular problem with transformer ratings in urban areas where air-conditioning load is likely to have a coincident peak. A substantial proportion of distribution circuits now see maximum loadings occurring during summer hot spells as opposed to winter cold spells.

– Precipitation: Increased rainfall will result in increased river flow rates and a potential increase in flood levels. Overhead lines are generally not susceptible to flooding, but there is a potential for statutory safety clearances to be affected in flood conditions. Equipment operating at substations can be vulnerable to flooding if water reaches certain critical depths. Increased rainfall brings the risk of surface water and ground water flooding that could threaten substations. Flooding presents the most serious climate risk to electricity networks and this includes current flood risk, as well as the higher risks forecast as a result of climate change from increased rainfall and higher sea levels.
– Sea level rises and storm surges: These types of incident can have an effect similar to river flooding, except that the volumes of water are potentially far greater with more widespread flooding, greater damage to infrastructure and a longer recovery period.
– Wind storms: Widespread interruptions to customer supplies often happen in many areas. Although this type of incident can be very disruptive, repairs can normally be carried out relatively quickly.
– Ice storms: Ice storms have the potential to interrupt customer supplies for longer periods than wind storms and there have been a number of incidents in several countries, such as Canada. Ice storms can cause extensive damage to overhead electricity networks. Due to climate changes, an increase in the frequency of stormy weather is possible and this is likely to lead to more frequent periods of high winds that can pose a threat to electricity distribution networks due to falling trees and windblown material.
– Heat waves and drought: Drought and heat waves can lead to equipment being damaged due to high operating temperatures. Localized drying of subsoil can increase ground resistivity, reducing the ability of cables to dissipate heat into the ground, leading to rapid degradation and failure.
– Lightning: Lightning storms frequently occur in many areas and can damage overhead lines and connected equipment. Distribution circuits are more difficult to protect against lightning and generally suffer more damage than transmission equipment.
– Vegetation: Increased vegetation growth rates and extended growing seasons are already affecting overhead lines resulting in higher costs to maintain clearance to conductors.

According to analysis results, climate changes and their impacts on electrical infrastructure are important for several reasons.

– Electrical facilities are designed based on regional features, such as historical climate data and the presence of natural resources.
– Estimated near-term and long-term threats of climate change and vulnerabilities to electrical facilities can vary considerably by region or location.
– Adequate resilience strategies for electrical facilities depend on regional and local circumstances, such as available resources, population trends, electricity demand and the mix of projected climate impacts.
– Electrical facilities such as electricity transmission and distribution facilities are usually installed outside, so they are vulnerable to various climate change impacts.

In order to investigate the relationship between climate changes and electrical facilities, it is necessary to assess major climate change risk factors. Currently, many activities provide regional and localized information as well as insights to assess risks and to develop effective resilience strategies for electrical systems vulnerable to climate change. The activities provide a base of regional information for decision makers in order to identify which projected changes in climate could be important for their specific energy assets and to evaluate a set of strategies for effectively increasing local, regional and national energy system resilience to climate change. These activities describe the key climate change trends, including rising temperatures and sea levels, changing precipitation patterns as well as more frequent and severe episodes of extreme weather that are already forcing electrical facilities to operate outside their design conditions and that threaten to damage or disrupt critical electrical infrastructure. Climate change and extreme weather increase the risk of damage to electrical equipment and facilities and cause shifts in electricity supply and demand [b-NPG] [b-ITU-T FG-DR&NRR].

Some industry initiatives already exist to develop indicators in order to evaluate various risks of climate change [b-NPG]. However, since multiple risk factors exist, the development of simple and effective methods for assessing the overall risk of climate change-related hazards is necessary. For this purpose, a spider web chart method is used to present the measured values of indicators. Spider web charts are frequently employed to analyse the efficiency, risks or effectiveness of the objectives in various fields. This Recommendation presents requirements and methodology for assessing risk metrics that show climate change risk factors using spider web chart methodology.

6.1 Climate change impacts on telecommunication facilities

Telecommunication networks consist of various types of equipment, such as radio base stations (RBSs), switches and repeaters, that require electricity. Unstable power supply can cause telecommunication failure because the RBSs, wireless repeaters and their subsystems require electricity for operation. Among these, RBSs are typical facilities that are vulnerable to climate change as they are often installed outdoors. Thus, RBSs may be more vulnerable to various climate change risk factors because they are more exposed to natural environmental factors, such as high or low temperatures, humidity, wind, snow and precipitation. RBSs play an important role in providing continuous telecommunication service, so their failure can affect access to communications. RBSs include subsystems such as rectifiers, accumulators, feeder lines and air-conditioning equipment. Table 1 lists typical subsystems installed in an RBS facility [b-GSM-LTE].

