Test-run for uprating of Overhead Lines using innovative Technologies at APG

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SUMMARY

Uprating of existing Overhead Lines is one approach to increase their capacity. APG is considering uprating certain 220 kV-lines to 380 kV in the near future. To this end new technical components have been developed. However requirements for an uprating are not exclusively technical, standards and legal aspects, environmental impacts as well as economical considerations have to be investigated in-depth. In the project “Innovation-Section” technical developments such as new conductor types and insulated cross-arms were tested on site. Monitoring of the line and relevant components were installed to gain experience with the new technology.

KEYWORDS

Overhead line - Conductor - Corona - Voltage uprate - Insulated cross-arm

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INTRODUCTION

Different approaches can be used to strengthen the transmission grid. Extraordinary long procedures for planning and authorization of new lines, often over decades, are no exceptions in many countries. Uprating of existing Overhead Lines (OHL) could be a method to overcome such hurdles. Considerations to increase the capacity of existing OHL are carried out all over the world. Such an uprating makes sense if the achieved additional capacity is sufficient for the envisaged strengthening of the grid. Each uprating method has its limits and in many cases new lines - either a replacement on the same route or on a new one - become necessary, if the gained increase due to uprating is not sufficient.

Many TSOs, including Austrian Power Grid (APG), which is the main TSO of Austria, follow the principle “optimization before extension”. Uprating is one such method and facilitates the prevention of building new OHL.

Uprating of Overhead Lines has been under discussion for many years in Cigré, and several publications and reports exist [1, 2, 3]. Examples of uprated OHL and experience can be found in discussion papers from the biannual sessions in Paris [4].

The expression “uprating” is used for different measures. Among them are:

- **Uprating** - The process by which the thermal rating of an overhead power line is increased [1].
- **Uprating of a line** is the increase in its transmission capacity [2].
- **Uprating** applies a physical solution that allows the system to be operated at a current level above its rated current, or applies a method or a calculation that leads to improve the assessment of the performance of the system. [5].

Thus from the definitions above, it was deduced that uprating is an approach to increase the capacity of an existing OHL by various methods. These methods are in principle:

- Reconductoring
- Thermal rating
- Increasing voltage e.g. from 220 kV to 380 kV “voltage uprating”

This paper outlines considerations for a voltage uprating from 220 kV to 380 kV. The so-called “Innovation-Section” with a length of 1,2 km was established on an existing 380 kV-line. The objective was to develop new conductors and insulated cross-arms, to test their installation under real 380 kV conditions on site, and to gain experience about the service, particularly of their environmental performance.

Advantages of uprating an existing OHL are mainly observed in the following:

- use of existing routes and corridors
- use of existing structures, foundations, conductors as much as possible
- no new landowners and communities are concerned
- normally faster approach than a new line
- very little or even no influences on the environment
- in general high acceptance
- cost efficient solution compared to a new line
CONSIDERATIONS FOR UPRATING IN THE AUSTRIAN TRANSMISSION NETWORK

Principally, Austria’s existing 220 kV-lines have two basic designs. Both of them use double system lattice steel towers with “ton”-configuration. One of the designs is equipped with single conductors ACSR 340/110, the other one with double bundles ACSR 560/50.

Due to audible noise considerations, double bundles are obligatory for 380 kV and are a minimum requirement in APG’s 380 kV grid. This entails 220 kV-lines with single conductors being excluded from voltage uprating. The installation of a second sub-conductor on such lines would exceed any reasonable enforcement for the towers, and would therefore lead to completely new lines.

To strengthen this argument it should be mentioned that APG undertook a test run with a large single conductor of 54 mm diameter in a short section of a 380 kV line in the 1980s. The test failed as the audible noise exceeded acceptable volume.

For actual uprating considerations in APG’s grid this means that 220 kV lines in the regions of Carinthia and Tirol can be considered for voltage uprating – depending on the final results from the “Innovation-Section”.

