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Usage and Benefit of an Overhead Line Monitoring System

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Abstract- **Overhead lines are the backbone of the electrical power transmission. Contrary to the distributions networks, the transmission system consists only in exceptional cases of longer cable lines. Typical exceptions are connections of cavern power plants, approaches to airports or bird sanctuaries and lines in urban centres. In the majority of cases, an overhead line is the most economic and practicable solution for the energy transmission.**

In tourism regions, an overhead line will be seen as impairment of nature or landscape and so the approval chain and procedure is in most countries long-winded and circumstantial. At the other hand, the energy consumption in Europe is growing and the volatility of transmitted power is also increasing during the last decade caused by the opening of the electric energy market. This opening process leads to a stopping of the enlargement of the interoperation network and to a minimisation of the maintenance of existing lines. Today the network operates more often at the limit of the equipment and the small and large-areas disturbances and blackouts are increasing. The operators of transmission lines are forced to ensure the electrical power supply and so they have to improve the reliability of the network. One solution is to monitor the critical (heavy loaded) overhead lines. For example with the knowledge of the thermal condition, the risk of unexpected outages can be reduced.

Today several monitoring systems are available on the market. They differ in the principle and techniques of the condition evaluation. The three most interesting output variables are the line temperature, the capable transmission power and the actual sag of the investigated section. In this paper an overview of existing overhead line monitoring system and also an outline over the usage and benefit for the application will be given. Thermal monitoring is one technique to improve the reliability of the network and for increasing or optimising the capable transmission power.

I. Introduction

A modern society is not imaginable without electrical power. In almost all parts of living, most of the devices work with electrical energy or are depending on it. Controlling, communication and visualization are realizable with electro or electronic technology. So the modern civilization depends on a sufficient and reliable electrical power source.

Electrical power can be produced economical in large units which are sometimes far away from the consumers. Also the availability grows by connecting more units to a lager system. So there is a demand in a reliable transmission system between power generation and consumption by intermeshing the grid.

Today two systems are dominating the transmission and distribution networks: overhead lines and cables. The third possibility which is becoming more and more of interest is a gas insulated line (GIL). Today only a few and short lines are realised in this technology

The cables have the advantage that they are (in most of the cases) buried in the ground or installed in tunnels. They are invisible for the normal citizen. But beside the costs, it is also the disadvantage of cable. Failures inside the cable have to be detected, localised and excavated which takes a lot of expenditure. The reallocation time after a major failure is high and is the region of several weeks.

There, overhead lines are easer to maintain and have a significant lower reallocation time. But they are fault-prone by effects of the environment and also not unusual seen as impurity in the landscape, especially in touristic regions. Intensification of obligations and resistance in the concerned population make new development or reconstruction of existing lines (overhead lines and cable) long-winded and extensive. Necessary modernisations and enhancements will be slowing and in the meantime the grid overages. But at the same time, the transmission of energy is growing. One reason is the increasing energy consumption of, for example 2% per year in Europe. The second reason is the free market economy of the electric energy generation which leads to a higher spread of the loads.

The increasing and fluctuating load currents and the lack of security stock in some parts the grid require new approaches in the operation methods of electrical power lines [1]. One of the new philosophies is the monitoring and thermal rating of overhead lines [2].

II. Line monitoring concepts

The transmission capability of lines is bounded by the highest operating temperature of the conductors. At overhead lines, additional limits can be the approved magnetic field or the ensured minimum distance to objects. For maximizing the transmission, the conductor temperature and/or the sag are the significant indicators.

Today, several monitoring systems are available on the market. Some technologies are commercial “mass” products; others are small series, pilot series or prototypes. In most cases an individual adaption on the investigated line and local conditions and requirements is mandatory; especially for the power supply and telemetry of on-side units.

The technical principles can be divided into direct and indirect measurements. The aims of both techniques are the evaluation of the thermal condition of the line and therefore the line temperature and the current-carrying ampacity are the most relevant parameters.

III. Direct measurement techniques

Systems on the base of direct measurements use technologies, which evaluate the sag or the conductor temperature directly from measurement points of the object under observation. They use distance measurements for evaluating the sag, temperature sensors inside the conductor or contactless temperature sensors to evaluate the conductor surface temperature [3].

