Automated Measurements of Mechanical Strength and Durability of Selected Cables

Attila Kment, Marek Pípa, František Janíček
Institute of Power and Applied Electrical Engineering
FEI STU in Bratislava
Bratislava, Slovakia
attila.kment@stuba.sk, marek.pipa@stuba.sk, frantisek.janicek@stuba.sk

***Abstract* – Contribution deals with automated measurements of mechanical parameters and current carrying capacity of selected Aluminum-conductor Steel-reinforced (ACSR) cables and a combined optical ground cable. After a detail description of realized tests indication of future use of obtained results follow.**

Keywords- transmission lines; ACSR cables; combined ground cable; mechanical strength; current carrying capacity; Labview;

I. Introduction

Life at 21 century is unthinkable without an effective, reliable and quality supply of electricity. To fulfill this challenging task the cooperation of government and private national and multinational companies active in the field of electricity generation, transmission and distribution is vital. Nuclear, thermal, hydroelectric or combined-cycle power plants with a large installed capacity provide the necessary regulatory reserve for primary, secondary and tertiary regulation in the power system. Electricity produced there has to be transmitted at high-voltage potential to electric stations near the point of consumption. Generation, transmission and distribution of electricity became more complicated by adding power plants with unpredictable electricity production based on renewable resources into the power system. Electricity grids of the European Union countries are interconnected, the ratio of implemented unpredictable sources in each country is different, and not every country is self-sufficient, that is why the role of the transmission system became more important. In some cases the uninterrupted electricity support is achievable only at the cost of overloading certain transmission routes.

The aim of this paper is testing of selected Aluminum-conductor Steel-reinforced cable (ACSR) and also selected type of combined ground wire using automated measuring and evaluation workplaces. The contribution provides a description of progress in workplace automatizing process.

This contribution/publication is the result of the project International centre of excellence for research on intelligent and secure information and communications technologies and systems, ITMS 26240120039 supported by the Research & Development Operational Programme funded by the ERDF.

II. Current Carrying Capacity Tests

Current capacity tests and estimation of maximum continuous operating temperature of power systems are important for long term thermal degradation and ageing of mainly organic insulating materials used in power engineering (insulators, cable insulation systems, etc.) [1]. Measurements were carried out on sample of ACSR cable shown on the left in Fig.1 and the combined ground cable shown on the right in Fig.1 as stated in Table 1. Measurement of samples' current carrying capacity was performed in short loop wiring as shown in Fig. 2.

TABLE I. Labeling of Samples

Labeling	Sample description
S11	Aluminum conductor of 450aAlFeb8c cable
S12	Steel conductor of 450aAlFeb8c cable
S21	Aluminum conductor of combined ground cable ASLH-D(S)bbb 1x24 SMF (AL3/A20SA 177/56 - 22,4)
S22	Steel conductor of combined ground cable ASLH-D(S)bbb 1x24 SMF (AL3/A20SA 177/56 - 22,4)

a. 450 cross-section of Aluminum conductors of ACSR cable in square millimeters

b. designation of ACSR cable

c. Aluminum and Steel conductors cross-section ratio, i.e. SAl / SFe = 8

Figure 1. Tested samples : left - ACSR cable, right - ground cable

ISBN 978-80-261-0386-8, © University of West Bohemia, 2015

Figure 2. Workplace for current carrying capacity tests

Loading current was induced into the sample loop using current transformer windows [2]. The current was measured by clamp ammeter. The applied current range was chosen from 250 A to 1000 A, with 250 A increments. For each applied current level the time dependence of samples' core temperature was measured by K-type thermocouple as shown in Fig. 3 left-hand-side. 5 seconds average temperatures were digitized using Fluke software. In addition the thermal conditions of the workplace during tests were monitored using Fluke Ti 55FT thermal imager.

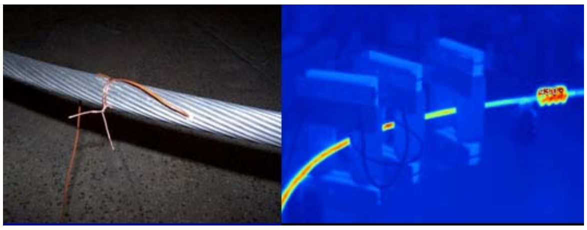

Figure 3. Details of current capacity tests workplace

During tests on combined ground cable the first applied current level was set to 150 A, then after the core temperature stabilization the next level of induced current was set to 300 A. The highest level of applied current was set to 600 A.

