The approach to preventive measures of icing on transmission and distribution overhead lines is offered at the expense of a warming-up of wires and ground wires by means of loaded devices. In the capacity of loaded devices surveyed: resistor equipments; segments of lines, included in the end on a short-circuit; grounding electrodes of a special construction.

Maintenance of overhead power lines in the glaze regions shows that glaze emergencies are considered to be the most complex and may cause power supply disorganization covering large territories. The power line de-icing method by the three-phasing short circuit is being widely used in Russia. The efficiency of the method depends on whether it is used in good time. As the preparation for de-icing and its fulfilling takes about 6 hours, the larger part of all faults happen during this time. The described method is aimed to the glazing control.

The preventive warm-up of phase and ground wires in the period preceding glaze deposits proves to be more efficient. The earlier reaction to the wind and glaze situation by switching on an artificial load at the formerly determined units during the period supposed glaze deposits allows to provide “self – protection” of overhead power lines phase and ground wires.

There are some variants of the procedure realization in practice.
1. Switching on resistor sets made of high voltage resistors (10 kV modules of 1.5 MWatts considered to function for a long period of time has been developed by BEL Co. Moscow, Russia).
2. Switching on the lines of low class voltage of 6 - 10 kV according to one of the schemes de - icing by short circuit currents (the current should not exceed allowable limits).
3. Usage of power line ground wires switched on under 6-10 kV as a sustained load.
4. Usage of specially designed powerful ground electrodes providing the scattering of essential power during a long period of time.

There are some circumstances, which ease the procedure realization:
1. The season, dangerous for icing, in one year makes a short period - on the average from 2 to 5 days.
2. The period, dangerous for icing, is possible to the precise metrology forecast.
3. In 30-90 % of cases the time of beginning and main glaze depositions happen at night and morning hours during a minimum load of lines.
4. On each power region there are dates on damaging of transmission lines and representative conditions of development of glaze emergencies.

5. The period of scrambling with icing has the obviously expressed seasonal nature and, as a rule, coincides with periods maximal or close to maximum loads in an electrical network.

And, at last, important circumstance is that there are power resistors possessing in high technical and economic performances, and they are produced by a series of firms of Russia.

The analysis of operating conditions of many electric power systems has shown, that the preventive heating of lines can effectively be utilized on lines 6+110 kV, fractionally 220 kV. For lines 220+500 kV because of their low-level rated load the application of this measure is hampered. The accident rate of lines of this class of voltage can be lowered at the expense of a heating of ground wires and non-admission of glaze emergencies because of ground wires. As the maintenance practices display, in a series of cases of a heating of ground wires it happens enough for saving transmission lines in operation.

Usage of the offered approach changes tactics of scrambling with an icing. According to such approach, the load-dispatching center enters scrambling with an icing at early stage before incoming front of a stream with the supercooled precipitations by connecting an additional load, which is dispersed on nodes of the electrical network. Such load is especially necessary during minimum daily loads. Thus the services of electric power systems should make a decision on connecting load devices not on the fact of a detection of glaze-ice accretion, and on the basis of precise informations of the meteorological forecast and experience of preceding years, which determine necessary operations on connecting a load. Whereas the period of ice storms does not exceed several day, additional change, bound with "unproductive" expending of the electric power, pay off by saving of operational condition of lines.

In this case group of lines, instead of any one line, appears in coverage of this measure.

The following fact speaks for the benefit of usage of an offered engineering solution [1]. In USA within four day of intensive storm on two parallel lines contoured by to the power company BPA, the buildup of an icing was observed. One line was loaded from 15 to 27 percent during the period while the other was loaded 24 loaded 43 percent of the current rating. The more heavily loaded line started developing ice 30 hours later than the other one and shed its ice seven hours earlier. It collected only 1.9 cm of radial ice compared to 4.1 cm on the lighter-loaded line. The rating is considered to be that current required to yield a 50°C rise in conductor temperature above an ambient of 25°C with 0.61 in/sec wind, 0.5 coefficient of emmisivity and sun.
Let's consider more in detail possible versions of execution of load devices.
1. Powerful high-voltage metal or composition resistors.
   
The resistive load device is agglomerated from resistive components for a heating of wires under the circuit a three-phase star with an isolated or earthed neutral, for a heating of ground wires as the single-phase block included sequentially with a ground wire.

   In Russia a composition resistive material - electroconductive concrete (corporation the manufacturer of BEL, Russia) has received broad application. The resistors from this material will be utilized in many electrotechnical devices. These resistors can be utilized with reference to a warm-up of wires and ground wires. At the same time considerable number of resistive components is required for making the load device about 1,0÷1,5MWatts. More perspective version is the version with resistive components from metal alloys. The corporation of BEL designs the resistive module of the device on voltage 10kV.