Table 1 – Example functions of subsystems in a radio base station facility

Type	Functions
Rectifier	Convert the AC power into DC power
Battery	Supply power to the base station in case of emergency
Feeder line	Transmit communication signals from the base station to the antenna
Air-conditioning equipment	Air-conditioning equipment for stable operation of communication equipment

Figures 2 and 3 show examples of climate change impacts on telecommunication and electrical facilities. Figure 2 depicts telephone poles damaged by a tsunami [b-ITU Response]. The potential of a tsunami to cause huge damage to telecommunication and electrical facilities is known. For example, a tsunami occurred in 2011 and cut off the supply of electricity, which stopped the operation of an RBS. Mobile and especially fixed telephony services were severely impacted. Telecom operators suffered damage to fixed network equipment that resulted in 385 buildings being out of service; 90 transmission routes were broken and 6 300 km of coastal aerial cables as well as 65 000 utility poles were washed away or otherwise damaged [b-ITU-T FG-DR&NRR]. Figure 3 shows a fallen telecommunication tower caused by a cyclone in a Pacific island. Climate changes may increase the intensity and frequency of tropical cyclones and cause damage to the telecommunication infrastructure [b-ITU-APRD].

Figure 2 – Damaged telephone pole due to tsunami [b-ITU Response]

Figure 3 –Telecommunication tower brought down by a cyclone [b-ITU-APRD]

Climate changes affect the ICT industry in many ways, e.g., the frequency and intensity of weather-related impacts are expected to increase as a consequence. Typical climate change impacts related to the telecommunication sector are as follows.

– Increase in the average heat level causing a rise in operating temperature of telecommunication equipment that affects stable operation and may result in premature hardware failure.
– Temperature rises lead to an increase in heat-related health and safety risks to telecommunication facility workers and suppliers.
– More frequent lightning strikes due to the increase in storm frequency may cause power outages by damaging transmitters and overhead cables.
– Changes in humidity may accelerate corrosion rates and patterns in telecommunication equipment.
– Sea level rises may increase the frequency of storm surges and tsunamis that accelerate the corrosion rate of coastal telecommunications infrastructure and the risk of flooding of underground infrastructure.
– Tsunami damage to outlying plant facilities, such as substations in coastal areas.

– Floods submerge cables in tunnels, potentially causing cable damage.

– Landslides destroy underground ducts and may cause failure of network structures.

– Telecommunication poles or towers collapse and aerial structures are damaged physically by hurricanes, tornadoes or wind storms.

As discussed, climate change cab have various effects on the stable operation of telecommunication facilities. Therefore, the development of climate change mitigation and adaptation methods for telecommunication facilities is required. This Recommendation presents a framework for assessing the impact of climate change risk factors on telecommunication networks and electrical facilities.

7 Background to the methodology of climate change risk assessment

There are many types of climate change risk factor for telecommunication and electrical facilities, such as those relating to flooding, heavy rain, ice, wind and lightning. As telecommunication and electrical facilities can be exposed to multiple climate change risks, they can be represented by a combination of indicators. Climate change risks comprise many risk factors and demand a multivariate quantification model. There are several methodologies for risk assessment using multiple indicators, but two are typically applicable.

– Theoretic modelling: This methodology is useful for identifying the baseline for assessment results. The development of a theoretical optimized engineering model, based on the creation of an idealized assessment specific to each utility, is required. The theoretical model incorporates the topology, demand patterns and population density of the service territory. Typical limitations of this methodology are that the theoretical models that support it can be very complicated and the structure of the underlying component relationships can be obscured through a set of assumed coefficients used in the optimization process.

– Indicator-based benchmarking: This methodology includes a set of specific assessment indicators, such as volume billed per worker, consumed energy per product, quality of service and coverage. Usually, these indicators are presented in ratio form to check the scale of operations. These partial measures are generally available and provide the simplest way to perform comparisons. Trends (e.g., in indicator values) can direct attention to potential problem areas.

Among the methodologies mentioned in the previous paragraph, indicator-based benchmarking methodology is useful for assessing climate change risk to telecommunication and electrical facilities because there exist many climate change risk factors and others may arise in future. Therefore, the adoption of the easily extensible methodology is necessary. The indicator-based benchmarking method may be further categorized into two types: performance indicator-based methods and chart-based methods.

– Performance indicator-based methods: In this category, the performance of the target is evaluated through performance indicators for the target. For example, frequency for central processing units (CPUs) and bytes for storage are typical performance indicators. This category allows accurate performance evaluation and comparison among targets, if the performance indicators are defined. A typical limitation of this approach is that it is difficult to compare the evaluation results if performance indicators belong to different dimensions with different units that are not easily aggregated.

– Chart-based methods: In this category, the performance indicators are evaluated by using chart methods, such as pie, bar, line and spider web. This category is useful for evaluating performance by displaying multiple performance indicators, making analysis easier.