TECHNICAL REQUIREMENTS

Technical requirements for uprating are intricate and need to be thoroughly investigated. Measures taken on lines have to be verified through reliable practice. The following main topics need to be focussed on:

- Standards and Legal Aspects
- Environmental Impacts
  - Electric and Magnetic Field
  - Audible Noise
- Technical Components
- Economical Considerations

STANDARDS AND LEGAL ASPECTS

Vital aspects in considering a line uprating are the standards which are applied and the legal scope.

All standards, including those for the design, erection and operation of OHL, may change over time. Standardization laws demand the periodic check of these standards. This together with technical innovations, alterations in procedures and changes in the political and natural environments, leads to adaptations after a certain period of time.

One of the main questions arising, regarding uprating, is which standard to apply, the one prevalent at the time of the erection or the latest one. In some countries this is legally defined. Design parameters (loads from ice and wind), internal and external clearances, design codes and design philosophy (deterministic/empirical, semi-probabilistic, full-probabilistic), material properties and many others play an influencing role. Requirements for maintenance and operation of the line need to be considered.

Permission from authorization bodies for existing lines normally define electric parameters and make reference to laws and standards valid at the time of the erection. If such parameters

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change due to uprating (current, voltage) the validity of the said permission should be investigated. This leads to the question: Which laws and regulations are adhered, if a new authorization procedure becomes necessary for the uprating?

The clarification of aspects of standards, laws, permissions, authorizations, is among the most important. It shall be clarified early when discussing uprating. The outcome is a decision about “go” or “no go”.

**ENVIRONMENTAL IMPACTS**

The most important issue regarding environmental impacts is to guarantee compliance with legal exposure limits of electric and magnetic fields (EMF) and audible noise (AN).

**Electric and Magnetic Field**

In the given uprating-scenario the current capacity of the OHL does not change, thus the magnetic field basically does not change. The modification from a standard lattice-tower-design to insulated cross-arms reduces the internal conductor-arrangement distances. This causes a slightly higher magnetic field directly underneath the OHL however it reduces the field strength depending on the lateral distance to the OHL. This is paramount when compliance to very strict regulations is necessary, as in the Swiss NISV (1 µT).

The operating voltage is raised from 220 kV to 380 kV, an increase of 70 %. The electric field increases in the same order. To remain within national exposure limits for the electric field (5 kV/m in 1 m above ground in Austria), a minimum ground clearance has to be applied. The advantage of the insulated cross-arm design, is that the ground clearance is already higher than that of the original OHL design. Nonetheless it has to be examined for every span, if there are any additional measures necessary to remain compliant within the given limits (e.g. raising pylons).

**Audible Noise**

The existing 220 kV-line considered for uprating has a very low corona noise level, due to the double bundle configuration. Increasing the operating voltage from 220 kV to 380 kV without any measures would have the consequence of significantly higher Audible Noise (AN) in bad weather conditions. Calculations reflect a rise of up to 15 dB under these circumstances. To put this into context, an increase of 10 dB sound level, amounts to the doubling of AN to the human ear.

The primary goal, is to keep AN of the uprated OHL in approximately the same magnitude as the existing 220 kV-line. This is ensured by the measures described in the following paragraphs.

To reduce the electric field, the diameter of the sub-conductor is increased, which reduces the electrical gradient field at the surface of the conductor, which is a known method used to reduce AN. This approach improves AN, by approximately, 5-10 %.

Additionally, a special coating is applied to the conductor, which has the same hydrophilic surface properties as an old conductor. This behaviour is different to new untreated conductors (hydrophobic surface) as it leads to a further reduction of up to 10 dB in AN compared to the new untreated conductors.