2. Segments of transmission lines 6-10 kV included at the end of a line on a short-circuit. As technical and economic calculations have shown, usage of load devices made from resistive components, rather expensive.
   
   In this connection there was a question on possibility of using of means available utilities for making a continuous simulated electrical load. There was a proposition to use for this purpose a wire and ground wires of lines, which are included on one of the possible circuits of a melt of ice accretions. Only in this case length of a line and level of the power source are selected from a requirement of limiting admissible continuous currents. In such condition the ground wires of high-voltage transmission lines and line of distribution network 6-10 kV (for example, lines of seasonal application, line in a ring etc.) can be exploited.

   Included in a condition of a short-circuit the segments of transmission lines 6-10 kV represent for an electric power system an active - reactive load. For wires of the mark an AC-25 the current 195 A is admissible continuous current (in view of 1,5 multiple loads in malfunction and temperature of an ambient air 0°C), for an AC-35 - current 262 A, for an AC-50 - current 315 A.

   If to accept bus voltage of substation 10,5 kV, consumed power in a condition of a three-phase short-circuit for wires of the mark the AC-25 makes 3,46+j0,67=3,54 MVA, for an AC-35 is equal 4,37+j1,85=4,7 MVA and for an AC-50 is equal 4,97+j2,86=5,72 MVA. The desired values of currents are ensured at lengths of segments of lines for all surveyed types of wires - 21÷23 km. It is possible to supply a series of values of load capacity with change of an expedient of connection of a line on a short-circuit (two-phase short-circuit without ground; a two-phase short-circuit with ground; a single-phase short-circuit at a series connection of wires etc.).

   For short segments of lines, where the currents exceed admissible values, the expedient of connection of a transmission line in an intermittent duty can be used. It is necessary to underline, that usage of such approach enables to include in particular nodes of a power circuit a load by power about 2÷10 MVA without damage to lines. Naturally, that these lines are in “inconvertible against an icing” a state and at any moment can be translated in a condition of normal operation.

3. Ground wires of high-voltage transmission lines which are included under a load on one of the circuits of a melt of ice accretions by short-circuit currents.
   
   It is known, that the icing is more intensively deposited on ground wires of a transmission line, because the currents in ground wires miss, and also because the ground wires is hanged above than wires. In maintenance the cases are marked, when it was enough to delete an icing only from ground wires for liquidation of glaze emergency.

   In this connection perspective the preventive measures of switch of ground wires of transmission lines under a load in regions, which fall in a band of influence of streams of the supercooled precipitations, are presented. Such switch is expediently made beforehand before incoming an airflow with the supercooled precipitations. Basically it is possible to create a power circuit 6-10 kV from ground wires on a period of possible glaze depositions by series-parallel switching of ground wires.

   The switch of ground wires under a load promotes the solution of two problems:
- Purely to heat a ground wire of a given transmission line in a period, dangerous for icing.
- To raise a load of wires of adjoining transmission lines.

   Accordingly in contrast to a melt of ice accretions by short-circuit currents which essentially are local measure on scrambling with an icing the offered solution has potentials to exercise influence on the processes simultaneously in group of transmission lines, i.e. this is measure of the region scale. The measure enables adequately to react to a piling weather condition, precisely to counteract on a place and time formation of an icing on wires and ground wires of transmission lines.

   The select of a voltage level of the power source for connection to ground wires should be applied from a requirement of supply of passing of a maximum admissible current on a ground wire. For a ground wire C-35 this magnitude is equal 75 A; for a ground wire C-50 - 90 A; for a ground wire C-75 - 125 A. The calculations display that the switch of ground wires on one of the circuits ensures an additional loading of a supply transmission line on 1-4 MVA (voltage of sources 6-35 kV). For passing of more symmetric loading of power sources the ground wires of various transmission lines are expeditiously switch on various phases of a source.

4. Load devices operating resistance of ground. Such resistor represents a system of grounding electrodes buried in the ground on corners of an equilateral triangle on particular depth. Three phases of voltage 6-10 kV from buses of substation are connected to these electrodes.
   
   The executed calculations have allowed to estimate parameters of grounding devices for making resistive load devices on voltage 6-10 kV by power 1÷1,5 MWatts, which ensure the currents on lines 75÷100 A (for lines with wires an AC-25, AC-35, AC-50). For grounds with a specific resistance 100÷200 ohm-m the earthing connectors of diameter of 1,5÷2 m are required which immersed in the
ground on 1±1.5 m. The electrode separation makes 8±10m. Time of usage of such resistive load device makes some day. The area held by such resistor device makes ~100 m² (10×10).