To avoid the necessity of testing personnel presence at workplace for safety reasons the automation of workplace with the ability of manual override from the place and by remote controlling followed.

To fulfill this purpose the following devices were used :

- measuring and signal generating modules from National Instruments (NI),
- NI CompactRio,
- NI CompactDaq,
- NI USB card carrier,
- digital multimeter Fluke with K-type thermocouple,
- temperature, relative humidity and atmospheric pressure sensors,
- digital oscilloscope.

To enable the automatic atmospheric conditions metering, it was necessary to adapt the sensors' output voltage level to NI cards readable format. For this purpose a small electronic box was needed to be created. Next the calibration process took place using reference thermo-, relative humidity- and pressure-meters. For programming purposes the NI Labview 2010 Development software was used. The platform is scalable across multiple targets and OSs, and, since its introduction it has become an industry leader. The easy flowchart together with its front panel is shown in Fig.4.

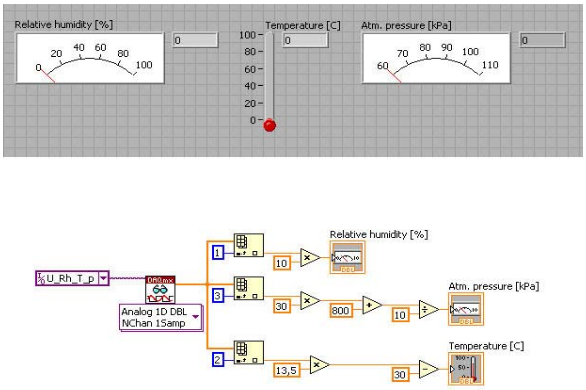

Figure 4. Flowchart and user interface for atmospheric conditions monitoring

As the next step, a digital signal controlled relay box needed to be created with 5 relays inside. One is needed to switch the source on, next for switching off, third to enable current rise, fourth for current lower and the last serves as total stop. To ensure the safety of high-current source, it was needed to wire the whole schematics with the priority of manual control by buttons on the control table. Next to the entrance to the workplace it was needed to place a "testing in process" warn signal. At this point the computer controlled voltage source was ready using a digital signal source NI card and a simply Labview 'vi' program, but without any feedback of current presence or its level. To solve this problem a voltage ratio box, i.e. voltage divider needed to be created with regard to maximum input voltage to analog signal measuring NI card. The divider then needed to be calibrated to enable measuring of current in short circuit. Creation of user interface followed, where the actual time, current, temperature of cable core and atmospheric conditions are shown. After the measurement it is enough to press the 'Off' button to decrease the current by motor driven regulatory transformer and switch the source off. Other buttons as 'Raise' and 'Lower' are active when no automatic processes are running only. Of course the highest priority is defined to 'Total stop' button, which switches the source immediately off. Part of user interface is shown in Fig. 5.

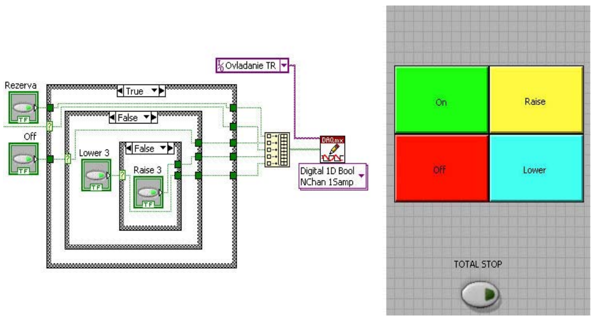

Figure 5. Current source's flowchart and user interface

Fig. 6 show the time dependence of core temperatures of the ACSR cable. As given by manufacturer of samples, the highest allowed core temperature is set to 90 °C, so these tests gives valuable data for modeling of in-operation overloads.

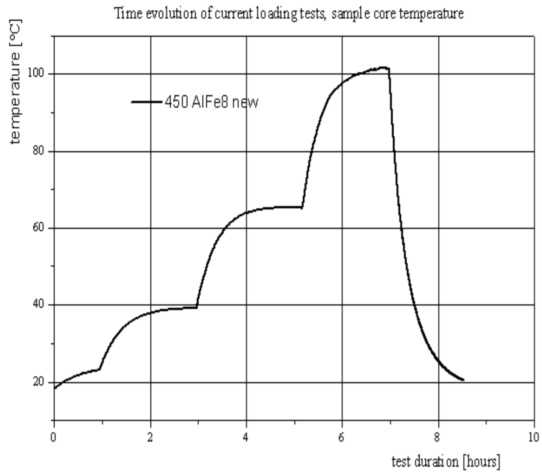

Figure 6. Time dependence of new 450 AlFe 8 ACSR cable's core temperature

Next the current carrying capacity of combined ground cable followed. As shown in Fig. 7, the time needed for core temperature stabilization was twice shorter in comparison with ACSR cable.

