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IMS Guidelines: Minimum Standard for Grounding and Lightning Protection System at the IMS Stations.
Standard content, implementation and its influence on data availability statistics

P. Martysevich(1), G. Diendorfer(2), Y. Sid Ahmed(1)

Poster No. PT4.3 - IT-160

POSTER

(1) Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization, IMS/ED
(2) OVE Service GmbH

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Based on statistics and experience in station's installation and operations, IMS/ED in cooperation with OVE developed a comprehensive guidelines / company standard for Grounding and Lightning Protection System at the IMS stations. The document first edition was issued in 2010 and then revised in 2018-2019.

The document provides comprehensive information for design and implementation of grounding and lightning protection system for all four IMS technologies. The guidelines steadily became an integrated part of all terms of references for IMS stations' installations and upgrades..

The standard has been implemented at over 20 IMS stations, which lead to significant reduction of damages caused by lightning strikes and power surges at IMS network and, consequently, to increased data availability in the IMS network

Source: https://actu.epfl.ch

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Background:

Initial surge and lightning protection methods implemented at IMS installations were very heterogeneous and based on multiple national and companies' standards and practices, partly obsolete and not reflecting requirements of modern equipment installed at IMS stations.

As a result, there were observed different approaches, loss of efforts and money and impossibility to assess quality of lightning protection system using same criteria.

Need of a standard approach arose with completion of IMS and accumulated statistics of failures during station's operation.

Power supply damaged by induced surge, ZALV

Lightning attractor with signs of multiple lightning strikes, IS41

Stations heavily damaged by lighting strikes / power surges in 2000-2009:

IS59, IS41, ZALV/IS46, IS35, IS47, IS09, IS11, DBIC and many others.

4903 relevant reports in IRS as of today

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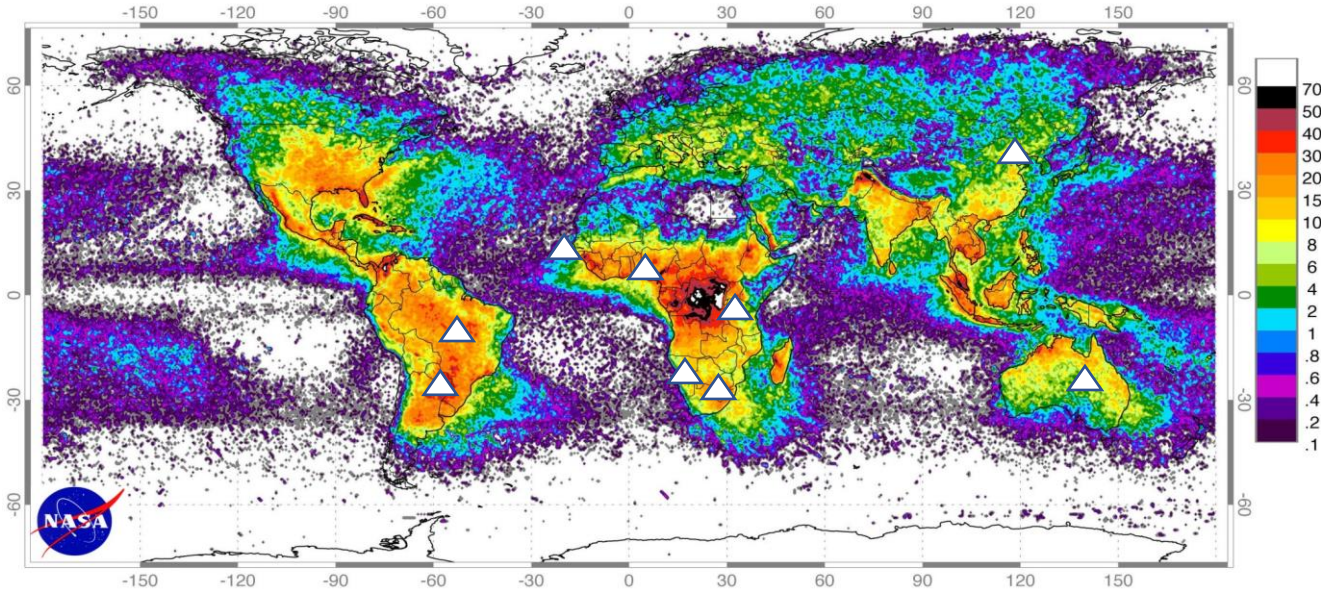
Locations of some stations (white triangles) damaged by lighting strikes on the map of global distribution of lightning activity.

