

OHL condition monitoring and engineering solutions of capacity increase to admissible maximum

I. Introduction

Rating of the most of existing overhead lines (OHL) has been established years ago as a rule during line design and construction. For the time being the situation drastically changed and up rating for increasing capacity of many existing lines has to be referred to the category of essentially actual problems of network companies. For the high voltage lines 100 – 330 kV, transmitting capacity could be increased, in general, up to the highest level of admissible high temperature operation. In this way two very serious restrictions must be taken into account: knee point temperature of ACSR conductors can not be exceeded and phase clearance to the ground and crossing objects (low voltage lines, communications, etc) also can not be less than normative value accepted by the utility's corporate standard.

To carry out verification of actual conductor clearances for some specific points or short OHL section one can use such techniques as optical and laser range meters, total stations and so on. But verification of the long line in available terms can only be done on the aerial laser survey (ALS) technique basis. Because of permanent changing of OHL condition (due to the influence of ice, wind, vegetation growth, repairing and restructuring activities), the most rational procedure is periodical network monitoring on the ALS basis. The report covers most efficient models of the periodical OHL monitoring and supplying network companies with effective databases supported by actual work performance experience.

Should conductor condition check performance or additional tension adjustment activities establish clearance to ground and crossed objects to satisfy effective standards, as well as in case safety clearance margin is detected, necessary pre-requisites for up rating can be deemed available. Dynamic up rating implemented, as shown in report , to increase current load of line twice and more. The report covers results of using OTLM monitoring devices, registering temperature, current and conductor X,Y,Z coordinates, for several 110, 220 and 400 kV OHL of Russian and Slovenian network companies.

The report provides results of ALS technology application for evaluation of a number of OHL technical condition, witnessing that actual values of conductor Every Day Stress (EDS) are considerably less than tension loads producing risk of conductor damage due to vibration and other external impact. This makes it possible to recommend conductor retention, that ensures clearance increase as much as it is required to increase conductor transmitting capacity up to 40-80 %.

II. OHL Conductor Condition Remote Monitoring Device

For OHL rating analysis, conductor temperature and current should be controlled at the power line's critical sections. Using results of such control, dispatcher service may increase OHL current load up to the maximum admissible point, and implement optimal load distribution on various network elements.

Telemetric Monitoring of Temperature (OTLM) device has been developed [1] as a specialized unit of OHL conductor current and temperature control. This device is equipped with a mean of attachment to conductor (Fig.1). The device is power supplied by capacity distraction from live OHL conductor.



