Conversion of AC OH line to DC for increasing of transfer power

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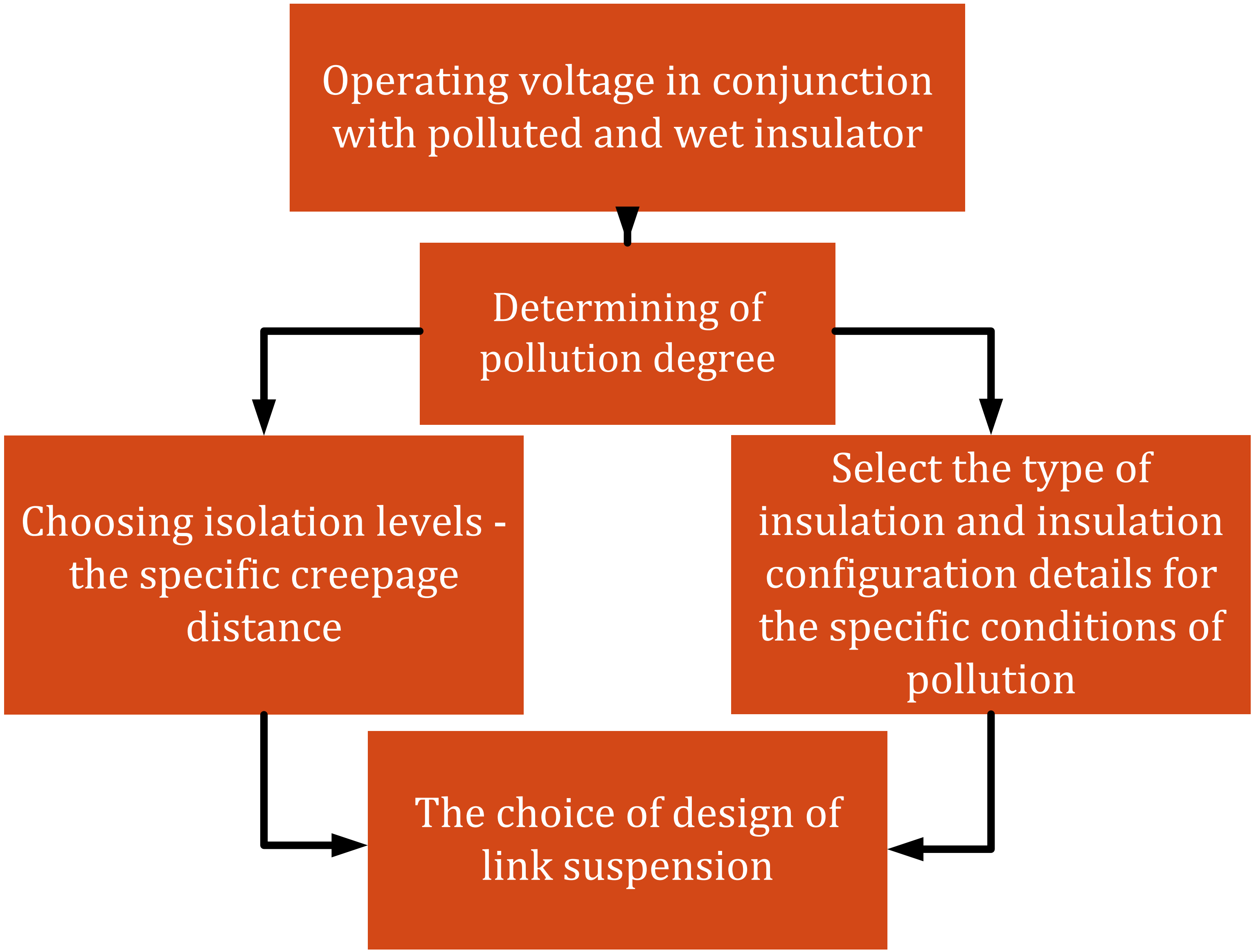
Selection of the main structural elements of the HVDC transmission line based on the expected weather conditions along the line route

- Line isolation (the contamination level)
- The air gaps in the insulation support and in the middle of the span (velocity head wind)
- The design of the pole (sleet load)
- Lightning protection system (storm activity in the area of the line route)
- The type and structure of the supports (wind speed, air temperature, ice thickness)

Selection of line insulation



Selection of insulating air gaps in the support and the dimensions to the ground

Design conditions determining the size of air gaps that define the geometry of the supports

