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PS1 / CHALLENGES & NEW SOLUTIONS IN DESIGN AND CONSTRUCTION OF NEW OHL

10629_2022

Latest Design Standard on Structures for Overhead Transmission Lines in Japan

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OVERVIEW

What is JEC std. on structure for OTLs ?

- Japanese Electrotechnical Committee (JEC) publishes.
- Verification methods for damage limit states are shown.
- The basic values of loads are for a 50-year return period (RP).
- RP conversion factors are also provided.

New std. JEC-5101 will be released in 2022.

- Previous ed. has limitations in evaluating **natural forces in complex climate in Japan** and applying them to design.
- ✓ Wind speed/direction by complex terrain and weather.
- ✓ Snow accretion modeling and its combination with wind.
- ✓ Evaluation of earthquakes and applications to OTLs
- We resolved these challenges and new std. will be released.

This poster shows main changes compared to previous ed.

Tab. 1 JEC publications and natural disasters after 1979.

Year	JEC publications / Natural disasters	tower collapse/damage
1979	JEC-127-1979 published	
1980	55-Gosetsu (wet-snow accretion in Tohoku district)	62 collapses
1986	61-Gosetsu (wet-snow accretion around Kanto-metropolitan area)	8 collapses
1991	Typhoon Mireille (strong wind in Chugoku, Shikoku and Kyusyu districts)	36 collapses
1993	Typhoon Yancy (strong wind in Shikoku and Kyusyu districts)	19 collapses
1995	Great Hanshin-Awaji Earthquake (magnitude 7.3)	1 collapse by landslide
1999	Typhoon Bart (strong wind in Kyusyu district)	13 collapses
2002	Typhoon Higos (strong wind in Kanto district)	9 collapses and damages
2011	Great East Japan Earthquake (magnitude 9.0)	1 collapse by landslide
2015	JEC-TR-00007 (technical report) published	
2019	Typhoon Faxai (strong wind in Kanto district)	2 collapses
2022	JEC-5101 (revised version of JEC-127-1979) expected to be published	

Many natural disasters on towers → Needs to revise 1979 ED.

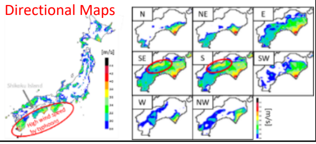
Fig. 1 Tower collapses and damages

Fig. 2 Terrain of Japan

Topics of new std. JEC-5101

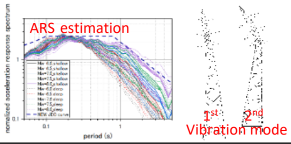
TOPIC1: Wind resistant design

New "Directional" basic wind speed maps.
> Enable rational directional wind resistance design.
> Use of long-term Meteorological model output (WRF).
> Typhoons, monsoons, downslope windstorms etc.



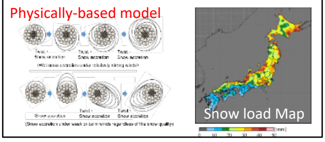
TOPIC2: Seismic resistant design

New layer shear force coefficient method
> Acceleration response spectrum estimation method.
> New coefficients considering various reference data
> Consideration of 2nd vibration mode.



TOPIC3: Snow resistant design

New snow load map and application method.
> New physically-based snow accretion model.
> Production of long-term icing data and new map
> Method to combine snow and wind loads



TOPIC1: WIND RESISTANT DESIGN AND NEW DIRECTIONAL BASIC WIND SPEED MAPS

Previous ed. has problems in estimation of directional wind speed at construction points. → We developed new directional basic wind speed maps.

Directional wind-resistant design method

* This method is same with previous ed. (JEC-TR-00007-2015)

- Wind loads on OTLs vary rapidly with wind direction.
- Equivalent static wind load method by gust effect factors.
- Unique points: elaborate formulae applicable to arbitrary wind directions, stringing conditions with similar accuracies.
- ✓ Sub-system wind loads for arbitrary wind directions and their combination by non-simultaneity of fluctuating components.
- ✓ Tension forces and non-simultaneity reduction coefficients introduced by correlation coefficients of fluctuating components between forward and backward spans.
- ✓ 72 wind directions with a 5deg-pitch

