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Origin and mitigation of increased electric fields at high voltage transmission line conductors

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ABSTRACT

In this paper analysis of the origin and mitigation measures of increased electric field at high voltage transmission lines in the electric power system of Bosnia and Herzegovina is given. In the analyzed period (2010–2017) in the electric power system of Bosnia and Herzegovina increased values of power frequency voltages was registered. The performed analysis shows that the increased voltages in the 400 kV nodes of the electric power system of Bosnia and Herzegovina are occurring during the night, mainly in the minimum consumption regimes. Increased voltages can occur throughout the year, but are most frequent during the spring and summer months. In the coming years, four 400 kV interconnection transmission lines to Serbia and Croatia will be built. Increasing of the voltage value causes the formation of the corona as well as energy losses. Taking into account the values of the energy losses due to the corona, it is important to determine the values of the electric field on the surface of the conductors and their immediate vicinity as well as the value of the corona onset electric field in order to know their values in the electric power system and to explore ways to mitigation them from the aspect of maintenance and management costs.

1. Introduction

In the recent years (2010–2017), increased values of the power frequency voltages in the electric power system (EPS) of Bosnia and Herzegovina (B&H) have been registered [1]. It has been noted that the increased voltage values in the substations (SS) of 400 kV voltage level of the EPS of B&H occurring during the night, mainly in minimal consumption regimes. In analyzed period most of the 400 kV lines of the EPS in B&H are loaded below the natural transmission power (550 MW), which causes the production of a significant capacitive load. Production of reactive power, the relatively low reactive power losses in the EPS and the low load during non-working days and at night, causes the occurrence of increased voltage values. With the domestic production of reactive energy, the contribution also gives interconnection transmission lines with the EPS of neighbouring countries. Registered values of increased voltages and their duration during year in one of the analyzed nodes (SS Sarajevo 10) in the period 1st of January 2010 up to 31st of December 2017 at the annual level are given in Fig. 1 [1]. The registered increased voltage values are above the permitted values according to Grid Code [2] and IEC Standard 60038 [3].

The maximum and minimum registered hourly load in the EPS of B&H in the analyzed period is given in Fig. 2.

Increased voltage values of power frequency causes the formation of a corona due to the ionization of the air around the conductor. The formation of the corona have the light effect, electromagnetic interference (EMI), audio noise (AN), ozone as well as corona losses (CL). Taking into account the values of the energy losses due to the corona, it is important to determine the values of the electric field on the surface of the conductor and their immediate vicinity as well as the value of the corona onset electric field in order to know their values in the transmission network of B&H and to explore ways to mitigate them from the aspect of maintenance and management costs of the EPS.

An important aspect of increased values of electric field is the influence of the corona on high voltage insulation. The increasing use of polymer insulator in the EPS of B&H, causes accelerated ageing due to the effects of the corona during their exposure to increased values of the electric field. Polymeric insulators are susceptible to degradation due to ultraviolet radiation arising from AC corona. The formation of the corona on the isolators in most cases arises from the accessories [4].

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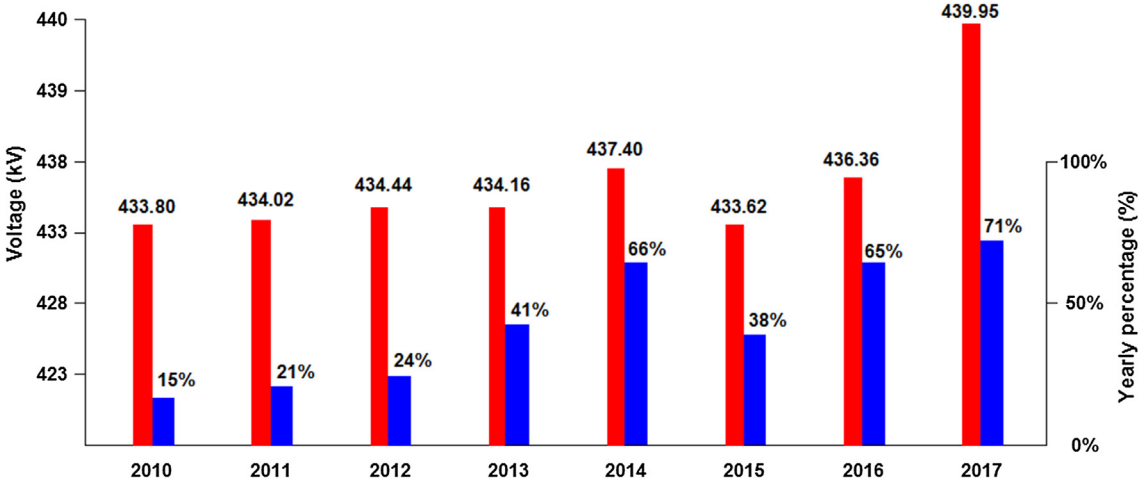