As the chart-based approach supports multiple indicators simultaneously, it is appropriate for a holistic method. The spider web chart in particular is well suited for the display and analysis of multiple indicators. It is also useful for displaying multiple measurement values of several indicators in a single chart, e.g., temporal measurement values of several indicators. Thus, this Recommendation focuses on the spider web chart-based climate change risk assessment model. The spider web chart model has been adopted due to its capability for self-visualization and overall risk assessment. Spider web charts are popularly used to assess and quantify the overall performance of various evaluation objectives. Figure 4 shows examples of the application of spider web charts to performance evaluation.

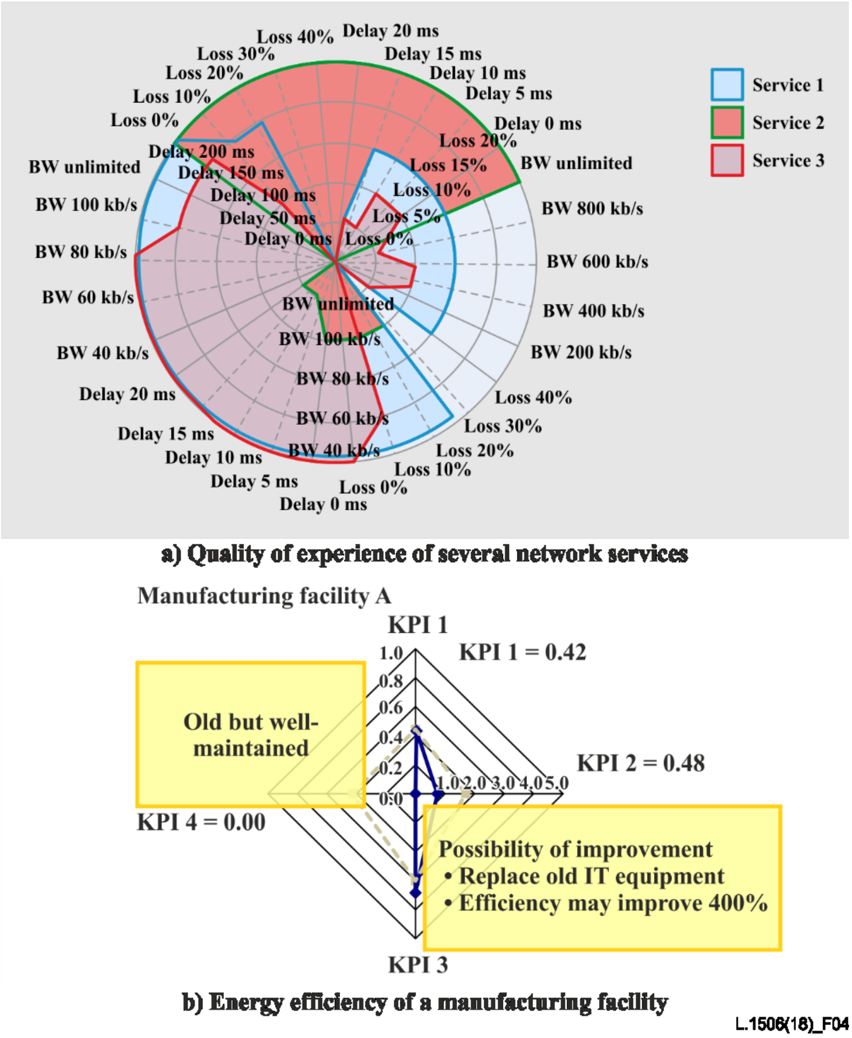

Figure 4 – Examples of the application of spider web charts to performance evaluation

7.1 Usefulness of spider web chart methods for visualizing climate change risk factors

The spider web chart consists of a set of indicators that are arranged in a circle. Indicator values are usually normalized from zero to one, one being the highest possible value, but unnormalized indicators may also be utilized. Individual indicators may need to be inverted in order for different indicators to correlate. It is clear that the quality of spider web charts depends on the validity, reliability and comprehensiveness of the assessment indicators. Spider web charts are known advantageously to show the status of assessment indicators.

Regarding visualization capability, spider web charts provide a synoptic description of multiple measurements and make trade-offs between measurements visible. Figure 5 shows a spider web chart consisting of three sets of measurements and five indicators. In Figure 5, each indicator has the originally measured unnormalized value; the greater the distance from the centre of the chart, the higher that value. Figure 5 enables visual comparison of multiple measurements and indicators to give overall status.