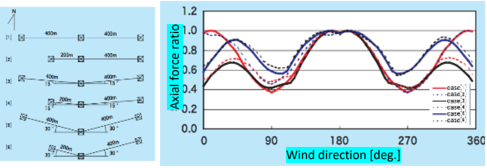


Fig. 3 Axial force ration and wind direction

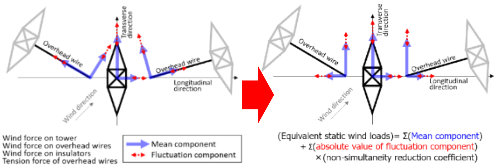


Fig. 4 Schematics of sub-system wind loads and sum of them

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Definition of basic wind speeds

- 150-year RP value of 10-min mean wind speed at 10m.
- Surface roughness category II (similar to category B in IEC)
- Represents wind speed in an area of about 5km.
- 8 directional sector (N, NE, … NW) and 2 seasonal sector (DEC-MAR/Monsoon and APR-NOV/Typhoon).

New directional basic wind speed maps

- **Values**: quality-controlled observation data (150 sites)

✓ Equivalent values for roughness category II at 10m are estimated by land use mesh data published by NGI of Japan.

✓ Local topographic accelerations/decelerations are eliminated by table of speed up ratio or fluid dynamics model.

- **Horizontal distribution**: meteorological database "CRRCMEr2"

✓ Dynamical downscaling by meteorological model (WRF)

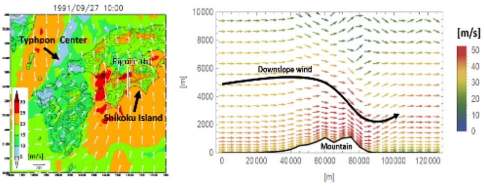
✓ Long-term (1957-2019), 5km-horizontal grid spacing data.

⇒ Bias of horizontal distribution of RP values is modified at observation points.

These maps and JEC-5101 enable designers to conduct rational wind-resistant design considering the directional characteristics at constriction points.

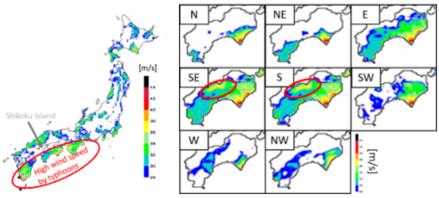
Characteristics of new maps

- Strong winds by typhoons: Pacific coast over southern Japan
- Downslope windstorms: Strong winds over inland regions mainly on top or leeward side of mountains.



(a) 10 m above the ground (b) Vertical distribution over Shikoku island

Fig. 5 Wind velocities in CRRCMEr2 (Typhoon Mireille in 1991)



(a) Maximum speed of all directional sectors (b) Directional maps (shikoku Island)

Fig. 6 Examples of directional basic wind speed maps (APR-NOV)

TOPIC2: LAYER SHEAR FORCE COEFFICIENT METHOD FOR SEISMIC DESIGN

Problems and improvements

- In previous ed., acceleration response spectrum (ARS) estimation method are not shown.
- Layer shear force coefficient method in previous ed. is based on limited reference data and disagrees with several cases because of ignoring 2nd vibration mode.
- Improvements of new ed. JEC-5101

✓ POINT 1: Ground-surface ARS estimation method based on Ground Motion Prediction Equation (GMPE).

✓ POINT 2: New coefficients considering various reference data and 2nd vibration mode.

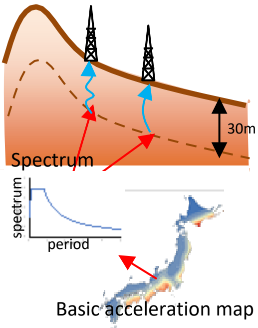
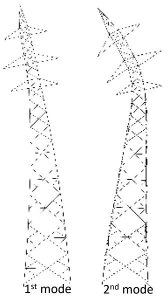


Fig. 7 Schematics of ARS estimation.



Displacements are exaggerated for visualization

Fig. 8 Vibration modes.

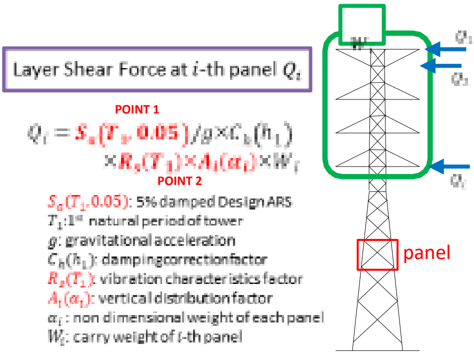


Fig. 9 Estimation based on layer share force coefficient method

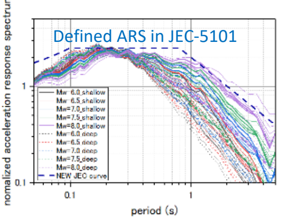


Fig. 10 Defined ARS on the base

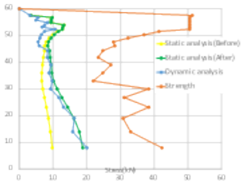


Fig. 11 Comparison between static and dynamic analyses

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TOPIC3: RESISTANT DESIGN FOR SNOW LOADS