Station	Expected annual flashes / km^2
IS41 / CPUP	40-45
IS47 / BOSA	20-25
IS35 / TSUM	10-15
IS09 / BDFB	10
IS17 / DBIC	20-25
IS32 / KMBO	10-15



High Resolution Full Climatology Annual Flash Rate

Global distribution of lightning April 1995-February 2003 from the combined observations of the NASA OTD (4/95-3/00) and LIS (1/98-2/03) instruments

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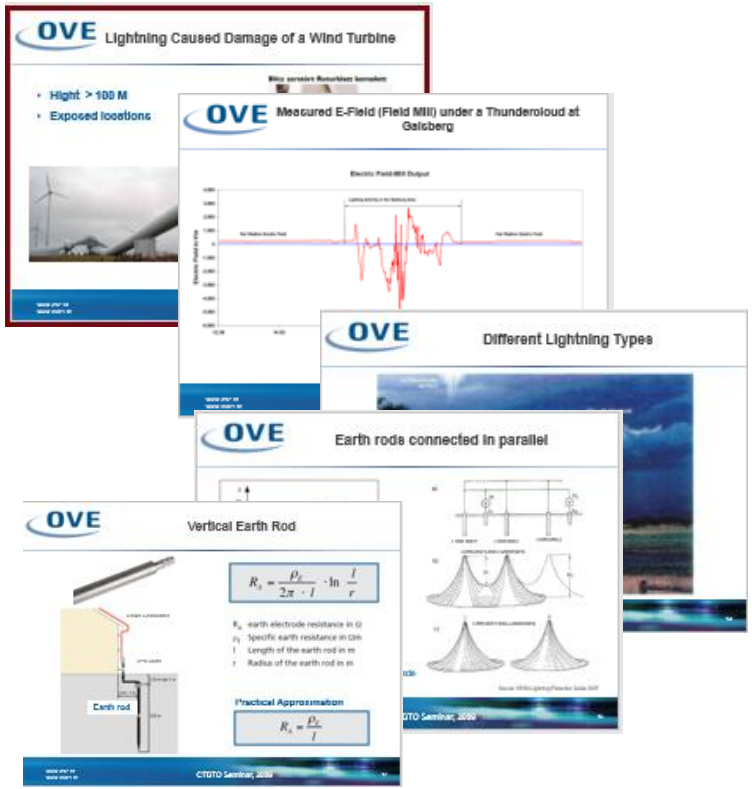
In order to elaborate a common approach to the surge protection, lightning protection and grounding requirements at IMS installations, IMS/ED started in 2009 a project for preparation of the Minimum Standard for Grounding and Lightning Protection System at the IMS Stations.

The project included

- Lightning Protection and Grounding Workshop, prepared by recognized international experts in corresponding area, OVE
- Preparation of the Standard by IMS in collaboration with OVE.



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Minimum Standard for Grounding and Lightning Protection

The result of the project is the Standard.