Fig. 1. Installation OTLM on conductors of OHL 400 kV

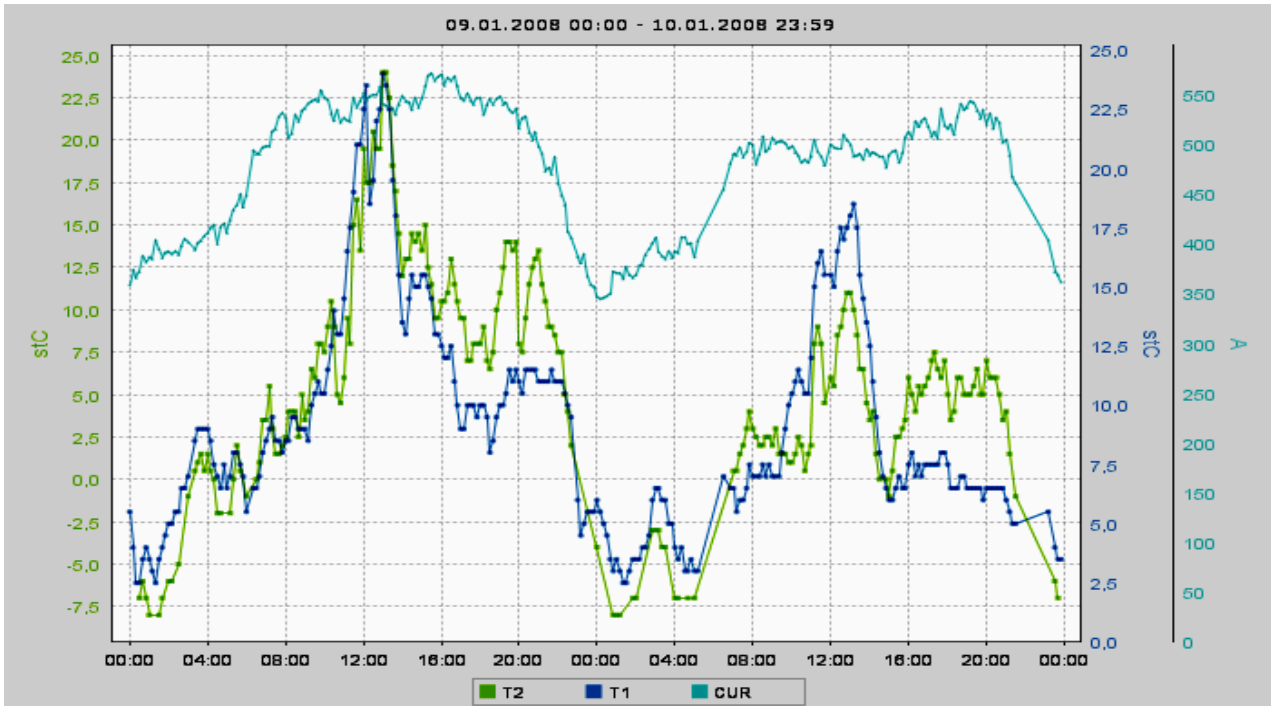


Fig.2. Data of on-line measurement of conductor temperature and current (OHL 110 kV “TEC 2 – TEC 3, Kazan, RF)

Numerical values of measured conductor temperature and current are transmitted via cell telephony channels to a receiver installed at a power network company control board. Conductor temperature can be measured (depending on customer’s requirements) within either a range of -40°C to $+125^{\circ}$, or from -15° to $+150^{\circ}$. Conductor current can be measured within a range of 250 A to 2000 A. The device is equipped with a Global Positioning System (GPS) signals receiver. Due to this, temperature and current measurement data is annotated by precise time, as well as X,Y,Z coordinates of the device location, whereof the accuracy depends on type of GPS receiver used.

OTLMdevice installation is recommended during planned OHL disconnection. Using a portable ladder fastened at a tower cross arm on one side and conductor on the other, allows installation of the device 1.5-2 m off a tower (see Fig. 1). Where favorable conditions of access to OHL are available, OTLM can be installed at any point of span using a hydraulic jack. A technique of the device installation on live power lines is being developed currently.

In complex terrain areas, highlands, it is recommended that OTLM devices are installed in spans where nature of area changes sharply, and conductors are shielded from wind by various natural or man-made barriers. Optimal number of OTLM recommended for installation at OHL running through a complex terrain area, should be around 4-5 devices. For the lines located in flat woodless areas, the number of OTLM installed can be reduced to two devices at the beginning and end of the route, or at the sections of considerable OHL pivot angles (45° to 90°).

Fig. 2 shows actual conductor current and temperature monitoring data at OHL 110 kV TEC2 – TEC3 (Kazan city, Russia), where since mid-2007 a non-stop control of conductor condition is being performed. Dependencies

shown in the chart describe condition of ACSR 185/29 conductor during a 24-hour period. During this period (January 9-10) at night (according to meteorological data) air temperature fell down to -27°C , current load made 350 A, therefore measured conductor temperature is within -7°C to $+5^{\circ}\text{C}$. In the daytime air temperature made -23°C , wind speed 1 m/s. As current load during the day grew up to 570 A (current density reached 2.6 A/mm^2), this has caused a significant growth of conductor temperature to $+23^{\circ}\text{C}$.

The above monitoring data make it clear that considerable conductor heating is the case at current density 2 A/mm^2 and over. Under growing load and hence growing current density over the above value, a need arises to control conductor heating temperature as for most of used ACSR conductors knee point level makes 65°C to 120° [2] depending on ratio of cross-section of steel core and conducting (aluminum) part of conductor.

III. Current Load Influence on Conductor Clearance to Ground and Crossed Objects

Important factors accounted during assessment of maximum admissible current load should include data on minimal conductor clearance to ground and crossed objects. Using line survey data out of which the most efficient is aerial laser survey (ALS) technique [3,4], as well as methods of OHL condition computer modeling in various operational conditions, allows to detect current loads and heating temperatures where a danger of breaking minimal legal clearances appears. Based on such analysis those critical sections of OHL are detected where capacity increase is limited.

In October 2006, the considering OTLM current and conductor temperature monitoring devices were installed on

the several OHL 110 kV and 400 kV which belongs to network company ELES (Slovenia). Among them OHL 110 kV "Bericevo – Trbovlje 1" and OHL 400 kV "Bericevo – Podlog". For grounding admissible capacity increase limits at these lines calculations were performed of estimated line behavior under various current loads. One of the critical (in terms of current load increase while meeting safe low conductor clearance to ground) on the line 110 kV "Bericevo – Trbovlje 1" was span between towers 14 – 15. Lower conductor clearance to ground in the said span depending on current is shown on Fig. 3. Minimum admissible clearance value in accordance with effective requirements for this class of lines is 6 m (NESC USA). Hence, base rating value for this OHL makes 900 A max.