The advantage of these systems is that the requested value is ascertainable without additional conversions.

A. Distance or sag sensors

These principle measure the clearance between conductor and object. Contactless sensors, radar, ultrasonic or optical detectors are in usage (see Fig. 1). Icing and wind driven deflection of the conductor can also be detected. The main advantage is that no interaction (except a reflector is needed) to the conductor is necessary, which can be important at existing lines (substantial modification of the approved installation).

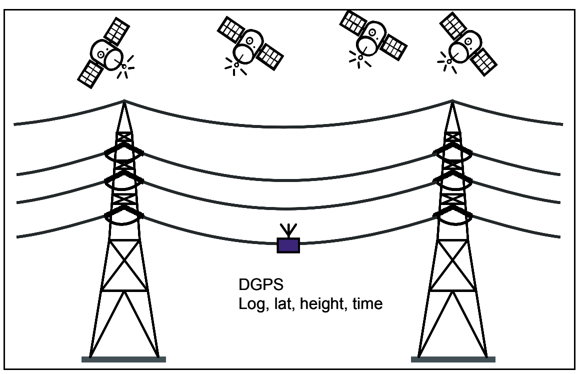

Fig. 1. Sag measurement with DGPS

Instead of the distances or the sags, the first derivation of the catenary curve can also be used (see Fig. 2). From the rope angle of the conductor and the geometry of the span, the sag and the distances to objects can be evaluated.

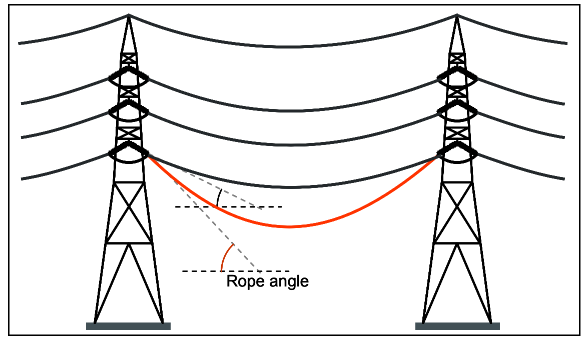

Fig. 2. Rope angle measurement with declination sensors

B. Temperature sensors with fibre optics

These techniques can be divided into two types of measuring principles: punctual and distributed measuring principle. With punctual measurements, a heat sensitive end of a fibre optic cable is inserted between wires of the conductor at a tension tower. At a distributed measurement, a heat sensitive fibre optic is installed inside the conductor and based on the Raman Effect the temperatures profile along the conductor can be detected (see Fig. 3).

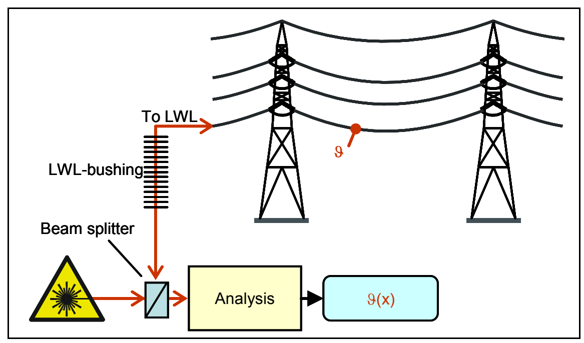

Fig. 3. Distributed temperature measurement using Raman Effect

C. Contactless temperature measurement

This principle uses the emitted long waved radiation of the conductors. Spot measure (pyrometer) and imaging (Thermography) systems can be used (see Fig. 4). An aged and darken surface eased the measurement but is not a requirement for the system and so no interaction on the conductor is essential.