The document is based on the modern international (IEC) and European (EN) standards:

- **IEC 62305,** PROTECTION AGAINST LIGHTNINGS
- **IEC 61643,** LOW-VOLTAGE SURGE PROTECTIVE DEVICES
- **IEC 60664-1:** INSULATION COORDINATION FOR EQUIPMENT WITHIN LOW-VOLTAGE SYSTEMS
- **IEC 61000-4-5:** ELECTROMAGNETIC COMPATIBILITY (EMC)
- **IEEE STD 1410-2004:** IEEE GUIDE FOR IMPROVING THE LIGHTNING PERFORMANCE OF ELECTRIC POWER OVERHEAD DISTRIBUTION LINES

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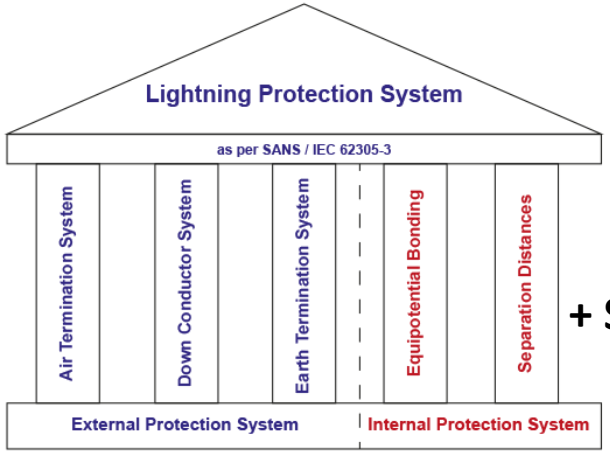
The Standard describes in details minimum requirements to Lightning Protection System of IMS installations:



Lightning Protection System (LPS) consists of the following sub-systems:

- **Air-termination System:** lightning rods / attractors
- **Down-conductors:** conductors between lightning rods and grounding electrodes
- **Earth-termination System:** grounding electrodes
- **Equipotential Bonding:** connection of chassis of all equipment to the ground
- **Surge Protection:** surge protection devices on all incoming lines.

+ SURGE PROTECTION!

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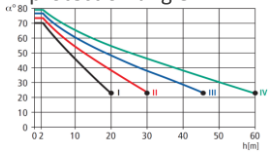
Main requirements to LPS of IMS installations are based on Lightning Protection Level II definitions as described in IEC 62305-1

SAMPLES OF LPL II REQUIREMENTS:

Air-termination system protection angle



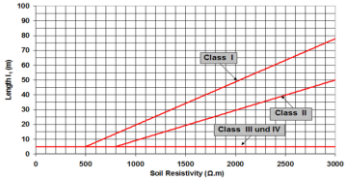
Rolling Sphere Diameter and Mesh Method

Class of LPS	Rolling Sphere Radius *r* (m)	Mesh Size *W* (m)
I	20	5 x 5
II	30	10 x 10
III	45	15 x 15
IV	60	20 x 20

Down-conductors

Class of LPS	Typical Distance (m)
I	10
II	10
III	15
IV	20

Minimum length of horizontal earth electrodes



Expected surge currents due to lightning flashes

LPL	Low voltage systems			Telecommunication lines		
	Flash to the service	Flash near the service	Near to, or on the structure	Flash to the service	Flash near the service	Near to, or on the structure
	Source of damage S3 (direct flash) Waveform: 10/350 µs (kA)	Source of damage S4 (indirect flash) Waveform: 8/20 µs (kA)	Source of damage S1 or S2 (induced current only for S1) Waveform: 8/20 µs (kA)	Source of damage S3 (direct flash) waveform: 10/350 µs (kA)	Source of damage S4 (indirect flash) measured: 5/300 µs (estimated:8/2 0 µs) (kA)	Source of damage S2 (induced current) Waveform: 8/20 µs (kA)
III-IV	5	2.5	0.1	1	0.01 (0.05)	0.05
I-II	10	5	0.2	2	0.02 (0.1)	0.1

Why LPL II?

