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B2 Transmission Lines
PS 2 : Latest Techniques in Asset Management, Capacity Enhancement, Refurbishment

Use of anti-torsional pendulums and interphase spacers to reduce Ice accumulation on 154kV and 400kV lines and increase their reliability

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SUMMARY

Ice accumulation on OHTL conductors causes permanent and temporary malfunctions and disrupt the smooth operation. The icing on the conductors is also a source of malfunction due to mechanical and dynamic effects.

It is very difficult to respond to permanent failures caused by ice loads and wind loads. Most of the time, even fault detection can be made with difficulty due to reasons such as closed roads, limited visibility and continuing rainfall. Especially, it takes months to fix the faults that result in tower collapse. Therefore, measures to prevent malfunctions caused by ice and wind are of vital importance.

In this session the techniques to prevent ice aggregation on phase conductors and OPGW/earth-wires will be presented, as well as the positive output of an initiated pilot project as well on dedicated lines of the Turkish TSO, running in ice areas.

KEYWORDS

Ice Loads, Wind Loads, IPS, Anti Torsion Pendulums

Use of Anti Torsion Pendulums and Interphase Spacer in Turkey

Atmospheric icing is a complex phenomenon affected by many fundamental components such as time, weather conditions and topography. It occurs as a result of precipitation icing, such as increased freezing rain and wet snow, or in-cloud icing, where excessively suspended droplets freeze. The icing types are examined in two main groups, precipitation icing, which is more advantageous in both, creating an ice model and preventing ice formation. In contrast, in-cloud icing is a very difficult type of icing to model and prevent.

Fig.1 – Ice accumulation on conductor

Fig.2 – Collapsed tower

In case of Turkey, particaularly, precipitation icing is observed more often. The duration of precipitation is critical in precipitation-induced icing. In cases where no action is taken, it can cause irreversible consequences.
The prevention of frost-induced breakdown is carried out with the following chronology in transmission system of Turkey.

1. Field measurements for determining ice and wind load on the line route
2. Reinforcing the existing towers of lines running in areas with heavy ice loadings
3. Installation of anti-torsional pendulums and interphase spacer (IPS) in "heavy icing" areas

As it is known, anti rorsional pendulums and interphase spacers prevents the formation of an ice helix as the torsional movement of the conductor is limited. Anti torsional pendulums are preferable used on earthwires and OPGW, respectivelly on phase conductors up to 154kV.
In case of earthwires and OPGW the reducted static weight due to less icing increases the clearance towards the phase conductors.
Interphase spacers are mainly used to guaranetee a safe phase clearance between adjacents phases, thus avoiding electrical outages and mechanical damages during severe weather conditions due to ice shedding or conductor galloping.

Fig.3 – IPS on a 154kV DC line

In Turkey, anti-torsional pendulum and interphase spacers (IPS) applications were introduced in 2018. The first pilot application was carried out on the 154 kV OHTL from Kovanlık to Altınordu. Both phase circuits has been equipped with interphase spacers, anti-torsional pendulums has been installed on the earth-wires. However, to verify the performance of the IPS and anti-torsional pendulums, they have been assembled on section 2 and not mounted on section 1. In the first winter after installation, 1 outage occurred in section 2 and 11 outages occurred in section 1, which had no protection against icing.

In the case of single circuit towers, anti-torsional pendulums installation was performed for both phase conductors and earth-wires. However, in cases where heavy wind loads are detected on these lines, IPS were applied on the phase conductor too. Double-circuit lines were protected with anti-torsional pendulums and IPS.
The influence of the additional static weight on the conductor sagging was verified upfront. Re-adjustments of the conductor sag were necessary in long spans, like crossings.

The expected benefits from these applications can be listed as follows:

1- Prevention of static and dynamic overloads on towers by reducing ice formation
2- Prevention of short circuit interruptions in case of ice shedding and galloping events
3- Preventing conductors from approaching each other due to unbalanced icing or reduced phase spacing
4- Limiting conductor swing in lines installed in the direction of the effective wind direction

Fig.4 – IPS on a 380kV line

Anti-torsional pendulums are installed with 50-60 m distance. Radial ice aggregation is reduced as it limits the rotation of the conductor. Ice sheds off in different periods in the same span which reduces the dynamic effect.

IPS are mounted on 154 kV lines with ~ max.150 m distance. When setting the IPS installation length it is recommended to verify the real site distance between conductors whenever possible. Otherwise, IPSs are exposed to torsional loads and buckling loads.

In the field investigations carried out after the assembly, it was determined that anti-torsional pendulums did not exhibit high performance in case of icing caused by intense wind. However, there was no temporary breakdown due to icing, but due to the dynamic loads during the ice shedding event. This limits the phase-to-phase or phase-to-earth conductor clearances.
Another observation is that anti-torsion pendulums are ineffective in the formation of icing in the cloud. In the line sections where this type of icing occurs, IPS and phase-earth interceptors will prevent the formation of temporary faults caused by dynamic oscillations.