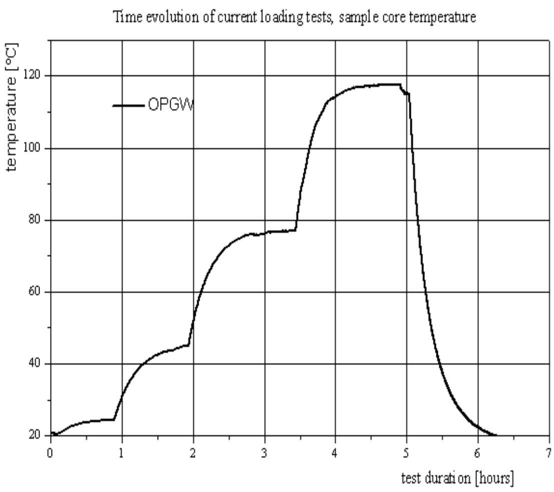

Figure 7. Time dependence of combined ground cable's core temperature

III. MECHANICAL TESTING

The test sequence was chosen based on the nature of the object under test recommendations to EN ISO 6892-1:2010 Metallic materials - Tensile test - Part 1 - Tensile test at ambient temperature. Because anchoring of whole ACSR cables to ripper was not possible, 70 cm long individual conductors of ACSR cable and combined ground cable were tested. The labelling of samples was done in accordance with data in Table 1. The test set-up during measurements is shown in Fig. 8. To make it easier to evaluate test data together with the oscillograph of the ripper several tensile gauges connected through National Instruments measuring cards and Labview interface to PC were used.

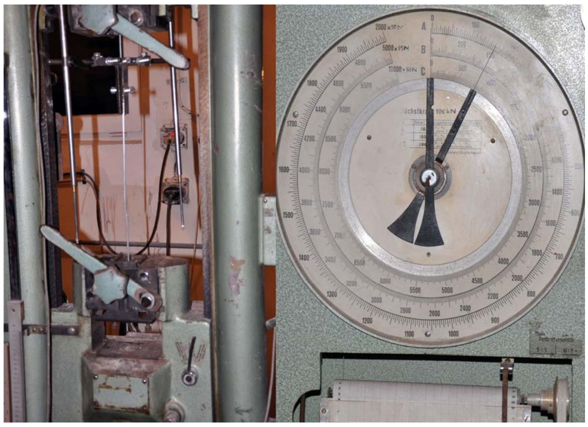

Figure 8. Workplace set-up during mechanical test of selected cables

During the test the graphical dependence of prolongation on burdensome force was recorded, which is called the diagram of ripper [3]. Test results, i.e. diagrams of ripper obtained are shown in Fig. 9 to Fig. 12.

To compare different samples, the load is calculated per unit area, also called normalization to the area. Force (F) divided by area (S_0) is called stress (1). In tension and compression tests, the relevant area is that perpendicular to the force.

$$\sigma = F / S_0 \quad (1)$$

tensile or compressive stress

$$\tau = F / S_0 \quad (2)$$

There is a change in dimensions, or deformation elongation, ΔL as a result of a tensile or compressive stress. To enable comparison with specimens of different length, the elongation is also normalized, this time to the length L. This is called strain, ε.