The cases which require lightning protection are following:

(1) Existence of large crowds
(2) Necessity of service continuity
(3) Very high lightning flash frequency
(4) Tall isolated structures
(5) Buildings containing explosive or flammable materials
(6) Buildings containing irreplaceable cultural heritage

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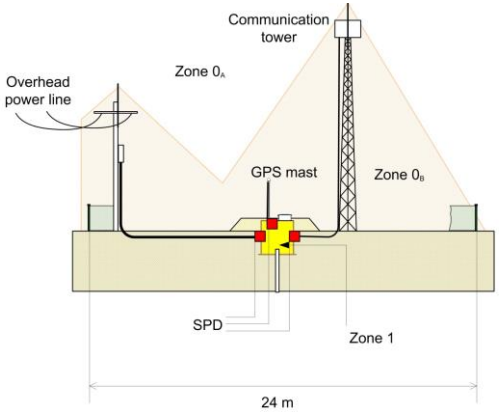
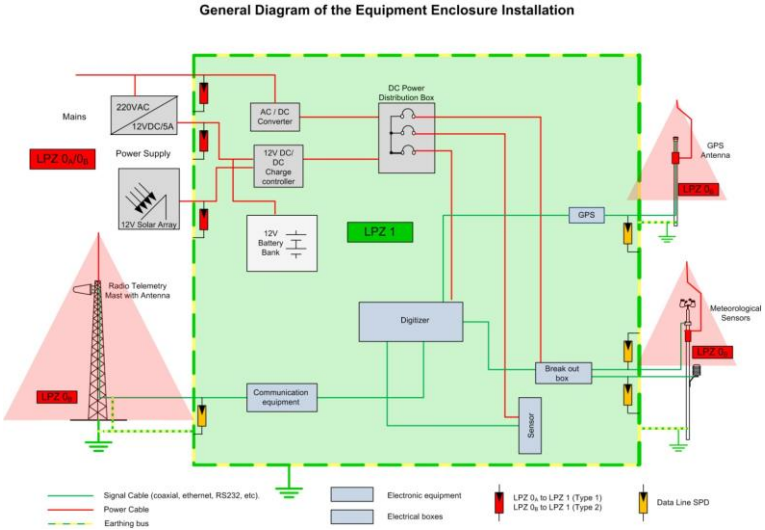
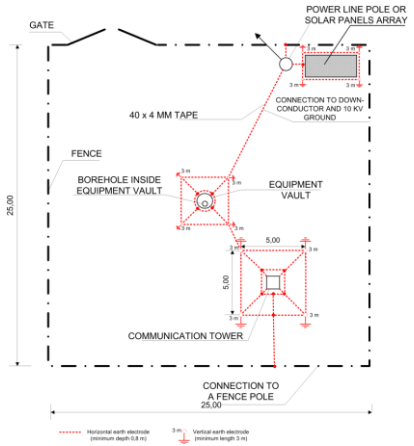
Lightning Protection Level II in figures:







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Coordinated Surge Protective Devices (SPD):

SPDs Type 1 ***(lightning current arresters)***: must be installed if partial lightning currents from direct strikes must be discharged (tested with current waveform 10/350 µs)

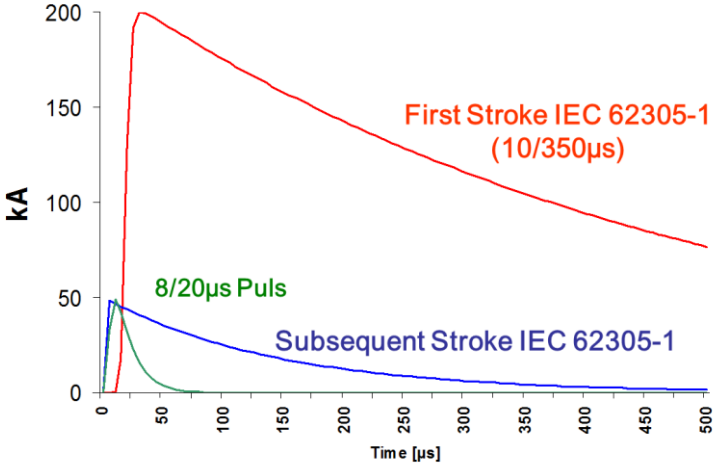
Type 1 SPD

SPDs Type 2 and Type 3 ***(surge arresters) are*** employed to protect against surges resulting from nearby lightning (tested with current waveform 8/20 µs)

Type 2 SPD

Type 3 SPD

Dataline protection:
Surge arrestors Type 1/2/3 exist for various data line interfaces/protocols (RS422, Ethernet, VHF radio, ...)