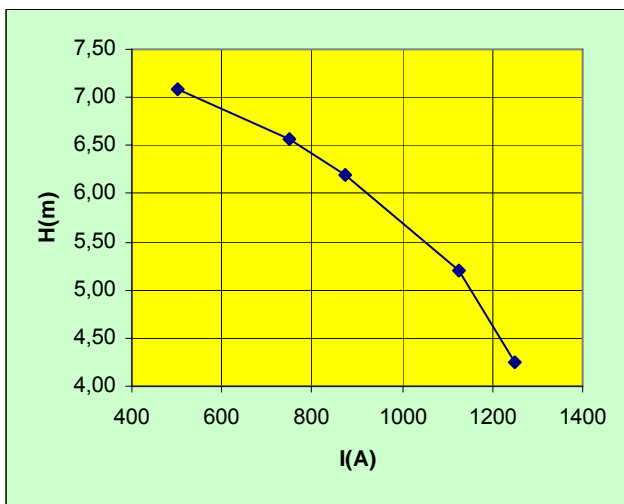


Fig. 3. Dependence of clearance H, m via current I, A for low wind speed $V=0.5$ m/c

For considered 110 kV line ampacity increase is limited with both necessity to ensure safe conductor clearance to ground, as well as thermal resistance limit which value depends on relation of aluminum and steel conductor cross-section. For OHL with such conductors as ACSR 240/40, thermal resistance limit makes 95° C.

Conductor heating temperatures depending on wind speed perpendicular for the given span are shown on Fig. 4. As per this data, maximum ampacity could be up to 1250 A at relatively low wind speed 2,5 m/s, and higher at wind speed π 5-10 m/s accordingly.

As a result of verification the technical conditions of OHL 110 kV "Bericevo – Trbovlje 1" components was detected the fact signification that conductor tension in most of spans with insufficient clearance makes 14,6% to 15,3% of conductor breaking strength limit. Increasing tension to safe 20% of breaking strength level shall allow a radical solution for majority of clearance problems.

Survey data analysis carried out for OHL 400 kV "Bericevo-Podlog" showed that in span between towers 10

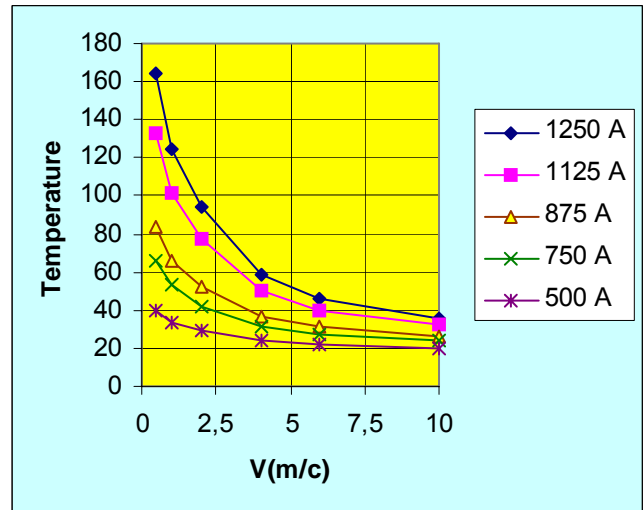


Fig. 4. Conductor temperature T via wind speed V for current I from 500 A till 1250 A

and 11 of this line mechanical conductor tension strain at $+19^{\circ}$ C makes for left, middle and right phases, accordingly 11,3%; 11,4% and 11,4 % of conductor breaking strength limit. In accordance with most conservative approaches, the safe conductor tension value makes from 15% to 20% of breaking strength limit. Thus, conductor tension at OHL 400 kV "Bericevo – Podlog" can be increased 1.5 – 2 times with no risk, that will allow solving all insufficient clearance problems and consider possible essential uprating.

IV. Engineering solutions

Since, according to results of dozen lines' surveys (performed with ALS technology in various countries [5]), in many cases capacity increase at existing power lines is limited by insufficient conductor clearances to ground and crossed objects, engineering solutions should be used to overcome such limitations. The following engineering solutions may be named among applicable in similar cases:

- ◆ Reducing lengths of supporting insulator chains;
- ◆ Replacement of vertical insulator chains with Δ -type installation;
- ◆ Replacement of porcelain or glass insulators with composite one of smaller length;
- ◆ Conductor tension adjustment (lifting up);
- ◆ Adding tower height;
- ◆ Reducing span distances by additional towers erection;
- ◆ Terrain leveling.