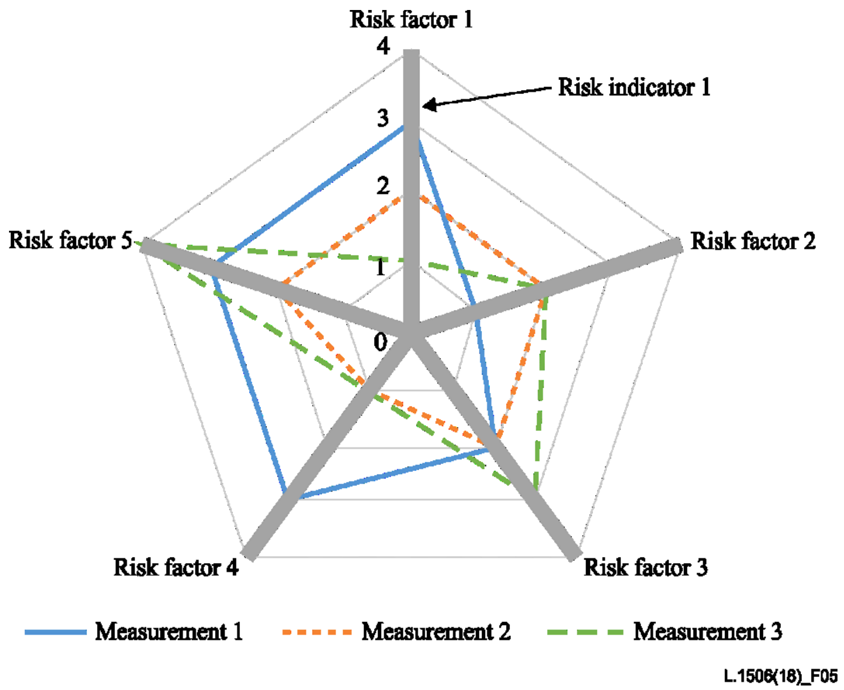

Figure 5 – Examples of assessment for three measurements using five risk factors

Due to their advantages, spider web charts are widely used to assess various evaluation objectives and to present a visual comparison of performance in various fields. As discussed in this clause, the visualization capability of a spider web chart can help telecommunication and electrical facility administrators to monitor specified risk factors and their changes over time in order to improve the stability of the facilities. For example, by regularly constructing the spider web chart showing the state of each risk factor, the telecommunication and electrical facility administrator can effectively monitor the temporal behaviour of risk factors. Further, the spider web chart has general advantages for assessing climate change risk factors over conventional charts, such as bar charts, when assessing multiple measurement values of multiple indicators.

8 Requirements for climate change risk assessment

This clause discusses the requirements for climate change risk assessment when applying the spider web chart method to the evaluation of risk to telecommunication and electrical facilities.

8.1 Differences between the relative importance among climate change risk factors

There are multiple climate change risk factors to measure and evaluate the risk to telecommunication and electrical facilities from various perspectives. However, depending on the situation of the facilities, the relative importance of each risk factor may not be equal. Those situations may include policy, locations and cost of reducing each risk indicator. Figure 6 shows several examples of location variability.

(a) (b) (c)

Figure 6 – Location variations of telecommunication and electrical facilities

Facilities located in a cold region [Figure 6(a)] may consider cold weather and snow risk factors more important than others. Similarly, facilities near a river [Figure 6(b)] need to consider rainfall and flooding risk. In desert areas [Figure 6(c)], however, high temperature and low humidity may be more important than other risk factors.

The arbitrariness of deciding different weights for each of the climate change risk factors needs to be considered as it is possible for each organization to set its own weights on risk factors and even to apply different weights for different facilities. Thus, each telecommunication and electrical facility may have its own weights on risk factors, for which the rationale and verification or validation for the declared weights should be recorded.

8.2 Overall risk assessment

As discussed in clause 8.1, there are many types of climate change risk factor. However, from an administrator's point of view, it is more convenient to monitor a single metric that shows the overall status of a facility. When a single metric for the overall status shows the overall potential risk for the facility, the administrator can compare risks between facilities and examine specific risk factors in detail.

Policymakers often combine individual indicators to create an overall metric, generally using a weighted average of the indicators. Thus, an overall risk metric is developed that could be used to communicate relative risk to a wide audience. An overall risk assessment using a spider web chart can easily be performed using an area-based performance evaluation method that serves as a quick reference index. A spider web chart can also be used for indicators that belong to the same category, so that an integrated metric can be obtained for indicators belonging to this category [b-IEEE TBME].

9 Climate change risk assessment methodology

9.1 Allocation of different relative weights to each risk factor

As discussed in clause 8, spider web charts are useful for evaluating multiple indicators by displaying the measurement results of each indicator in a circle and analysing the status of the indicators. However, conventional spider web charts assume equal weight among the indicators. Depending on the situation or location of an electrical facility, the relative importance for each risk factor may be different. The situation of an electrical facility includes policy, locations and costs of reducing each risk factor. Therefore, it is necessary to allow different relative weights for the risk factors. One way to enable different relative weights to risk factors is to develop a weighted spider web chart.