The exposure limit used for legal evaluation of AN of a new OHL in Austria, is the WHO threshold value of 45 dB(A) at night, measured outside a residential home. When adapting an existing OHL legal guidelines requires that there is no significant increase in AN. Whether the first or the second scenario applies is yet to be seen.
TECHNICAL COMPONENTS

In the project “Innovation-Section” a 1.2 km long part of an existing double circuit 380 kV-line in Austria was used for a test-run for two new technical innovations necessary for an uprating project. The section was equipped with new developed insulated cross-arms and new developed conductors. The planning of the project started at the end of 2013 and the conversion of the cross-arms and installation of the new conductors, took place in autumn 2015.


Initial results and an evaluation of the project will be available after a long-term measurement of audible noise reduction during 2017.

Insulators

To raise the insulation level from 220 kV to 380 kV the internal phase clearance has to be adapted. Insulated cross-arms are therefore used and are directly mounted to the suspension-tower body. For the tension-towers the insulator-string has to be adapted to the 380 kV level. The lattice-steel cross-arms from the tension-towers remain unchanged.

Conductors

Existing 220 kV-lines in the Austrian transmission grid considered for voltage uprating consist of a twin bundle conductor configuration. The sub-conductor diameter is much less than those of modern 380 kV-lines. For an uprating from 220 kV to 380 kV it is necessary to use conductors with a larger diameter to reduce corona noise. To maintain mechanical loads at an acceptable range for the tower construction, a special conductor with lower self-weight is used. In these conductors metallic wires are replaced by plastic elements as seen in Figure 1. Additionally a hydrophilic coating for the conductor is used to reduce water drops on the surface and subsequently decrease corona noise emissions.

Figure 1: Sketch of the cross section of the special conductor
(Metallic wires in blue, plastic elements in grey)
**Tower**

Suspension towers were adapted by installing insulated cross-arms instead of the previous lattice steel. The existing steel cross-arms are removed from the tower and the insulated cross-arms are suspended on a special substructure. Figure 2 shows on the left the original lattice steel suspension tower and on the right the adapted construction with insulated cross-arms. The construction has to be evaluated if it is capable to withstand the new load-cases, due to the new conductor and the altered suspension point.

![Comparison between lattice-steel (left) and the new 380 kV insulated cross-arms (right) of a suspension tower at the “Innovation-Section”](image)

**Figure 2: Comparison between lattice-steel (left) and the new 380 kV insulated cross-arms (right) of a suspension tower at the “Innovation-Section”**

**Installation of cross-arms and conductors and line maintenance**

The installation process has to be optimized that the shutdown time of the line is minimal during the uprating. This is done by a special substructure. Most parts of this construction can be installed while the line is under full operation. The removal of the steel cross-arm and the mounting of the insulated cross-arm are done within a few hours, per tower, and the shutdown-time of a single system is therefore reduced to a minimum.

A customized hoisting device was developed to facilitate installation and maintenance of the cross-arm.

Figure 3 shows the insulated cross-arm installed on the new substructure with mounted hoisting device.
ECONOMICAL CONSIDERATIONS

Compared to erecting a new line, uprating of an existing overhead line is a significantly more economical method of gaining new capacity. Although total costs vary according to projects, when comparing technical costs (for adaptations of towers and reconductoring) cost savings of up to 60% could be realised compared to a new line. Granted, a new line would still have more capacity, however cost savings per MVA rated capacity reach up to 40% (see Table 1).

<table>
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<th>costs per km (EUR)</th>
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<tr>
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CONCLUSION

Uprating of existing Overhead Lines is a method to increase the capacity and could facilitate reducing the need to build new lines. APG is considering uprating some 220 kV-lines to 380 kV in the near future. New conductors and insulated cross-arms were developed to allow such an uprate given the current standards and conforming with the current climatic and topographic conditions. In the project “Innovation-Section” the new design was tested on site. Experience with the installation and service are so far satisfactory. Measurements of audible noise are being recorded and will be evaluated. Depending on the outcome of these results, a final conclusion will be ascertained, and decisions about future voltage upratings, can then be taken.
BIBLIOGRAPHY