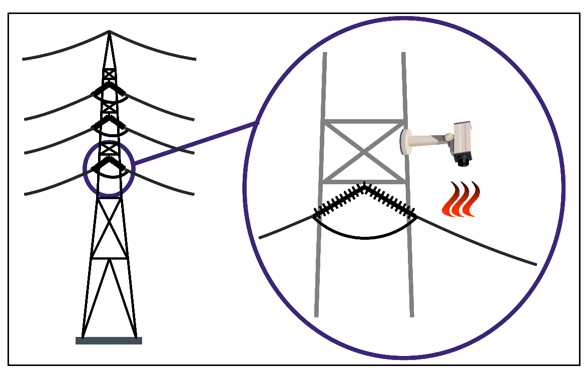

Fig. 4. Contactless temperature using Thermography

IV. Indirect measurement techniques

Systems on the base of indirect measurements use technologies, which evaluate the sag or the conductor temperature indirectly from measurement points of the object under observation via suitable physical indicators. They use the rope tensions, temperature sensors in clamps, environmental conditions or phase angle measurement between substations. The handicap of indirect measurement techniques is that a conversion from the received values to the requested values is mandatory essential. This conversation can be more or less complex or depending to other influencing variables. But nevertheless, indirect measurement techniques allow in some cases a simpler implementing on existing lines.

A. Rope tension

The conductor tension is a function of conductor length, temperature and additional load (ice, wind). With one tension sensor, a whole section from one dead end insulator to the other can be (averaged) observed. On this principle one of the most common commercial systems is based. The tension sensor is inbuilt in the "cold-side" of the dead end insulator and can be assembled under live operation (see Fig. 5).

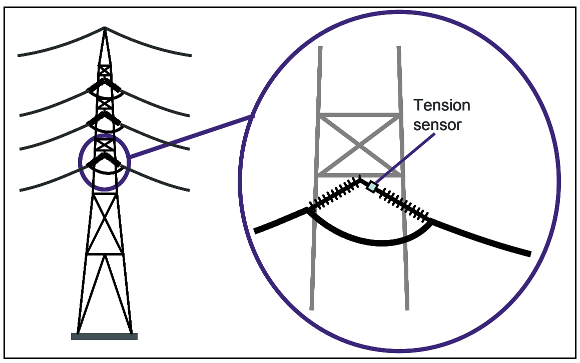

Fig. 5. Rope tension measurement in dead end insulator

B. Clamp sensors

The disadvantage of discrete temperature sensors is the prerequisite of thermal coupling to the conductor. Additional the telemetry and auxiliary power unit require space and also the high voltage design needs a field optimisation (see Fig. 6). So a deviation between unaffected conductor temperature and temperature of the sensor in/on an auxiliary clamp is given. By set up an adequate thermal network, these errors can be compensated. With one sensor only a small area can be observed.

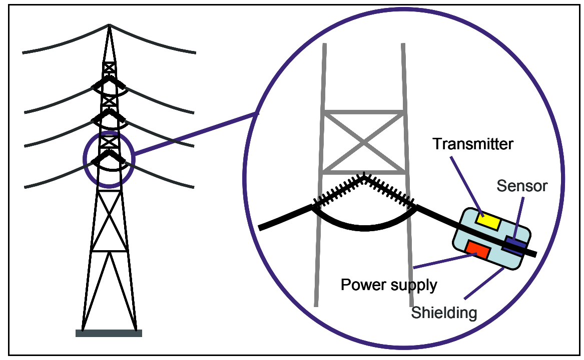

Fig. 6. Example of temperature measurement with a clamped device

An advantage offers the usage of passive temperature sensor like the SAW technology. They use energy from basis station to evaluate the temperature of sensor and so they needn't a power supply on the conductor.

C. Weather parameter method

This technique uses the heat balance between incoming and outgoing thermal energies on the conductor mass. The heating and cooling effect are derived from the environmental conditions and the electrical load. Conditional to the topographical situation and the microclimatic changes, a restricted area can be observed (see Fig. 7). For this method, algorithms are given at IEEE, Cigre and so on [4].

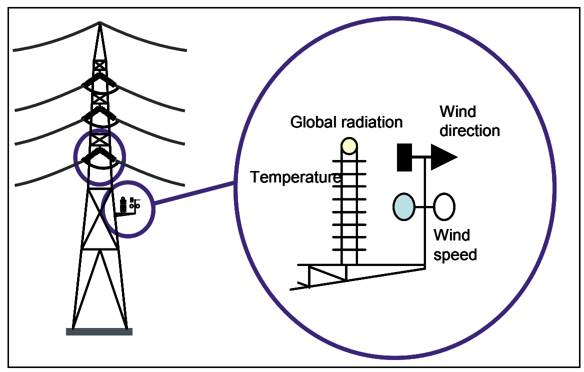

Fig. 7. Environmental condition measurement

D. Phase Angle Measurement

The ohmic losses of a line depend mainly on the load current but also on the conductor resistance (see Fig. 8). By measuring the conductor resistance, the averaged conductor temperature over the whole line can be evaluated. Therefore a time synchrony measurement and a sufficient load current are required. This principle is easy to implement because no interaction on the line in necessary but a higher afford in measurement accuracy and measurement transformer calibration is needed.