Let α, β, γ, δ be the relative weights of each climate change risk factor (risk factor 1, risk factor 2, risk factor 3, risk factor 4, respectively), where $\alpha + \beta + \gamma + \delta = 1$, $0 \leq \alpha \leq 1$, $0 \leq \beta \leq 1$, $0 \leq \gamma \leq 1$,

$0 \leq \delta \leq 1$. The weighted spider web chart can be constructed as shown in Figure 7. The angles of each risk factor are decided based on the relative weights of each risk factor. The weight of risk indicators can be determined by organizations using the methodology.

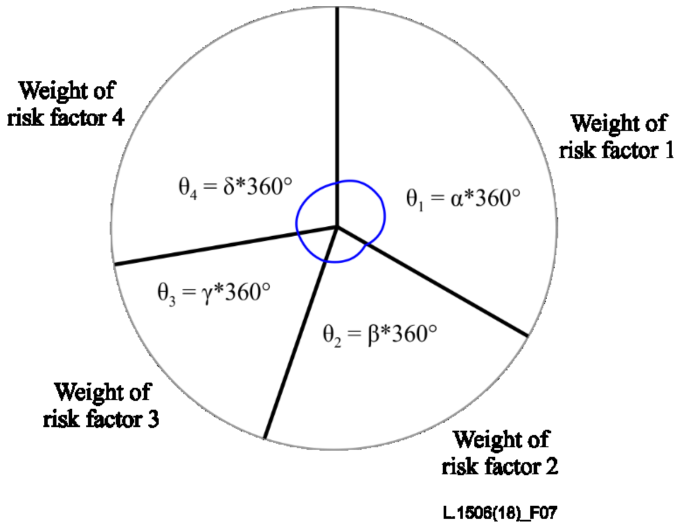

Figure 7 – Allocations of different relative weights to four risk factors

In general, a weighted spider web chart can be constructed as follows. Let w_i and θ_i be the weight of the ith risk factor and central angle of the ith arc, respectively. Also, n denotes the number of risk factors.

$$\theta_i = w_i \times 360, \qquad 1 \leq i \leq n$$

$$\sum_{i=1}^{n} w_i = 1, \qquad 0 \leq w_i \leq 1$$

In order to display the values of the indicators in a single weighted spider web chart, the values of the indicators need to be rescaled so that the values are fitted into a single weighted spider web chart. The rescaling can be done by a normalization method. There are several normalization methods and min-max normalization is used in this Recommendation. Min-max normalization is performed as follows.

Let v be a value of an indicator and $v_{\min}$ and $v_{\max}$ be the minimum and maximum value of v. Also, let v_{nor} be the normalized value of v. Then, v_{nor} can be calculated as follows.

$$v_{\text{nor}} = \frac{v - v_{\min}}{v_{\max} - v_{\min}} \text{ where } 0 \leq v_{\text{nor}} \leq 1$$

Let r_i be the normalized value of the ith risk indicator $(1 \leq i \leq n, 0 \leq r_i \leq 1)$.

Then, a weighted spider web chart is constructed by dividing a circle with radius 1 into n arcs and the central angle of the ith arc is θ_i. The circle of the weighted spider web chart is marked off in accordance with the number of risk factors and the weights calculated in the foregoing. Some radial lines are formed by the centre of the circle and the marked point. These lines are regarded as coordinate axes. Figure 8 shows a spider web chart having different relative weights among four risk factors.

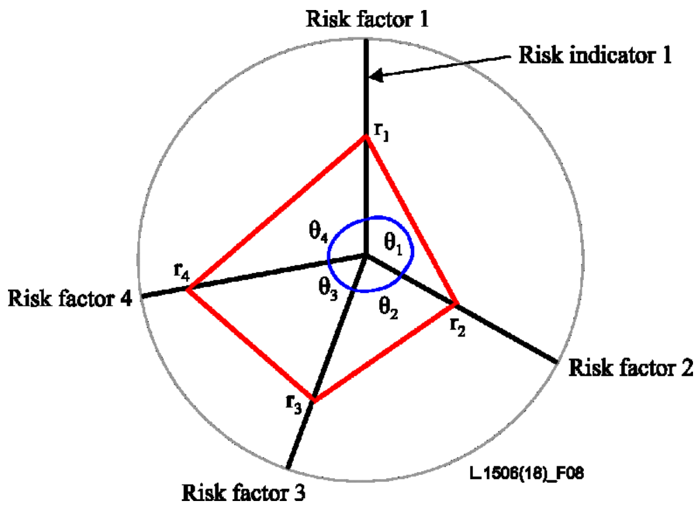

Figure 8 – Weighted spider web chart for four risk factors having different relative weights

9.2 Overall climate change risk assessment

Conventional spider web charts have an advantage for the visualization of measurement results of multiple indicators in a single chart. However, the overall risk of multiple indicators is not provided. In order to resolve the limitation of the conventional spider web charts, surface measure of overall performance (SMOP) is generally used [b-FS I 98-205].