The electrical load of the majority of consumers continuously varies during day and year. So, the relation of a minimum total loading of a daily load curve to maximum magnitude makes about 0,5 for regions with a large industry and 0,3 or even less for regions with the underdeveloped industry. About the same relations are characteristic for minimum and maximum power flow on transmission lines. Taking into account changes of electrical loads during day, the resistive load devices should be introduced in operation in such time of a period dangerous for icing, when the current of a line is insufficient for preventing formation of icing and with such necessary power, which guarantees with a particular degrees of probability a reliable operation of a transmission line.

As already noted, the glaze period coincides periods maximum or near to maximum demands in an electrical network. The load of many lines during the majority of day is sufficient for preventing formation of an icing, but in night hours this load is insufficient. Therefore power of load devices should be selected on a level of a minimum load of transmission lines in a daily profile and maximum level in yearly profile.

The problem of the selection of rational places and powers of the resistive load device is very important for effective application of a preventive action. The problem of selection rational places of connection the resistive load device in distribution network falls into group of optimization problems. The basic purpose of selection is considered to be in the position determination and powers of the resistive load device ensuring a preventive heating of transmission lines, which go into a band of its operation, under the condition of saving in tolerance limits of powers generators of stations, voltages in node of an electrical network, currents on other lines.

Measures usage ensures:
- early reacting on a piling icing situation; a capability of preventing of formation of an icing, scrambling with icing at early stage of process; a multiplicity of usage in the icing period;
- saving of a heated line in requirements of normal operation (absence of commutations in the primary circuit of substation feeding the heated transmission line; saving quality of the electric power in a current network);
- possibility of simultaneous warming-up of wires of transmission lines of various classes of voltage; spanning of major territory of the electrical networks which have exposed to effect by icing;
- the compatibility of measure from a melt of ice accretions by short-circuit currents (as a switching unit can be used the switch of a melt of ice accretions; the melt of ice accretions by short-circuit currents in this case is an extreme measure of scrambling with an icing, its closing stage);
- possibility of regulation of a load current of a heated line and, as consequence, possibility of the coordination of operating mode of resistor load devices with a load curve of an electric power system;
- possibility of using of resistor load devices for a heating and melt of ice accretions of wires and ground wires of short lines;
- possibility to automatize process of preventing of formation of icing;

Technical and economic calculations have shown for the efficiency of measure:
- higher power expenses as contrasted to melt of ice accretions by short-circuit currents;
- considerable investment costs on load devices because of the high cost of resistors are necessary.

In many respects the efficiency of offered measure depends on timeliness and quality of the meteorological forecast. The technical and economic indexes can be improved in case of usage of the last effects in the field of composition resistors and resistors on new principles.

In addition other means can be attracted in amplification of a load on lines: load management by connecting suitable items such as storage heater, hot water heaters, heat pumps etc.

**CONCLUSIONS**

1) The offered engineering solution allows to change tactics of scrambling with icing. The active counteraction to an icing is carried out beforehand on the basis of the meteorological forecast by switch in particular nodes current network of resistive load devices in a period dangerous for icing. The periods of minimum loads at night and morning hours (till 6-7 o'clock P.M.) can become the most probable periods of operation of load devices. For rational usage of devices the period of their operation should be compounded with a power curve of heated lines.

2) The simultaneous switch of a series of load devices in power region fallen in an area of icing effects, allows to influence on passing processes of formation of icing as a whole on group of lines of various classes of voltage. Thus in most cases it is not required to reconfigure a basic current network of power region and to operate "unnatural" commutations of electrical equipments.

3) The calculations have shown, that the lengths of transmission lines, reference for each class of voltage, can be comprised by offered measure subject to technical limitations on tolerant decrease of voltage, overload capacity of equipments, oscillations of frequency.

4) The technical realization of the present measure guesses usage of resorts of melt of ice accretions (switches, disconnectors, short-circuiting switches) available in electric power systems.

5) The conducted technical and economic comparison has shown, that in a lot of practical cases usage of resistive load devices appears economically justified. The greatest effect can be reached at usage of resistive load devices of which don’t require considerable capital outlays (first of all it is ground wires of transmission lines and short-circuit segments of lines - 6÷10 kV of seasonal application and transmission lines feeding of non-essential consumers). The resistor load devices are economically justified at
heating of transmission lines of feeding most responsible consumers or transiting on hard-to-reach lines.

6) The conducted calculations made for series of actual electrical networks of electric power systems of Russia, have shown, that the load approximately 15-20 % of lines 110-220 kV during possible icing deposions (in lack of measures) is sufficient for a preventive warming-up of wires. By redistribution of power (in basic at the expense of disconnection parallel lines) it is possible to achieve an increase of this index approximately twice. Preliminary and particular (on a place) the turning on 3-5 substations of power regions of an artificial load of aggregate power 10-20 MVA allows to supply "self-protection" of basic lines of region without disconnection of parallel lines and limitation of consumers.

REFERENCES