Gap	Design condition
Vertical spacing "wire-traverse support"	The length of insulating string, chosen for normal operating conditions, i.e., the effects of operating voltage in conjunction with a polluted and wet insulator surface
Horizontal gap "wire-support"	Maximum operating voltage taking into account crosswind insulating string deviation; the impact of switching surges (K = 1.8-2.0) at design wind pressure; safe operation of a support under voltage
The gap between the pole wires in the span	Maximum operating voltage, overhead line design parameters and climatic conditions (dancing and whipping of the wires)
Gap "wire-to-ground" in the span	Switching overvoltages, environmental requirements and the electric field intensity under the line at an operating voltage

Selection of lightning protection system

Specific features of HVDC line:

- Lightning-proof bipolar HVDC line ensured by the rope protection
- Lightning in 90% of cases is negative, so the isolation of the positive pole is subject to a large extent overlap
- Reverse overlap during impact to support only occurs at the positive pole
- Bipolar overlap from lightning strikes are virtually eliminated

Selection of the wires and assessment of the impact of HVDC line on the environment

Pole design

The possibility of using a smaller number of components in the larger cross-section of each wire in comparison with the HVAC

Electric field intensity on the surface of constituent wires in the pole E_M

$E_M \leq 0{,}9\ E_0$

where E_M - the maximum electric field intensity on the surface of the wires, E_0 – total corona inception voltage at a constant voltage higher than AC one