Figure 9 shows an example of applying SMOP to a spider web chart with four risk indicators, whose normalized values are given in Table 2. SMOP indicates the surface area of a polygon marked by blue line and it can be calculated as follows: Since the four risk factors have the same relative weights, the central angle of each risk factor is 90°. Also, the spider web chart can be divided into four triangles, so the SMOP of the spider web chart in Figure 9 is the sum of the areas of four triangles.

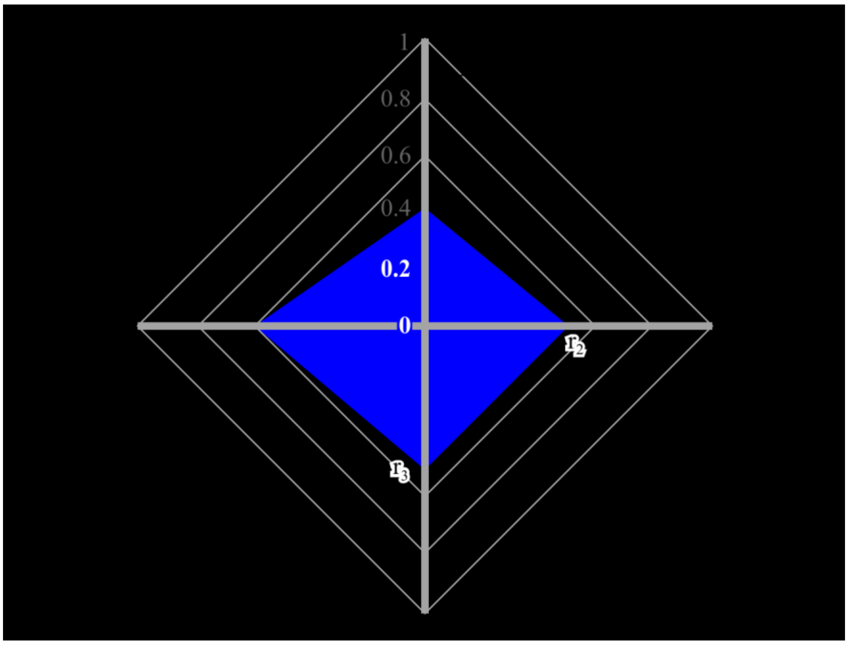

Figure 9 – Example surface measure overall performance calculation of a spider web chart

Table 2 – Normalized values of the four risk indicators

	Risk factor 1	Risk factor 2	Risk factor 3	Risk factor 4
Indicator value	0.4 (r_1)	0.5 (r_2)	0.5 (r_3)	0.6 (r_4)

Therefore, the SMOP of Figure 9 can be calculated as follows:

$$\mathrm{SMOP} = \frac{\sin 90° \times r_1 \times r_2}{2} + \frac{\sin 90° \times r_2 \times r_3}{2} + \frac{\sin 90° \times r_3 \times r_4}{2} + \frac{\sin 90° \times r_4 \times r_1}{2}$$

$$= \frac{\sin 90°}{2} \times \{(r_1 \times r_2) + (r_2 \times r_3) + (r_3 \times r_4) + (r_4 \times r_1)\}$$

$$= \frac{\sin 90°}{2} \times \{(0.4 \times 0.5) + (0.5 \times 0.5) + (0.5 \times 0.6) + (0.6 \times 0.4)\}$$

$$= 0.44$$

The generalized equation with *n* risk indicators can be formulated as follows:

$$\mathrm{SMOP} = \frac{\sin 360°/n}{2} \times \{(r_1 \times r_2) + (r_2 \times r_3) + \cdots (r_n \times r_1)\}$$

The SMOP method can be applied to a weighted spider web chart in order to assess the overall risk, i.e., weighted surface measure overall performance ($\mathrm{SMOP_W}$) [b-IEEE ICTC].

$\mathrm{SMOP_W}$ can be calculated as follows:

$$\mathrm{SMOP_W} = \sum_{i=1}^{n} \left\{ \frac{\sin \theta_i}{2} \times (r_i \times r_j) \right\}$$

where $\theta_i = w_i \times 360, \sum_{i=1}^{n} w_i = 1$

$$i = 1, \cdots, n$$

$$j = (i+1) \bmod n$$

In the above equation: n denotes the number of risk indicators and r_i and r_j indicate the values of the ith and jth risk indicator; w_i and θ_i represent the weight of the ith risk factor and the central angle, respectively.