Background and Motivation

- In JEC-127-1979, a snow load map was published, but no statistical analysis using continuous icing data was performed. **The snow load, wind load, and their combination are experience-based.**
- In previous ed., **a practical model to evaluate snow accretion on overhead power lines, which has been developed in the 1990s, was only reviewed.** Since it was necessary to improve the accuracy, no attempt to create a snow load map was made.

→We developed a more reliable snow evaluation method.

Snow accretion model

- A new physically-based snow accretion model is adopted in JEC-5101 to generate a long-term icing data from meteorological observations and analysis.

- ☐ This model is based on a cylindrical accretion model that is used to generate a snow load map in Europe.
- ☐ An identification method of precipitation type is introduced. This method is empirically based on the melting processes of snowflakes falling aloft. Shedding is also accounted as a random process.
- ☐ Accretion efficiency is evaluated according to the snow accretion type that is classified from the wind speed and the precipitation type.
- ☐ **This model works well both for wet and dry snow accretion**, which was validated using field observation from full-scale transmission lines (Figure 15).

Generation of a snow load map

- The snow accretion model is applied to simulate the time series of the radial of thickness on a conductor. (icing data of 40 years or more at 760 stations are created and used).
- The vertical profiles of temperature and wind speed are estimated assuming the constant temperature lapse rate and the roughness category II of the ground surface.
- This simulation is performed for a lot of setups with various height above the ground (10-150 m, 10-m intervals), 4-line directions, and 3-conductor diameter.
- The peak-over-threshold (POT) method as the extreme value analysis is applied. **Snow accretion with a return period of 50 years is converted to the equivalent radial of thickness with a density of 600 kg m^{-3}.**
- The extreme value of snow accretion at each station is calculated by consideration of the maximum among the setups. Spatial distribution is estimated using a simple interpolation technique (Figure 16).

Combination of ice and wind loads

- In JEC-5101, **the basic wind speed for designing under icing conditions is set from 15 m s^{-1} to 18 m s^{-1}, depending on the equivalent radial of snow thickness** (Figure 17).
- In addition, **when applying the directional wind resistance design method, the above basic wind speed is increased by 2 m s^{-1}** in order to account easily the non-linear effect of aerodynamics and the structural nonlinearity under relatively weaker winds.

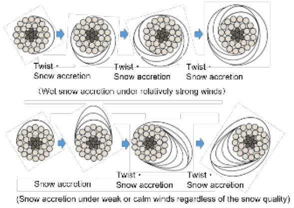

Fig.12 Schematic diagram of changes in snow accretion body shape according to snow accretion type

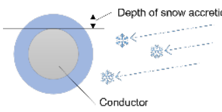

Fig 13 Schematic concept of cylindrical snow accretion

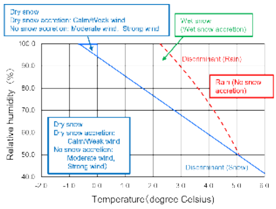

Fig 14 Schematic diagram for discrimination of precipitation particle type and snow accretion type (elevation: 430m)

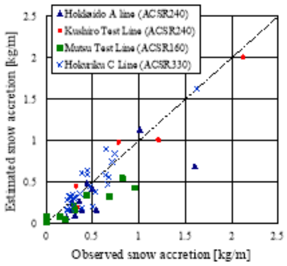

Fig. 15 Comparison between observed and estimated snow accretion

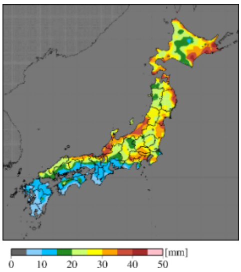

Fig. 16 Estimated snow loads considering a 50-year return period

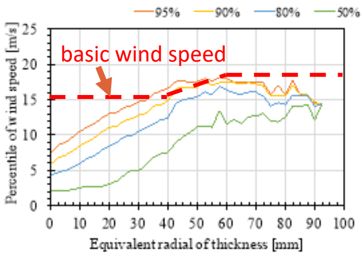

Fig. 17 Percentile of the wind speed under icing conditions

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