Study Committee B2

OVERHEAD LINES

10515_2022

COUNTERMEASURES FOR HIGH AND EXTREME ICE LOADS BASED ON THE CONCEPT OF HEATING OF SHIELD WIRES AND PHASE CONDUCTORS

A. Dernfalk, C. Ahlholm, J. Lundengård, I. Gutman[1], B. Adum[2]

[1] I2G, [2]Statnett

Motivation (service experience)

- Icing events in Norway cause failures of overhead lines, which may result in outages that last days
- Specific Norwegian ice load conditions are:
    - Non-uniform distribution of ice loads
    - Extremely high local ice loads (> 100 kg/m in some areas)
    - Remote areas affected
- At present "striking" pole is used after the event
- Goal of "Icebox" project: Development of concepts for the most promising modern technologies to reduce and remove ice from OHLs
- **Goal of this paper: Feasibility study of practical for Statnett countermeasures for ice removal using current heating of both phase conductors and shield wires**

Motivation using critical literature review (phase conductors)

- Load shifting between different overhead lines: Not promising, not always possible to find a network topology
- **Re-distribution of current between bundled sub-conductors: Promising**
- Conversion of load current into high-frequency current: Not promising due to complexity of this approach with respect to reliability in a harsh environment

Motivation using critical literature review (shield wires)

- **Current injection of AC current: Promising for insulated shorter sections**
- Current injection of DC current. Not promising due to the cost of rectifying equipment for high power DC supply

Approach: case study for two operational 400 kV OHL with known ice issues (OHL-1 and OHL-2)

- Actual design (types of conductors and shield wires) , long-term operational and climatic data used
- Black dots indicate locations for which detailed weather data have been obtained

Conclusions: phase conductors

- This feasibility study was focused on re-distribution of the current between the sub-conductors in the bundle
- This concept requires that the line has a sufficiently high loading current to be effective, thus this was not a promising solution on its own for Statnett conditions
- Potentially promising solution would be to combine this concept with an increased phase conductor current obtained by intentional short circuiting of the line at the remote end, possibly via a transformer

Conclusions: shield wires

- Heating by AC current is considered a practical proposal, although requiring insulation of the shield wires at critical section
- Based on preliminary economic estimations, de-icing is more promising, especially if the cost for equipment and material can be optimized

http://www.cigre.org

Study Committee B2

OVERHEAD LINES

10515_2022

COUNTERMEASURES FOR HIGH AND EXTREME ICE LOADS BASED ON THE CONCEPT OF HEATING OF SHIELD WIRES AND PHASE CONDUCTORS

continued

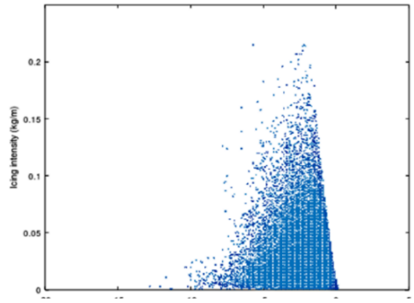
First weather data set (4-6 years)

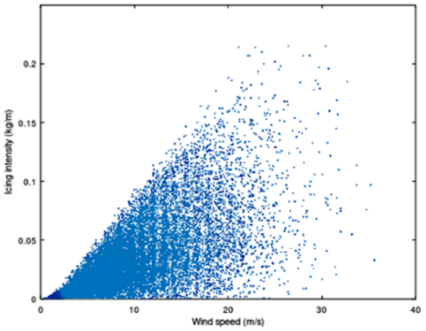
- Resolution 5.5x5.5 km, 4 times per day

Name of parameter	OHL-1			OHL-2		
	End-1	Ice area	End-2	End-1	Ice area	End-2
Average ambient temperature (°C)	4.9	4.6	6.5	4.5	2.5	7.2
Min. temperature (°C)	-15.9	-11.5	-10.4	-15.9	-23.7	-14.5
Max. temperature (°C)	26.8	26.4	26.6	29.0	25.8	30.3
Average wind speed (m/s)	2.9	6.2	2.6	2.7	6.0	2.7
Max. wind speed (m/s)	12.8	24.5	11.4	11.1	25.1	11.6
Average wind direction, >1m/s (deg.)	166	187	169	181	194	171
Average yearly precipitation (mm)	2522	2473	2180	1206	2902	3069
Time with temp. <0 °C (h)	8022	7998	4002	14496	20094	5784
Part of time with temp. <0 °C (%)	23	23	11	28	38	11

Second weather data set (40 years)