A criteria to elect a solution out of the above list is a technical feasibility evaluation at specific conditions and comparison of technical and economical parameters of various options and their combination. Evaluation and comparisons done by us have proven conductor tension adjustment to be one of the most reasonable engineering solutions.

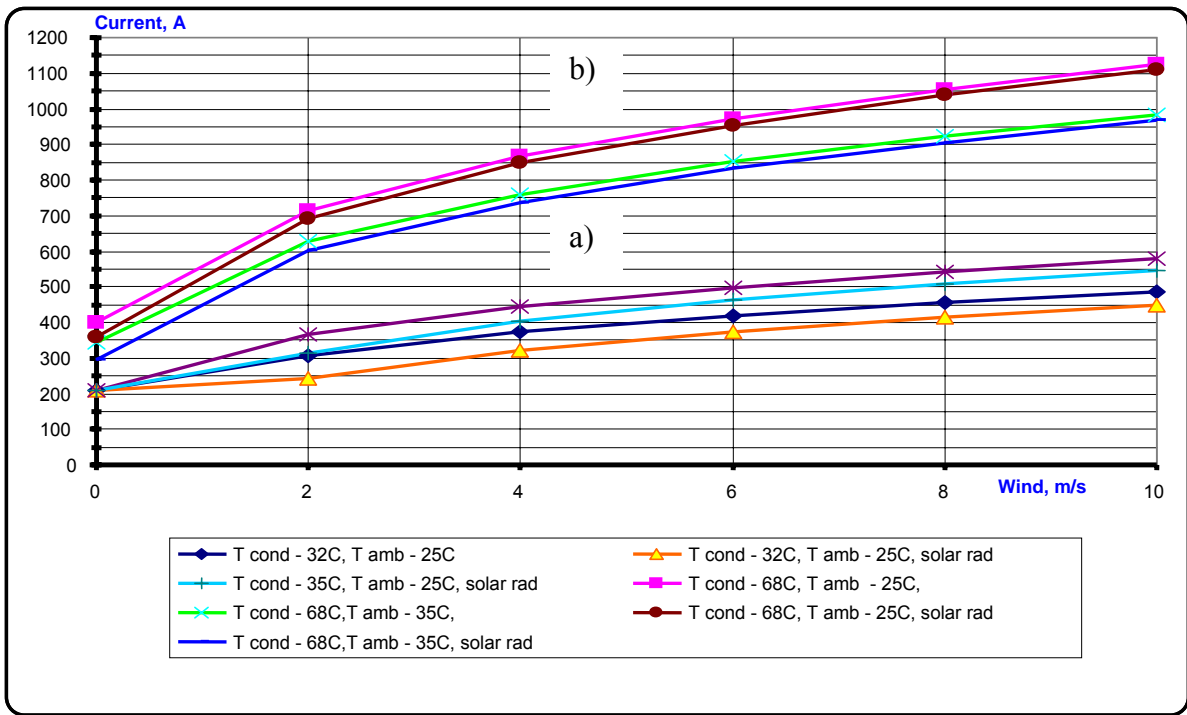


Fig. 5. Maximum admissible current via wind speed and ambient meteorological conditions for OHL 110 kV “TEC2-TEC3” (Kazan city, RF)

An option to increase conductor tension is conditioned by sag increased during line’s long-term maintenance (accompanied by reduced tension strains in conductor’s wires), due to ACSR conductor creep phenomenon, conductor expansion due to accounted and extra wind and ice loads, as well as air temperature extreme lows. Besides,

in many countries a provision to keep a so called safety clearance margin was applied in design and construction of existing power transmission lines, which value made 1 to 1.5 m. This means that conductors of most of existing lines have a considerable reserve of mechanical tension strength that can be used to eliminate or essentially fix insufficient conductor clearance to ground and crossed objects.