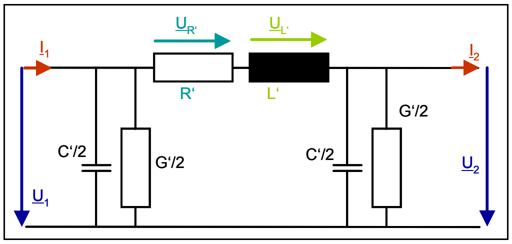

Fig. 8. Equivalent network of line (telegraphic equation)

V. Components of a Monitoring System

Almost independent from the measuring principle, the basically components of a monitoring system are measuring unit with power supply and data communication, a receiving station with data processing and storage as well as a (graphical) user interface for the operator or an input of an automatic control unit (see Fig. 9).

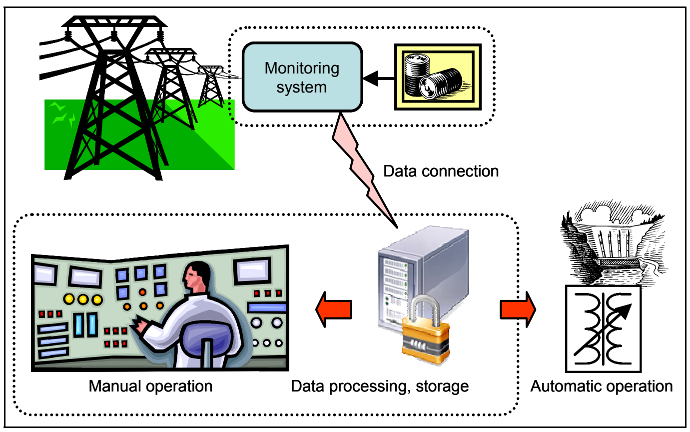

Fig. 9. Schema of a monitoring system

Every monitoring system for the operational service in an electrical network has to fulfil the rudimental safety requirements. This includes a robust measurement and processing design, a failsafe data communication as well as plausibility check of the results. Otherwise a backup or emergency system is obligatory.

Especially the availability of public cellular phone network, which are a simple solution for data communication, cannot be guaranteed and so unavailability scenarios are requested.

VI. Usage of Monitoring System

The main application of thermal rating line monitoring systems is the maximum utilisation of "weak" transmission lines (focus on uprating of the transmission, see Fig. 10).

Another use case is the safe-guarding of the required ground clearance and so for improving the reliability of the power supply (focus on down rating of the transmission, see Fig. 11).

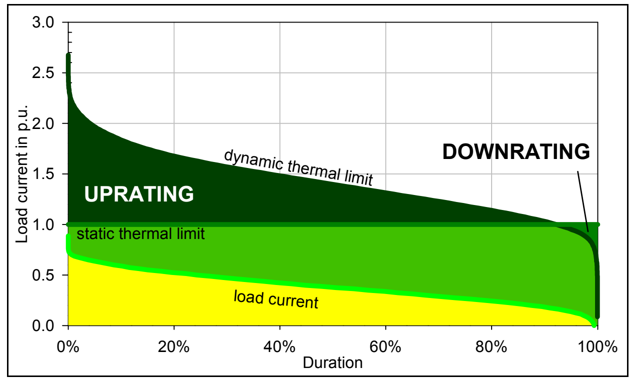

Fig. 10. Example of dynamic thermal rating

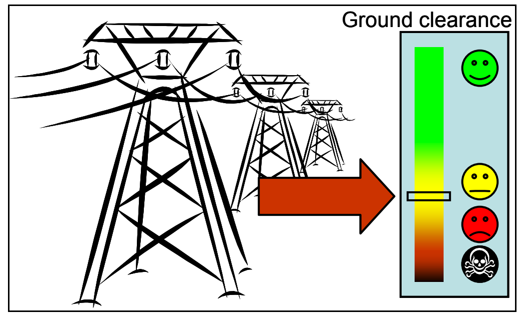

Fig. 11: Example of a safety monitoring

With a dynamic monitoring tool of a line, overload times can be given. Forward-times in the range of 10 to 30 min are for the operators of note. So, more time to make interaction without endanger the security of supply is given.