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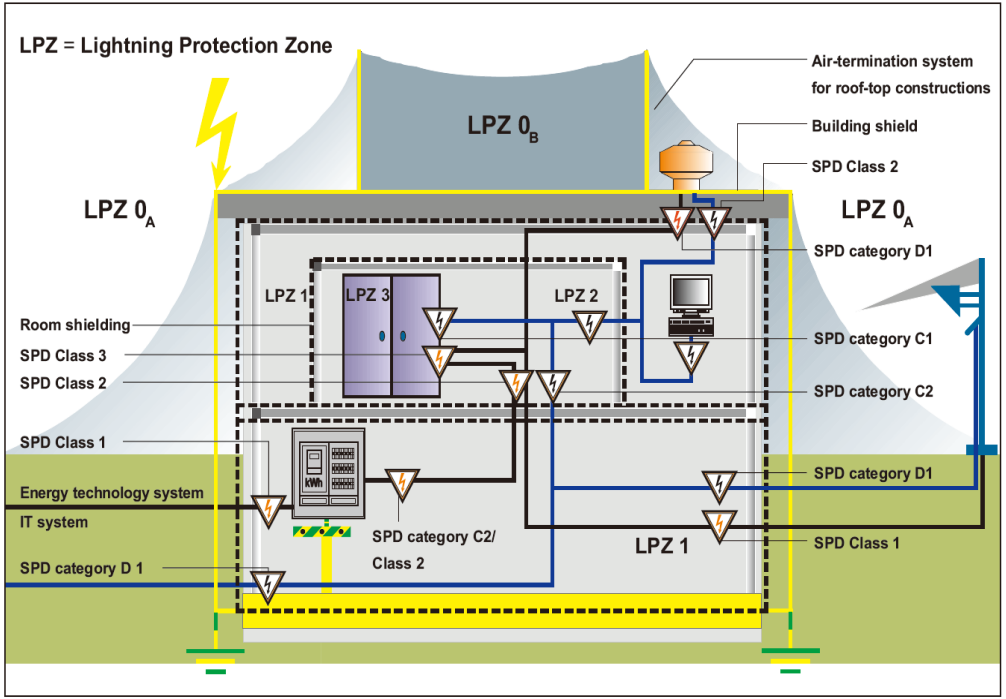
Lightning Protection Zones Concept:

Applied to complex installations (e.g. data or dispatch center) with high reliability requirements

Object and surrounding is divided in lightning protection zones

- LPZ 0_A: Direct strike and full lightning EM field
- LPZ 0_B: **NO** direct strike, full lightning EM field
- LPZ 1: Surge currents limited by current sharing and by SPDs at the boundary. Spatial shielding may attenuate the lightning electromagnetic field.
- LPZ 2, 3...: Surge currents further limited by current sharing and by SPDs at the boundary. EM fields attenuated by spatial shielding



Source: https://www.lsp-international.com/

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Technology Specific Situations:

The Standard accumulates extensive IMS and IMS equipment providers' experience in IMS technology specific situations:

- **Seismic installations**
- **Infrasound installations**
- **Radionuclide installations**
- **Hydroacoustic installations**

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Annex E, Compliance Matrix:

The Compliance Matrix is an integral part of the CTBTO Minimum Standard for Grounding and Lightning Protection and summarize the essential requirement for LPS for each sub-system with references to applicable standards, such as:

- **Design Parameters;**
- **Conductors Material;**
- **Diameter/cross-section of conductors**

The Compliance Matrix can and should be used as a check-list by contractor and PTS staff responsible for a station construction.