Fig.5 – Site supervision during ice event

Fig.6 – Span with partial ice aggregation

The priority in preventing malfunctions caused by ice load and wind load is to determine the maximum ice and wind loads correctly and to prepare line projects in accordance with these values. Anti-torsion pendulums and IPS are very successful, especially in preventing temporary failures caused by dynamic oscillations. It also contributes positively to the reduction of precipitation-induced ice formation.
In Turkey, with the installation of the IPS and anti-torsion pendulums a serious drop in the number of permanent and temporary malfunction has been recorded. Because of annual variations of ice and wind load formation at least 5 years' observation of post-assembly performances will give more accurate results.

Statistical information for some assembled lines

Name of Line	2017	2018	2019	2020
154 kV Mut RES-Gezende RES EİH	6	6	0	0
154 kV Tunceli-Mercan HES EİH	15	24	23	0
400 kV Yeşilhisar-Konya 4 EİH	17	13	16	0

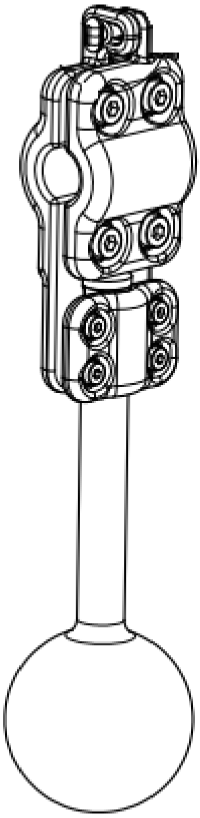
Table 1 – Statistics of line interruptions

The number of “winter-induced” failures in Turkey for some of the critical lines are given in the table above. There was no winter failure in these lines after the assembly.

Field detections in IPS and anti-torsion pendulums designs in Turkey

The basic approach in anti-torsional pendulums design is to increase the torsional stiffness. This can be achieved by moving the pendulum center of gravity away from the wire center as much as possible.

Pendulums, which will operate under the heavy wind effect, must be used together with armor rods in order not to damage the outer wires of the conductor it is installed. Again, it is recommended to use wedge-locking washers against loosening of bolts and nuts that may occur due to the effect of wind induced vibrations. In pendulums design, spherical counterweight part should be preferred because it shows superior performance compared to cylindrical form. In the IPS design, on the other hand, low weight and superior performance for all loads scenarios (i.e compression, buckling, torsion) are targeted. Lightness for IPS can be achieved with composite insulators and aluminum material.



For the installed IPS in Turkey an adjustable design (telescope principle) was preferred in order to adjust the exact phase distance, thus avoiding buckling loads. This design is considered to have higher electrical and mechanical performance. As in anti-torsion pendulums loosening of bolt-nut connections is an essential, it is also recommended to use locking washers for bolted connections too. In order to prevent tearing and twisting in the connections between the telescopic pipes, 3 connection bolts should be used. In IPS clamp connections, articulated connections should be chosen to prevent high moment formation at the connection point in all planes. The fact that the clamp center and the conductor are in the same plane will prevent the formation of additional torsional moment. Misalignment between centers will cause permanent failures resulting in breakages. The bolted clamps should be installed on armor rods to reduce the mechanical stress towards the conductor.

Fig.7 – Anti-torsion pendulum design

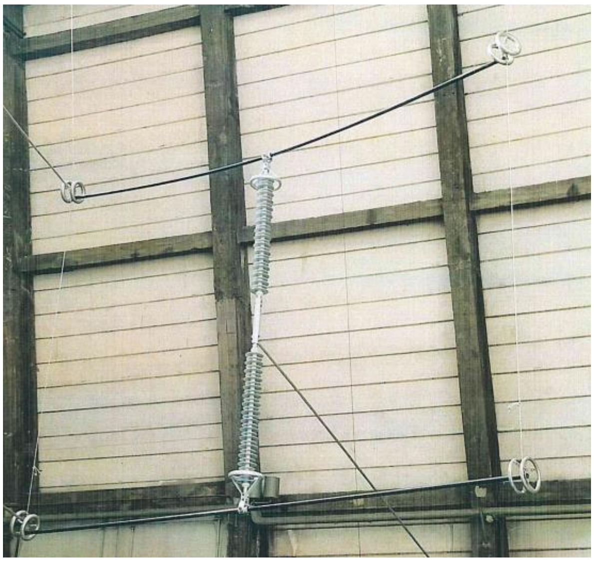


Fig.8 – 154kV IPS in test lab

In IPS installations, while determining the IPS length, choosing the phase-phase distances according to the project criteria may lead to erroneous results. Therefore, when determining the IPS installation length, the current phase-to-phase distances in the field should be determined.

To sum up, after 2018 in Turkey installed anti-torsion pendulums and interphase spacer showed high performance and reduced the ice and weather-based interruptions essentially. Clearer determinations will be made after longer observation periods and the widespread use of the application.

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