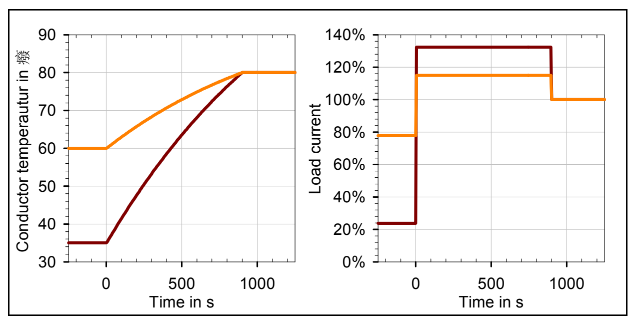

Fig. 12. Example of emergency overload currents for 15min depending on precondition and environmental

In Fig. 12 two examples of rated overload currents are shown. At low preloads (24%) of the line a higher overload (132%) can be allowed. If the line is high loaded (78%), a lower overload (115%) can be approved.

For these three applications an online monitoring system offers a sensible tool. But for a strategically long term forward planning, monitoring systems are "irritating" due to the variable transmission capability (see Fig. 13). At the one hand the transmission capability can be raised and so the benefit grows. But at the other hand, without an excellent forecasting the lines can not be warrantable uprated and the benefit is nullified. So conservative assumptions based on statistical data and weather forecast should be taken for a long term planning and the results of the monitor in combination with a short term forecast for the operation.

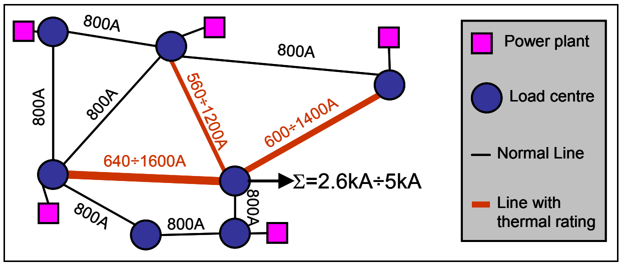

Fig. 13. Transmission capability of a fictive network with thermal rating

VII. CONCLUSION

Monitoring systems for thermal rating of overhead lines are currently available on the market with different measurement principles. The operators can select their optimum system which fulfils the specific circumstances and requirements for their applications. With an effective monitoring system in most cases an increasing of the transmittable electrical power can be achieved. But at the moment the thermal rating of overhead lines is not state-of-the-art [5]. Challenges like strategic planning (day-ahead), protection relays settings and cascaded failures have to be solved and therefore new concepts with dynamic line ratings must be developed. With a monitoring system, separated lines can be uprated. A real-time usage on a widespread intermeshed network is from today's perspective not adequate. The troubles with the protection systems and forecasts overbalance the benefit of increasing capability and so a reinforcing of the network or a regulation of the load flows is the long-term and prospective solution.

REFERENCES

[1] P. Pramayon, et.al., “Increasing capacities of overhead lines needs and solutions”, *Cigre Session* B2-108, Paris 2008

[2] L. Barthold, D. Dale, D. Woodfort, “Maximizing the capability of existing ac transmission lines”, *Cigre Session* B2-109, Paris 2008

[3] M. Muhr, S. Pack, S. Jaufer, “Overhead line measurements and monitoring for increasing system reliability”, *Cigre Symposium - Transient Phenomena in Large Electric Power Systems,* Zagreb/Kroatien 18.04.07

[4] Cigre Working Group B2.12, “Guide for selection of weather parameters for bare overhead conductor ratings”, *Cigre Brochure* 299, August 2006

[5] H.-J. Dräger, D. Hussels, R. Puffer, “Development and Implementation of a Monitoring-System to Increase the Capacity of Overhead Lines”, *Cires Session* B2-101, Paris 2008