Part of Compliance matrix: Air-Termination System

	CTBTO guidelines minimum requirements	Reference	
AIR TERMINATION SYSTEM			
Design Parameters	Rolling sphere radius: 30m Mesh size: 10 m x 10 m Protection angle: see Table 2 of IEC 62305-3	IEC 62305-3, Table 2	
Air termination system material	Galvanized steel Stainless steel Copper Aluminum	IEC 62305-3, Table 6	
Air termination conductors diameter / cross-section	Galvanized steel: solid round Ø8 mm or cross section 50 mm^2 Stainless steel: solid round Ø8 mm or cross section 50 mm^2 Copper: solid round Ø8 mm or cross section 50 mm^2 Aluminum: solid round Ø8 mm or cross section 50 mm^2	IEC 62305-3, Table 6	

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Standard Implementation Status:

Starting from 2010, the Standard became an integral part of all technical terms of reference for IMS stations' constructions and upgrades.

Over the last 10 years the Standard was implemented at more then 20 IMS stations, among them at the stations with the highest rate of failures caused by lightning strikes and power surges, such as IS41, IS31, IS46/ZALV, IS47, IS09. Those 6 stations contributed up to **21%** of total lightning / power surge related tickets in the IRS in comparison to all SHI stations

Station	Date	Remarks
IS01 Argentina	2019	New installation
IS07 Australia	2013	Upgrade
IS09 Brazil	2017	Upgrade
IS14 Chile	2016	Upgrade
IS20 Ecuador	2017	New installation
IS31 Kazakhstan	2019	Upgrade
IS32 Kenia	2012	Upgrade
IS37 Norway	2013	New installation
IS40 Papua New Guinea	2012	New installation
IS41 Paraguay	2018	Upgrade
IS43 Russian Federation	2016	Upgrade
IS44 Russian Federation	2013	Upgrade
IS46 Russian Federation	2013	Upgrade
IS47 South Africa	2019	Upgrade
PETK Russian Federation	2013	Upgrade
ZALV Russian Federation	2013	Upgrade
KMBO Kenia	2012	Upgrade
WRA Australia	2013	Upgrade

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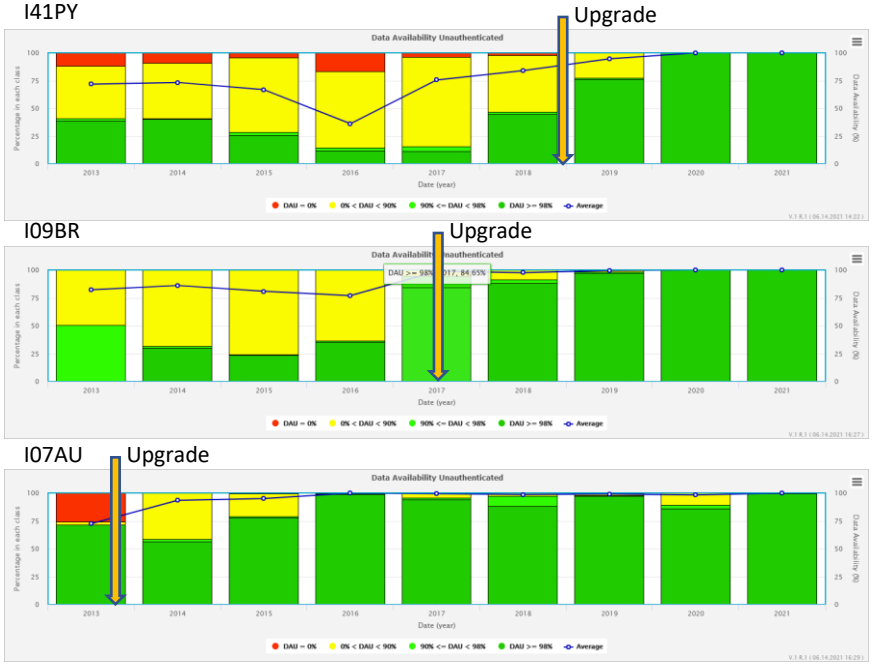
Results of implementation following station upgrades:

The results of the Standard implementation have been analyzed using the Data Availability / Timely Data Availability (DA/TDA) statistics of the upgraded stations and the IMS as a whole.

It has to be mentioned that the upgrade of Lightning Protection System is normally a part of a complex station's upgrade.



Data Availability (DA) graphs of some stations in subject, with the indication of the upgrade works time

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Results of implementation following station upgrades (DA for Primary Seismic and Infrasound stations)

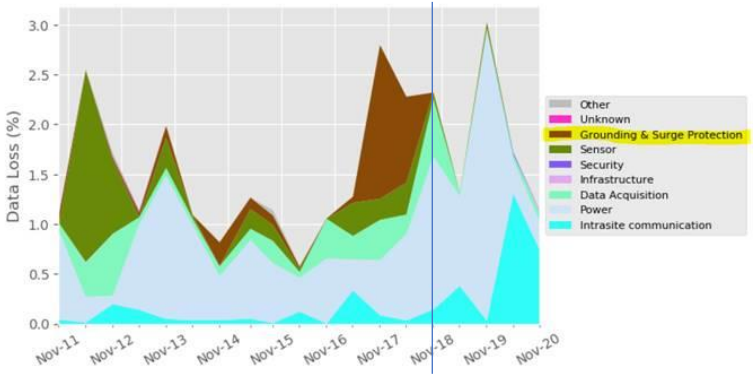

Figure 8. *PS stations historical trends of DL by station subsystem*

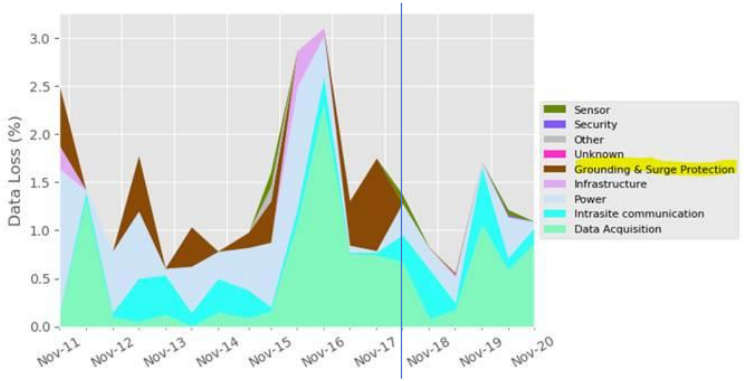

Figure 14. *IS stations historical trends of DL by station subsystem*

For Primary Seismic (PS) stations, grounding and surge protection issues impacting DA show:

- not to be consistent over the years
- not to contribute since 2018

For Infrasound (IS) stations, grounding and surge protection issues impacting DA show:

- to be consistent over time from 2011 to 2017
- not to contribute since 2017

- Failure statistics tend to show that the implementation of IMS Guidelines limits grounding and surge protection issues impacting data availability