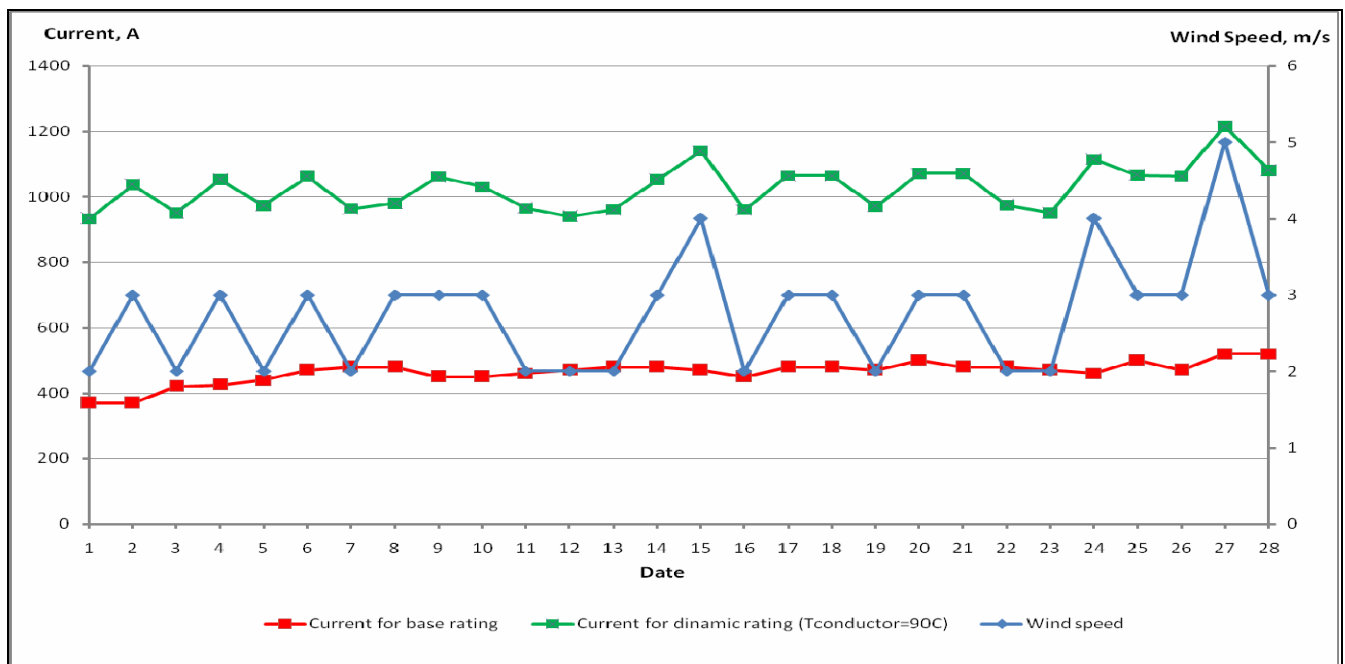


Fig. 6. Maximum admissible current in accordance with base (red line) and dynamic (green line) ratings for conductor temperature limit +90⁰ C and influence of wind speed (blue line) at the period from 1-st till 28-th of November 2007

As it has been mentioned above (see paragraph III), at OHL 110 kV "Bericevo – Trbovlje 1" and OHL 400 kV "Bericevo-Podlog" surveyed by us in Slovenia, conductor tension in spans where conductor clearance fail to meet international standard requirements can be increased 1.5-2 times with no risk.

Similar situation has been detected upon survey of OHL 110 kV "TEC2-TEC3" (Kazan city, RF). In number of spans where clearance to ground fails to meet corporate standard requirements, tension makes 17-20% of the conductor tension strength limit, under average yearly air temperature. As the corporate standard allows tension of 30% UTS, tension increase adjustment can solve insufficient clearance issue at this line.

Dependencies shown on Fig.5, make it possible to consider possible line capacity increase under various maintenance conditions. At +25°C air temperature and absence of wind the line load should not exceed 200 A. With lower air temperatures and crossing wind up to 8-10 m/s current load can be increased up to 550-600 A. Conductor tension adjustment can provide for load growing up to 300-400 A under still conditions, and 900-1000 A with wind of 8-10 m/s. It is quite obvious that dynamic rating application (taken with account of actual conditions) is completely impossible without using technical devices of power transmission line condition real-time monitoring.

V. Conclusions

1. Upon completion of monitoring activities using most recently developed technical means, parameters of increased capacity of a number of 110 kV and 400 kV OHL have been studied.

2. Upon analysis of the mentioned OHL condition, a prospect of their considerable extra capacity increase was shown as a result of tension adjustment and increasing conductor clearance to ground and crossed objects.

VI. References

- [1] B.Mekhanoshin et all, "Overhead line uptating using ALS and real time monitoring of conductor temperature", in Proc. ISH-2007, 15th International Symposium, Ljubljana, Slovenia.
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- [3] B.Mekhanoshin et all, "Diagnostics using airborne survey and fault location systems as the means to increase OHTL reliability", Proc. IEEE conf. "PowerTech", St. Petersburg, 2005.
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- [5] B. Mekhanoshin et all, "Use of an airborne laser locator to improve availability and quality of maintenance of overhead lines", CIGRE Session 2000, report 22-204