$$\varepsilon = \Delta L / L \quad (3)$$

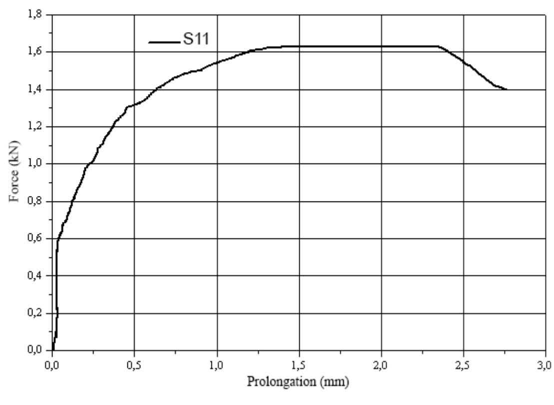

Figure 9. Graphical dependence of prolongation on force for S11

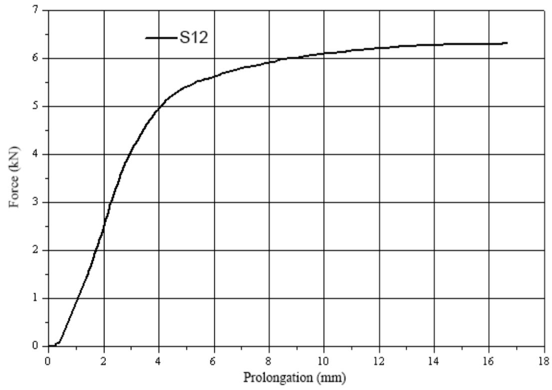

Figure 10. Graphical dependence of prolongation on force for S12

The change in dimensions is the reason we use S_0 to indicate the initial area since it changes during deformation. One could divide force by the actual area, this is called true stress. In tensile tests, if the deformation is elastic, the stress-strain relationship is called Hooke's law:

$$\sigma = E \cdot \varepsilon \qquad (4)$$

That is, E is the slope of the stress-strain curve. E is Young's modulus or modulus of elasticity. In some cases, the relationship is not linear so that E can be defined alternatively as the local slope:

$$E = d\sigma / d\varepsilon \qquad (5)$$

If the stress is too large, the strain deviates from being proportional to the stress. The point at which this happens is the yield point because there the material yields, deforming permanently (plastically). Hooke's law is not valid beyond the yield point. The stress at the yield point is called yield stress, and is an important measure of the mechanical properties of materials. In practice, the yield stress is chosen as that causing a permanent strain of 0.002.

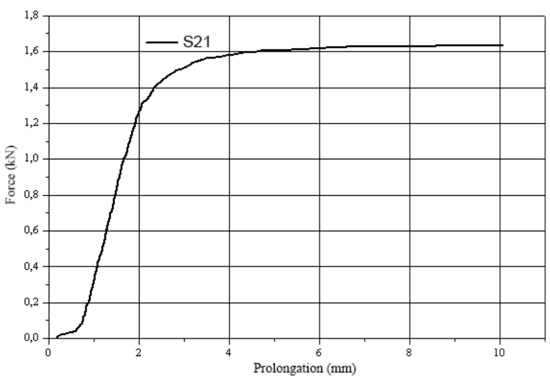

Figure 11. Graphical dependence of prolongation on force for S21

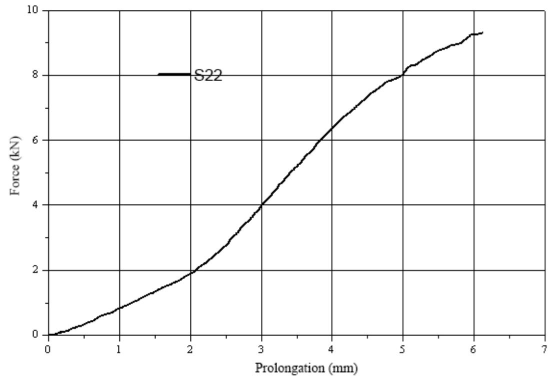

Figure 12. Graphical dependence of prolongation on force for S22

IV. CONCLUSION

Performing measurements and tests on the samples of ACSR cables and combined ground cable yielded many important data for further evaluation. Measuring the mechanical strength parameters for the samples were obtained working diagrams of used steel and aluminum conductors in individual cables. These diagrams and voluminous data obtained during mechanical testing enables the construction of mathematical and physical model based on real experiments needed for the following mechanical expertise, for example using one of method of finite elements modelling.

Depending on the measurements of current carrying capacity allow to model various operating states of congested transmission paths. Increased current load of these cables have an adverse effect on the life of overhead lines whether in the form of excessive extension or filler leakage. After losing the filler it is necessary to consider the impact of increased mechanical wear and mechanical abrasion.

Using these data in conjunction with models of poles used in transmission and distribution lines enables to make a complex overhead line PC model. This model then allow us to define and simulate boundary conditions when dealing with the problem of increasing the power safety from the view of long time overload possibilities or when dealing with the problem of unusual atmospheric conditions.

REFERENCES

[1] J. Pihera, P. Martínek, J. Klasna, B. Paslavský, R. Polanský, V. Mentlík, P. Trnka: Partial Discharges of Thermally and Electrically Aged Insulation, 2009 Annual Report Conference on Electrical Insulation and Dielectric Phenomena. Virginia Beach : IEEE DEIS, 2009.

[2] STN EN 60060-1:2011 High-voltage test techniques. Part 1: General definitions and test requirements.

[3] EN ISO 6892-1:2010 Metallic materials. Tensile test. Part 1: Tensile test at room temperature