Minimum cross-section of the pole is determined

Requirement for the economic current density

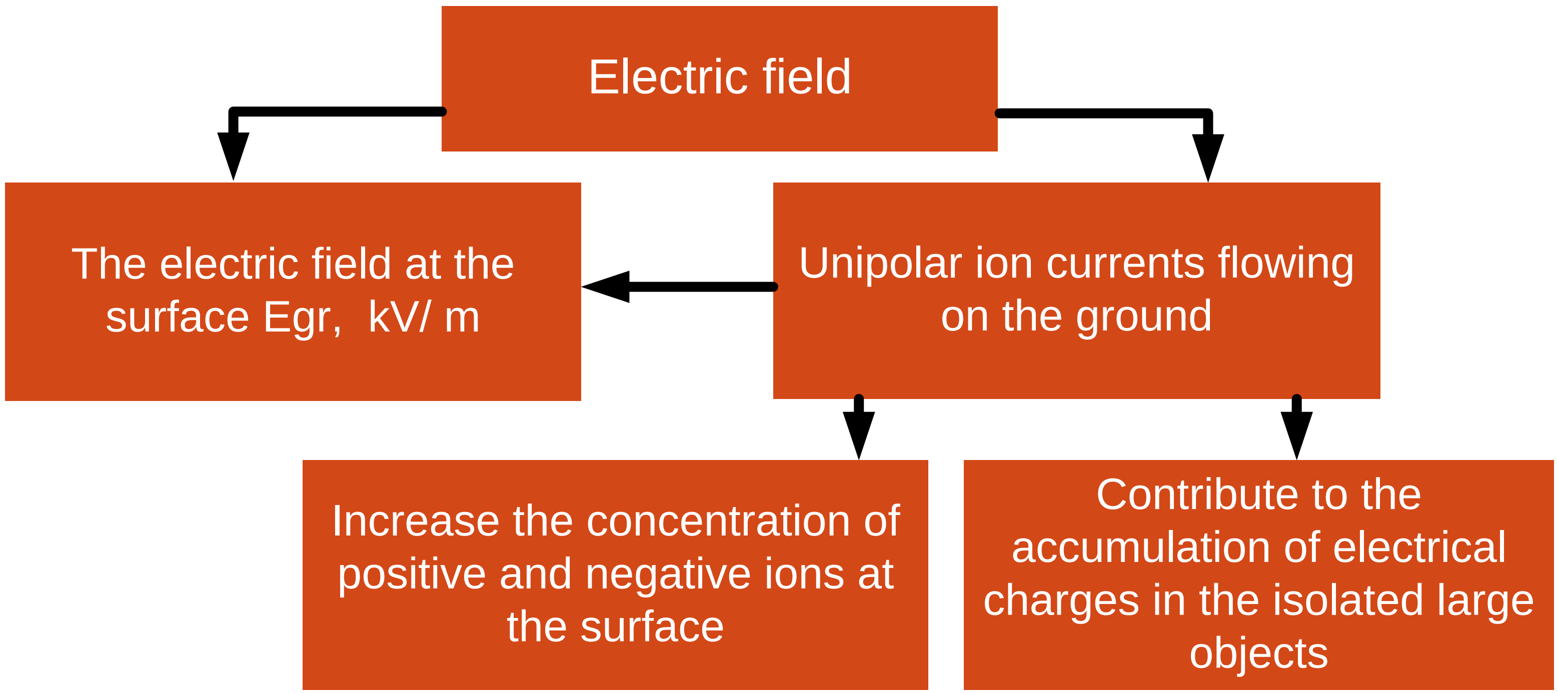
A limitation of the corona

Ensure of an acceptable levels of interference

The mechanical strength of the wires

Assessing the impact of HVDC overhead line on the environment

The main factors of biological influence of the HVDC line



For bipolar HVDC overhead line it is recommended for the maximum permissible values:

$E_3 = 30 \div 40$ kV/m – the electric field intensity at the surface of the earth;

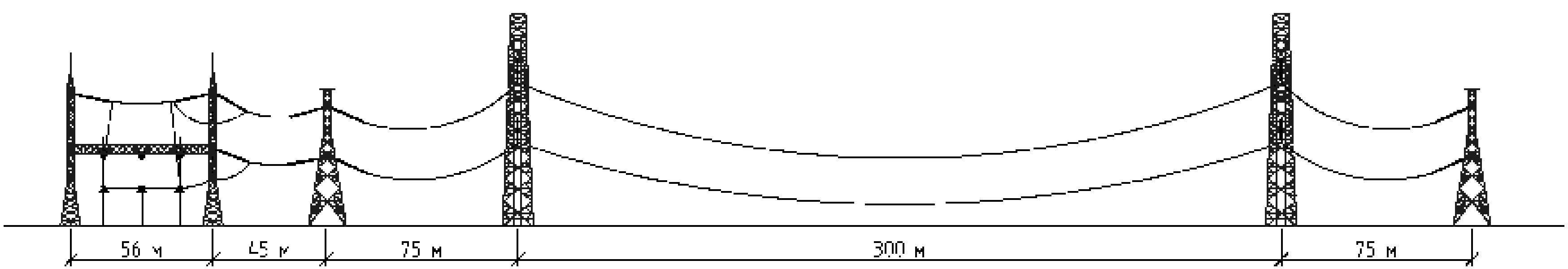
$j_{max} \leq 100$ nA/m^2 – an ion current density in the ground;

$n \leq 3 \cdot 10^5$ cm^{-3} – on concentration at the ground surface at j_{max}

Line range as part of the projected Federal Test Centre (FTC)

To create a modern HVDC lines as part of FTC it is created a line range consisting of:

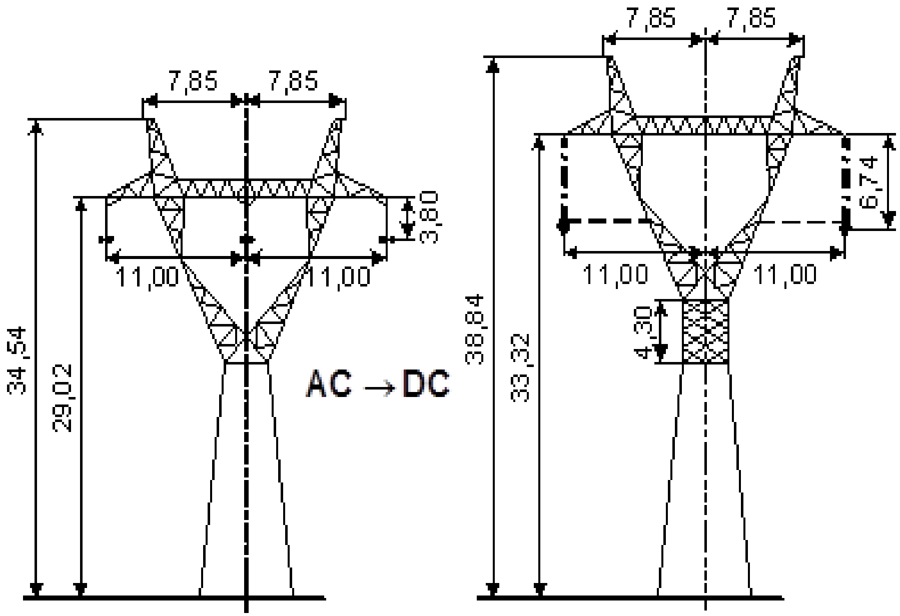
- experimental HVDC line(± 800 kV)
- experimental HVAC line (1000 kV)
- complex high-voltage test systems (DC, AC and pulse voltage)
- Laboratory for testing of external insulation of electrical installations