- Weather and ice intensity (max 0,22 kg/m/h,) 24 times per day
- Icing can be expected at temperature above -10 °C, and more typically at temperature above -5 °C
- Majority of icing events occurs below 20-25 m/s.
- **Keeping the conductor above 0 °C is the main criterion for the evaluation of effectiveness of ice prevention/reduction**
- The estimation of ice accretion is conservative since possible ice shedding is not considered





Historical current loading (hourly)

Parameters	OHL-1	OHL-2
Period of data collection	2015-2018	2013-2018
Average load current (A) with the line in or out of operation	157	165
Average load current, line in operation (A)	217	208
Maximum current (A)	1120	1282
Average current in operation and ambient temp. <0 °C *	242/250/272	213/213/236

* Values corresponded to temperatures at the three positions along the line route

Feasibility for phase conductors

- Power loss of approximately 30 kW/km is required to prevent 90% of the ice accreted on a single HTLS conductor
- This power loss corresponds to a load current in the order of 500 A, i.e., more than twice the average load current of any of two lines
- The thermal capacity of the OHL allows for such currents, but the actual load currents are too low to heat the conductors sufficiently
- Considering actual load currents of 200-250 A, about 30% of expected ice accretion may be prevented

Power and current required to prevent ice accretion on a single HLTS conductor.

Estimated from expected icing events in the period 1980-2020.

Percentage of prevented ice accretion	Required power for iced areas (kW/km)		Required current for iced areas (A)	
	OHL-1	OHL-2	OHL-1	OHL-2
10%	3	4	146	174
30%	7	9	232	267
50%	12	15	301	332
70%	16	21	350	400
90%	27	32	452	495
99%	42	51	562	619

- Current is too low to provide the desired ice removal in practical cases, which requires consideration of additional measures
- Higher current levels may be obtained by applying an intentional three-phase short circuit to the line
- Confirmed that relevant current levels can be provided by application of short circuits to lines energized at a reduced voltage level
- However, the equipment's current rating is crucial
- **A potential solution to the problem could be to combine short-circuiting with load transfer within the bundle, allowing for de-icing of one sub-conductor at the time**

Study Committee B2

OVERHEAD LINES

10515_2022

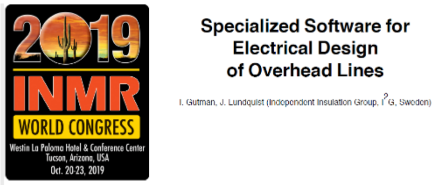
COUNTERMEASURES FOR HIGH AND EXTREME ICE LOADS BASED ON THE CONCEPT OF HEATING OF SHIELD WIRES AND PHASE CONDUCTORS continued

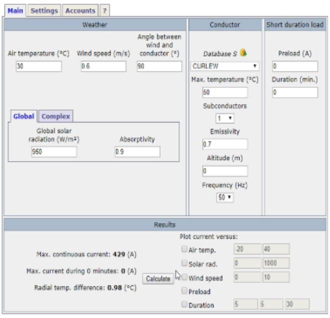
Feasibility for shield wires

- Two strategies for ice prevention by current heating of shield wires are proposed
- Anti-icing: Maintain the conductor temperature above 0 °C, thus avoiding any ice accretion.
- De-icing: The heating could be applied temporarily to melt already accreted ice
- The power requirements for the different strategies depend on temperature, wind velocity, heat exchange involving wind and water droplets, and ice thickness

Anti-icing strategy

- Maintain the temperature of the shield wires > 0 °C
- Typical conditions: T > -5 °C and wind speed < 20 m/s
- I-line program is used





Parameters	OHL-1 (Trima)	OHL-2 (Sveid)
Average power (kW/km)	2.6	2.9
Maximum power (kW/km)	101	54
Energy (MWh/km/year)	23	25

De-icing strategy

- Conservatively it is assumed that high icing intensity occurs each day
- De-icing of the shield wires is then performed regularly to keep the ice load below the design load
- Based on maximum icing intensity, de-icing shall be made every 5th day during the winter season
- **Anti-icing will lead to higher energy consumption and costs for the heating, while the required power is significantly less compared with de-icing**

Parameters	OHL-1 (Trima)	OHL-2 (Sveid)
Average power (kW/km)	104	117
Maximum power (kW/km)	268	348
Energy (MWh/km/year)	3.4	8

- Additional benefit of using insulated shield wires is the reduction of OHL losses in normal operation
- Using historical current loadings and actual conductor data, calculations were performed using the Tower/Pole Earthing (TPE) software
- The average annual reduction of losses by insulating the shield wires on OHL-1 and OHL-2 was estimated as 660 kWh/km and 1540 kWh/km, respectively, for the period 2015-2018