HTLS and HVDC solutions for overhead lines uprating

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1. Abstract

The increase in power demand has made that existing overhead transmission lines need to transmit more energy. In addition to this, the legislation of many developed countries hinders or even forbids the construction of new overhead lines because of their environmental impact. Furthermore, and as a result of this, some transmission lines can be close to its critical capacity limit.

In this paper, several uprating technologies are compared taking into account environmental conditions, maximum stress bearable by the towers and maximum sag as well as economical concepts to develop a mapping criterion of conductor selection.

Keywords: Line capacity, HTLS, overhead line uprating, HVDC, knee point.

2. Introduction

Nowadays, the permissions and licenses needed to build new lines and in some areas even the retrofitting of the previous lines are very difficult to obtain. Moreover there are many social objections against this kind of facilities. The previous drawbacks have made electric utilities to consider the uprating of existing overhead lines in order to manage with the demand increase.

There are different ways to improve an overhead line capacity: real-time monitoring, increase cable stress, replace ACSR conductor with High Temperature Low Sag (HTLS) conductor and transform the AC line into HVDC.

The cheaper method to get an overhead line uprating is real-time monitoring. By this method the line operator has the information to decide the maximum line current without exceed the conductor thermal and sag line limits, according to instantaneous weather conditions.

The second option consists of increase conductor installation stress. This solution is feasible only if conductors and towers can withstand the new stress.

The main problem of these solutions is that usually, the upgrading is not enough to deal with increase of the demand. For this reason, in a high percentage of uprating lines the options chosen are replacing conventional conductor by HTLS or transform the AC line into HVDC. In this paper the main features of these solutions are detailed.

There is a wide range of HTLS technologies commercially available. The Figure 1 shows the improvements and costs of the different conductors compared with the other uprating solutions.

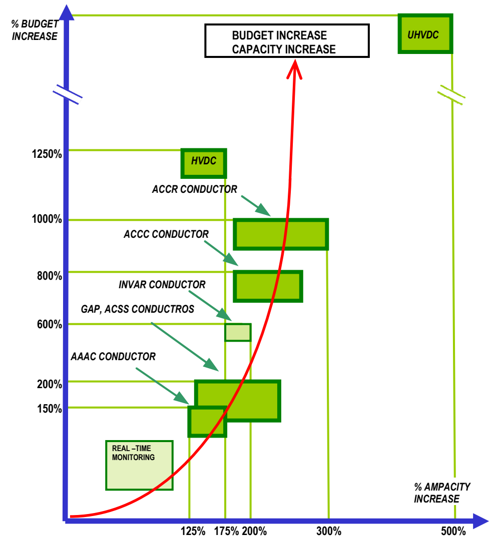

Figure 1. Capacity increase and cost of each uprating solution.

The conversion of an AC overhead line to HVDC is the most expensive solution because of converters stations in both ends of the line. Nevertheless, HVDC has important advantages: low losses, line reliability improvement and it can get the biggest capacity increase.

CO_2 emissions of each uprating have been calculated with the losses, which have been calculated with the exact equivalent circuit, and taking into account an average emission factor of the utility.

3. HTLS Conductors

Thermal limit of conventional conductor is round 90ºC, above this temperature the material suffers plastic deformations. To improve this behavior HTLS conductors are based on aluminum alloy and annealed aluminum, thereby they can operate between 150 and 210ºC without damages. One of the most important characteristic of the HTLS conductors is the knee point. The knee point is the temperature from which the whole conductor stress is withstood by the core. Therefore if the temperature is higher than the knee point the conductor presents excellent mechanical properties, low coefficient of thermal expansion (CTE) and high tensile strength, guarantee low sag values. In HTLS, the pure aluminum of the ACSR conductors has been replaced by a high temperature aluminum alloy. The main features of the HTLS conductors considered in this paper are:

- **G(Z)TACSR:** It has a gap between core and aluminum fill with grease, as a result, aluminum can slide over the core. By this way the whole stress is supported by the core when the conductor exceeds installation temperature.
- **ACSS:** It is based on annealed aluminum so the maximum temperature is increased. If the steel core is coated with galvanized or with a mischmetal alloy, the thermal limit increase up to 250ºC.
- **(Z)TACIR:** The core is made up of steel-INVAR alloy with a low CTE.
- **ACCR:** It is made up of aluminum oxide fibers which reduce the weight and increase the total conductivity, achieved a great capacity.
- **ACCC:** It is based on annealed aluminum over high tensile strength carbon fiber cover with glass fiber of reduced CTE, therefore low sags are obtained.
- **AAAC:** It is not a HTLS because of its maximum temperature is 90ºC but capacity increases are reached because the whole section is aluminum.