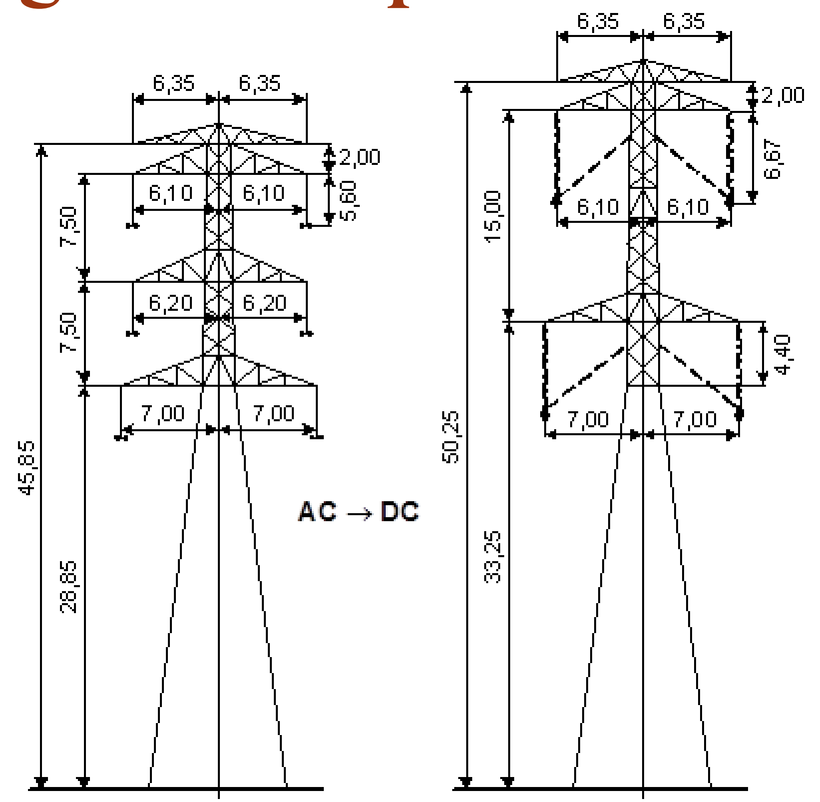
The main options for increasing the transfer power of overhead lines

1. Substitution on aged wires similar new ones
2. Increasing the voltage of overhead lines
3. Increasing the load current by increasing wire size or by increasing the temperature of the wires
4. Construction of a second extra overhead line or double circuit overhead line instead of single-circuit one
5. Conversion of overhead lines from AC to DC voltage with the ability to control the power flow, and reduce losses

Conversion of overhead lines from AC to DC voltage for increasing transfer power



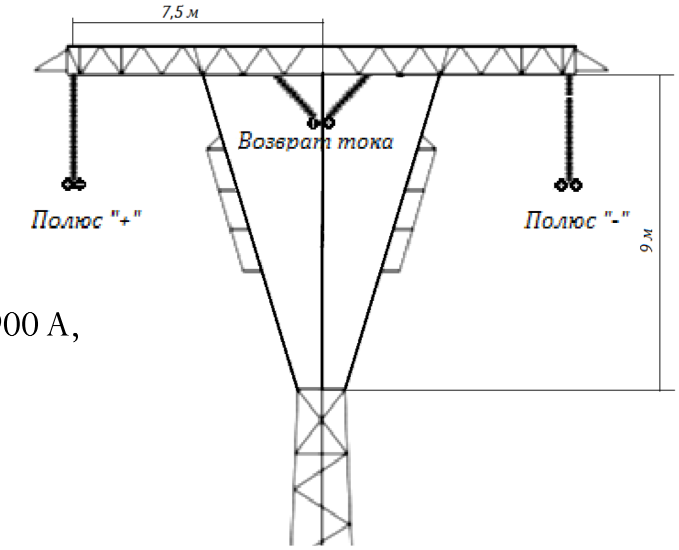
Converting of the 330 kV single-circuit AC overhead line with the phase of 2×AC 380/50 (Nigeria) to the bipolar ± 500 kV DC line with the pole of 3×AC 380/50



Converting of the 330 kV double-circuit AC line with the phase of 2×AC 380/50 (Nigeria) to the bipolar ± 500 kV DC line with the pole of 3×AC 380/50