In this Recommendation, the overall climate change risk is defined as the value of $\mathrm{SMOP_W}$ of a weighted spider web chart consisting of multiple climate change risk indicators that have different relative weights.

Figure 10 shows an example of a weighted spider web chart with four climate change risk indicators having different relative weights.

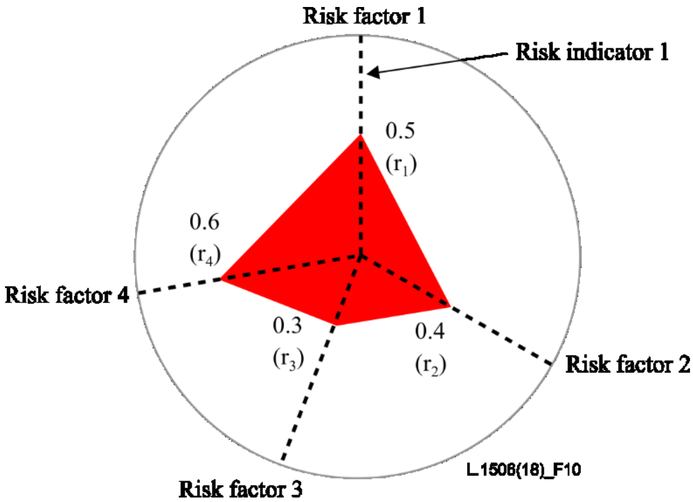

Figure 10 – Example of a weighted spider web chart for a weighted surface measure overall performance calculation

Table 3 and Table 4 list the normalized values and relative weights of each risk indicator.

Table 3 – Normalized values of four risk indicators

	Risk factor 1	Risk factor 2	Risk factor 3	Risk factor 4
Indicator values	0.5 (r_1)	0.4 (r_2)	0.3 (r_3)	0.6 (r_4)

Table 4 – Relative weights of four risk factors

	Risk factor 1	Risk factor 2	Risk factor 3	Risk factor 4
Weights	0.35	0.2	0.15	0.3

$SMOP_W$ of the weighted spider web chart in Figure 10 is calculated as follows:

$SMOP_W$

$$= \frac{\sin(360° \times 0.35) \times 0.5 \times 0.4}{2} + \frac{\sin(360° \times 0.2) \times 0.4 \times 0.3}{2} + \frac{\sin(360° \times 0.15) \times 0.3 \times 0.6}{2}$$
$$+ \frac{\sin(360° \times 0.3) \times 0.6 \times 0.5}{2} = 0.14$$

Therefore, the overall climate change risk is calculated as 0.14.

As presented in this clause, the weighted spider web chart is a useful method for evaluating the facility that is exposed to multiple risks. Further, by applying the $SMOP_W$ scheme to the weighted spider web chart, it is possible to present an overall climate change risk.

9.3 Considerations for applying the risk assessment methodology

The climate change risk assessment methodology defined in this Recommendation is based on the weighted spider web chart method that relies on the geometric visualization of risk indicators. Thus, there exist considerations for using the risk assessment methodology, as follows.

– Ordering of the risk indicators on the weighted spider web chart: Since a weighted spider web chart is constructed by connecting the marked points of each risk indicator on a circle, the shape of the weighted spider web chart can vary according to the ordering of the risk indicators arranged on the chart. Therefore, it is necessary to keep the same order of risk indicators on the chart when comparing two weighted spider web charts.

– Scaling and normalization of the risk indicator values: When each risk indicator has different scales or dimensions, it might be difficult to construct a weighted spider web chart. Each axis of the weighted spider web chart has the same length, so the scale for each axis may be different because the possible ranges for each axis are different. In that case, normalized values of the risk indicators can be used to construct a weighted spider web chart.

10 Documentation of climate change risk assessment results

When documenting assessment results using a weighted spider web chart, the report should include at least the following information:

– overall climate change risk value;
– number of risk factors;
– type of each risk factor (e.g., rainfall, snowfall, temperature, humidity, etc.);
– weights of each risk factor;
– measurement values of risk indicator for each risk factor;
– facility identification (e.g., name, facility type, address, owner/administrator, etc.);
– date of assessment;
– purpose of reporting;
– historically recorded data of overall climate change risk;
– reference to this Recommendation, i.e., Recommendation ITU-T L.1506.

Appendix I

Example of use of the climate change risk assessment methodology

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

This appendix presents an example of the application of the climate change risk assessment methodology defined in this Recommendation to a power transformer in an electricity pole.

Step 1: Choose target facility:

– Target facility for monitoring: power transformer in an electricity pole

Step 2: Determine climate change risk factors for monitoring:

– Types of climate change risk factor: temperature, humidity, wind speed, precipitation, snowfall, drought, insolation, lightning, wind storm, snow storm, etc.