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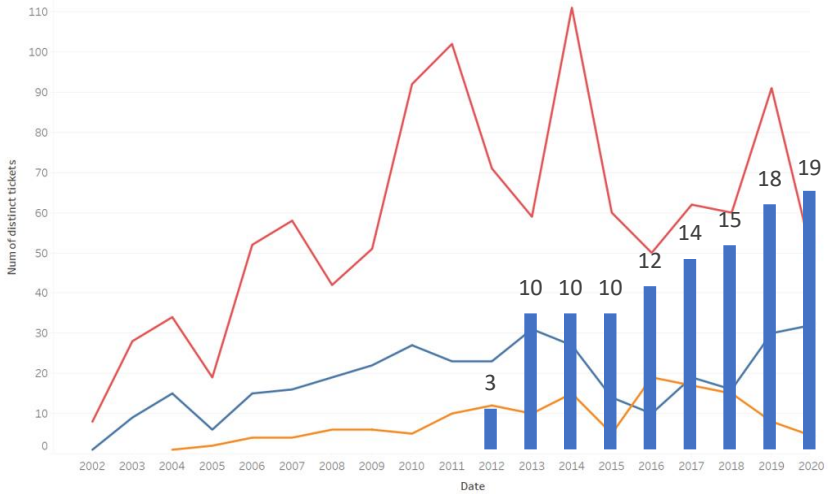
Results of implementation following station upgrades (tickets relating to grounding issues in the IRS for PS, IS and HA networks)

At the network level, review of IRS tickets show that:
- IS is more impacted by grounding issues than other networks
- grounding issues tend to reduce as the new guidelines are implemented in the network (from 2013)

Estimation of the number of IRS tickets relating to grounding over time tends to show that the implementation IMS Guidelines limits the number of tickets created due to grounding and surge protection issues

IRS ticket mentioning “grounding”, ”lightning”, “thunderstorm” and “surge” for PS, IS and HA.
Bars represent cumulative number of stations passed the upgrade of lightning protection system



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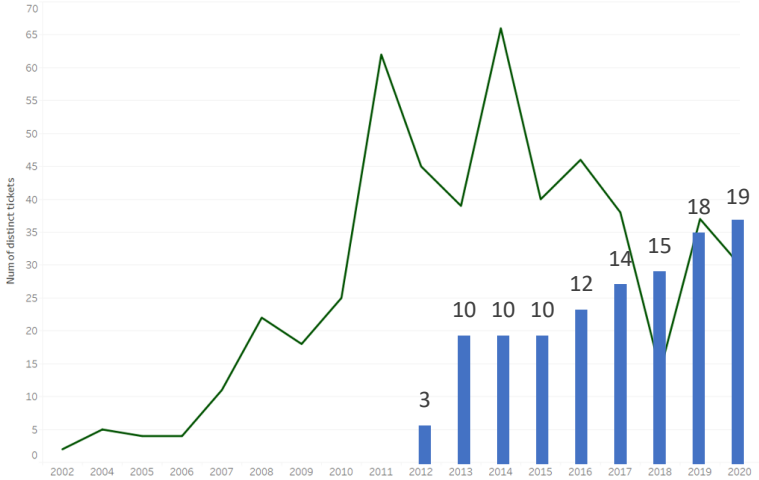
Results of implementation following station upgrades (tickets relating to grounding issues for stations listed in table above)

Selected stations:

- subject to lightning and grounding issues due to location and design features;
- experienced station upgrade including grounding and lightning protection (between 2012 and 2018)

IRS ticket mentioning “grounding”, ”lightning”, “thunderstorm” and “surge” for selected stations. Bars represent cumulative number of stations passed the upgrade of lightning protection system



Estimation of the number of IRS tickets relating to grounding over time tends to show that the implementation IMS Guidelines limits the number of tickets created due to grounding and surge protection issues

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Conclusion:

The development and implementation of the IMS Guidelines for Grounding and Lightning Protection System lead to significant improvement in systematic approach in lightning and surge protection design of IMS stations and visible decrease in lightning/surge issues at the stations.

Way forward:

The implementation of the IMS Minimum standard has to be an integral part of any IMS station construction / upgrade / recapitalization. Since the grounding and lightning protection fields are closely connected to the design of power supply system as a whole, introduction of the IMS Electric Power System Guidelines, which are under development, will be the next step forward in achievement of sustainable IMS stations operations.

Source: https://dehn.com