To select the conductor that better fits with the new line conditions is necessary to study its maximum sag and current. Both parameters depend on installation stress and the knee point of the conductor. Installation stress is limited by the existed towers lines and knee point. Knee point temperature varies from 15 or 20 ºC in G(Z)TACSR to 100ºC in (Z)TACIR.

4. HVDC conversion

The key points to consider in a HVDC uprating are the next:

- **Low conductor losses.** In HVDC solutions the increase of capacity is accomplished by rising nominal line voltage. Therefore current flow through the conductor is the same than in the previous ac line and conductor losses due to Joule effect will maintain constant.
- **Maximum nominal line voltage.** This parameter depends on the tower features. If the existing tower can be modified or not, the maximum nominal line voltage changes.
- **Insulator string behaviour in dc.** DC isolation is more complex than AC due to no polarity alternation in current. According to [3] in some cases an improve protection against corrosion can be apply to get higher voltages, in other cases, specially when very high voltages are needed, ac insulators have to be replaced by specific dc insulator with different geometry.
- **Line configuration.** There are different ways to lay out the DC conductor over the towers but bipolar is the best one. It has two voltage level and symmetrical polarity in each pole. In spite of being more expensive, it maximizes the line capacity. If towers cannot be modified, the layout depends on the ac tower geometry. If towers can be modified the best option consists on replace the 6 existing cross-arm (when the ac line have 2 circuits) with 2 longer and more resistant cross-arm, one for the positive polarity and the other for the negative.

5. Case Study

In order to analyze the different uprating solutions, a study has been made in a real overhead line. The length line is 23km and the conductor installed is a LA-280 Hawk.

The HTLS conductors behaviour has been studied with PLS CADD. This program calculates the main line parameters depending on conductor properties and weather conditions defined by user.

Firstly HTLS uprating is studied replacing the ACSR conductor by HTLS conductor.

Then, the maximum nominal line voltage has been calculated by changing the line to HVDC with the same tower and insulator strings.

In the last case, tower and insulator strings modifications are taken into account to calculate the maximum uprating with HVDC.

6. Conclusions

According to manufacturers, replacing ACSR conductor by HTLS the uprating varies from 125 to 300%, in the studied case and under the specific line conditions the maximum uprating reached is 230%.

When the line is transformed to HVDC the capacity line increases up to 175%. In this case the new line keeps the previous insulator strings, towers and conductors. Only the substation must be changed.

Whether the whole facility is modified in order to get the maximum capacity increase, HVDC solutions achieved up to 500%.

In those cases in which a extreme uprating would be necessary, above 500%, both solution, HVDC systems with HTLS conductors, can be applied together and so their benefits are multiplied.

Acknowledgements

The authors wish to express their gratitude Endesa Network Factory for their collaboration in this project.

References

[1] Exposito, A.G. Riquelme Santos, J., Cruz Romero, P., “Planning and Operational Issues Arising From the Widespread use of HTLS conductors”, IEEE Trans. On power systems, VOL.22, NO.4, Nov. 2007

[2] D.M. Larruskain, I. Zamora, O. Abarrategui, A. Iraolagoitia, M. D. Gutiérrez, E. Loroño y F. de la Bodega, “Power transmission capacity upgrade of overhead lines,” presentado en International Conference on Renewable Energy and Power Quality (ICREPQ), Palma de Mallorca, España, 2006.

[3] UNE-EN 61325, “Aisladores para líneas aéreas de tensión nominal superior a 1000 V. Elementos aisladores de cerámica o de vidrio para sistemas de corriente continua. Definiciones, métodos de ensayo y criterios de aceptación”, Abril, 1997.

[4] M. P. Bahrman, B. K. Johnson, “The ABCs of HVDC Transmission Technologies,” IEEE Power & Energy Magazine, Marzo/Abril 2007, Vol. 5, No. 2.