Analysis of the possibility of line converting from the AC to DC voltage

The main parameters of OHL 220 kV

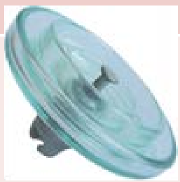


- Rated voltage of -220 kV
- Wire – 1xAS 500
- Modern requirements
    - **Economic current density of 0.8 A / mm2**
    - **Current - 400 A**
    - **Power - 160 MVA**
- To increase the transmission power OHL operates at a current of 600-900 A, resulting in deterioration of wire
- Service life - 50 years
- Type of intermediate support PMT - 220
- Pollution degree – 1
- Existing linear insulation::
    - **14hP-4,5 (overhead clearance 234 cm)**
    - **14hP-7 (overhead clearance 238 cm)**
    - **The length of the insulating suspension is about 300 cm**
- The need for increased transfer power is 2-3 times (MVA 320-480) and ensure the ability to control the transmitted power

Possibilities of increasing the transfer power of overhead lines AC

- With voltage of 220 kV and the transfer power of 320 MVA we need to replace the wires with 2xAS 500, and to reduce the mechanical stress on support we need to install additional support at each span
- Transmission power of 480 MVA required the construction of a new AC overhead line

Construction length of DC overhead line

Type of insulator		$U_{нр}$, kV	Leakage path length of the insulating string, $L_Г$, cm	Number of insulators in the chain, n	Construction height of the insulating string, $H_{Г(стр)}$, cm
DFI 250		200	764	2	**240**
		250	956	2	286
		300	1146	2	332
PSV 120 Б		200	792	18	**229**
		250	990	23	292
		300	1188	27	343
PSV 160 A		200	792	15	**219**
		250	990	19	278
		300	1188	22	321
PSV 210 A		200	792	15	**255**
		250	990	18	306
		300	1188	22	374
PSV 300 A		200	792	13	**254**
		250	990	16	312
		300	1188	20	390

Permissible values of air gaps on a support

Design condition	Climatic conditions	The smallest insulation distance (cm) for air gaps on the support of the HV DC lines, depending on the rated voltage		
		±200 kV	±250 kV	±300 kV
Lightning overvoltages	Wind stress 50 Pa. Temperature +15°C. No ice	195	245	290
Internal overvoltages		170	215	255
Ensuring of safe lifting on the bar of support (without going to traverse) without turning off the overhead line	Temperature −15°C. No ice and wind	220	270	320
Operating voltage	Maximum wind at – 5°C. No ice	80	90	100

An analysis of the dimensions of the PTM-220 support shows that it meets the requirements to the size of the air gaps for all of the options under consideration of the HVDC lines by voltage class, estimated climatic conditions and electrical requirements.

The minimum dimension to the ground in an uninhabited area at an operating voltage of ± 200, ± 250 and ± 300 kV

Operating voltage	±200 kV	±250 kV	±300 kV
Dimension to the ground , м	6,5	7,0	7,5

Controlling of the dimension to the ground on the biological impact:

- The limits:
- Electric field intensity at the ground surface: $E_з = 30 \div 40$ kV/m
- The density of the ion current in the ground for population: $j_{max} \leq 100$ nA/m^2

Selection of the electrical parameters of the DC OHL

- Bipolar DC overhead line
- Increasing the transfer power 2,25-3 times (360-480 MBA) in relation to the actual operating transfer power of exciting overhead AC line (160 MVA)
- DC voltage "pole-to-earth“options: 200, 250, 300 kV
- Metallic Return

DC OH line Options

Current Density A/мм²	Current, A	Transfer power, MBA	Voltage, kV	Pole design	Length of string, м	Note
1,2	**800**	480	300	1×AS650	3,3	Replace wires. Install additional or reconstruction of existing supports
	600	360	300	1×AS500	3,3	Reconstruction of existing supports
		300	250	1×AS500	2,8	Presumable reconstruction of existing supports
		240	200	1×AS500	2,3	No need replacement of wires and reconstruction of existing supports

Proposals for the development of HVDC overhead lines in Russia

1. To organize an international scientific-technical conference of BRICS countries and other interested countries and organizations in the research, design, development and operation of the HVDC super- and ultra-high voltage lines in 2016 in Russia
2. To consider the strategy of development of the electric grid complex if the Russian Federation taking into account the construction of long-distance DC power lines of super- and ultra-high voltage, as well as rational use of translations of the HV AC to DC lines to increase transfer power
3. To perform a research on the selection of optimal translation variants of the HV AC to DC line in order to increase their transfer power to develop technical solutions for the overhead line and conversion terminal devices.