– In this example, it is assumed that the administrator considers temperature, wind speed, precipitation and lightning as risk factors for monitoring:

  – Risk factors for monitoring: temperature, wind speed, precipitation, humidity.

Step 3: Determine relative weights to risk factors:

– The administrator or organization owning the facility may determine the relative weights of risk factors depending on the situation. It is considered that all risk factors for monitoring have the same relative weights by default. In this example, Table I.1 lists the relative weights of four risk factors.

Table I.1 – Relative weights of four risk factors

	Temperature	**Wind speed**	**Precipitation**	**Humidity**
Weight	0.4	0.2	0.2	0.2

Step 4: Calculate the central angles of each risk factor:

– The central angle of the weighted spider web chart is calculated by using the relative weights determined in Step 3. Table I.2 lists the central angles for risk factors.

Table I.2 – Central angles of four risk factors

	Temperature	**Wind speed**	**Precipitation**	**Humidity**
Central angle (°)	144	72	72	72

Step 5: Measure the values of risk indicators for each risk factor:

– The administrator measures the values of risk indicators. Various methods such as sensor-based measurement or manual measurement may be used. Table I.3 lists the measurement values of the four risk indicators.

Table I.3 – Measurement values of four risk indicators

	Temperature	**Wind speed**	**Precipitation**	**Humidity**
Indicator value (unit)	40 (°C)	3 (m/s)	35 (mm)	100 (%)

Step 6: Normalize the measurement values of the risk indicators:

– Since each risk indicator may have a different dimension and scale, it is necessary to normalize the measurement value between 0 and 1 to be fitted into a weighted spider web chart. In this example, a minimum-maximum normalization method is used. Table I.4 shows the normalized values of four risk indicators:

$v_{\text{nor}} = \frac{v - v_{\min}}{v_{\max} - v_{\min}}$, where $0 \le v_{\text{nor}} \le 1$; v is the measured value of a risk indicator

Table I.4 – Normalized values of four risk indicators

	Temperature	Wind speed	Precipitation	Humidity
Measured value (unit)	40 (°C)	3 (m/s)	35 (mm)	100 (%)
Minimum value	30	0	20	20
Maximum value	80	10	90	100
Normalized value	0.20	0.30	0.21	1.00

Step 7: Calculate overall climate change risk using the SMOP$_W$ method:

Overall climate change risk

$$= \frac{\sin 144° \times 0.2 \times 0.3}{2} + \frac{\sin 72° \times 0.3 \times 0.21}{2} + \frac{\sin 72° \times 0.21 \times 1.0}{2} + \frac{\sin 72° \times 1.0 \times 0.2}{2}$$

$$= 0.16$$

Optionally a weighted spider web chart may be constructed in order to provide a visual representation. Figure I.1 shows the weighted spider web chart using the examples in this appendix.

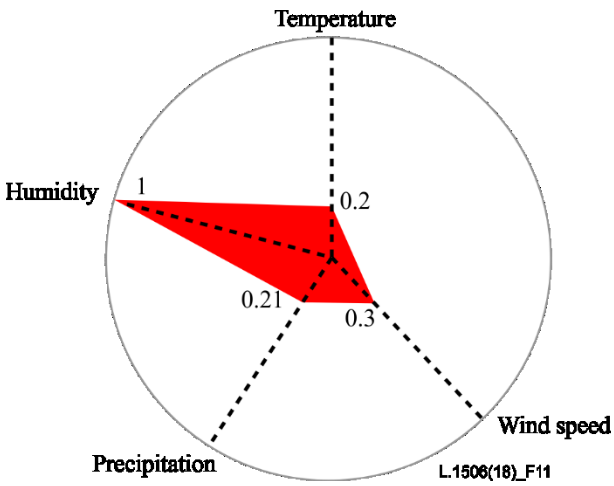

Figure I.1 – Weighted spider web chart constructed using the example

Step 8: Document the calculated overall climate change risk and relevant information:

– overall climate change risk value: 0.16;

– number of risk factors: 4;

– type of each risk factor: temperature, wind speed, precipitation, humidity;

– weights of each risk factor:

  – temperature: 0.4;

  - wind speed: 0.2;
  - precipitation: 0.2;
  - humidity: 0.2.
- measurement values of risk indicator for each risk factor:
  - temperature: 40;
  - wind speed: 3;
  - precipitation: 35;
  - humidity: 100.
- facility identification:
  - facility type: power transformer
  - address: 123 Road, AAA City, BBB Country
  - administrator/owner: CCC/DDD Electric
- date of assessment: YYYY-MM-DD
- purpose of reporting: weekly monitoring
- historically recorded data of overall climate change risk: not available
- assessed according to Recommendation ITU-T L.1506

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