Fig. 1. Increased maximum voltage values ■ in kV and time duration ■ in yearly percentage% when voltage is higher than the maximum allowed values 420 kV during period 2010–2017 [1].

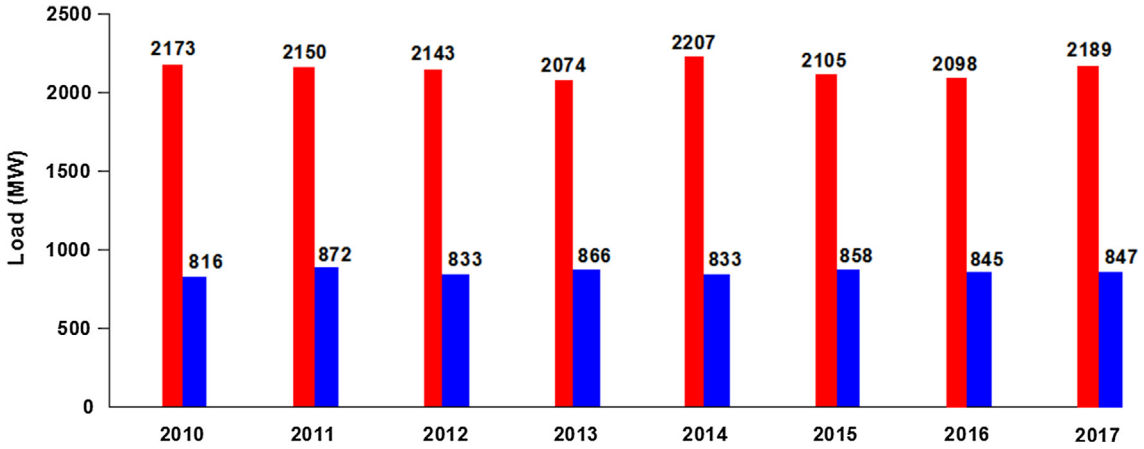

Fig. 2. The maximum ■ and minimum ■ load (MW) measured hourly in the analyzed period 2010–2017 [1].

2. Transmission network of Bosnia and Herzegovina

The transmission network in B&H is composed of transmission lines on three voltage levels: 400 kV, 220 kV and 110 kV. Due to the problem of corona discharge, which is the subject of this paper, the only OHL of 400 kV voltage levels are analyzed. In the EPS of B&H there are currently 14 OHL of 400 kV voltage level with total length of 865 km. There are 4 interconnection transmission lines to Croatia, Serbia and Montenegro, Fig. 3 [5]. TPP Stanari was put into operation in late 2016.

In the future it is planned to build two additional 400 kV interconnection transmission lines to Serbia (SS Višegrad – Bajina Bašta and SS Višegrad – Bistrica – Pljevlja), one 400 kV interconnection transmission line to Croatia (SS Banja Luka 6 – SS Brinje) and upgrading transmission line TPP Tuzla – SS Đakovo with increased voltage level from 220 kV to 400 kV [6].

The typical configuration of 400 kV towers in the EPS of B&H is the horizontal with the galvanized steel towers type AKZ Y, Fig. 4 a), and the OHL 400 kV SS Tuzla 4 – SS Višegrad installed galvanized steel towers type AKZ YN, Fig. 4 b). 400 kV OHL SS Tuzla 4 – SS Višegrad was built in 1988 with reduced horizontal tower's dimension. Conductors are the most commonly used type of ACSR, 2xAl/Fe 490/65.

Development of transmission system requires to select the minimum insulation strenght, or minimum clearance, since reduction of horizontal dimensions has a significant impact on minimum cost. That is a reason for design and construction compact OHL with increased value of specific transmission power per available right-of-way, the less visual perception, a narrower corridor and less exposure to people and equipment to electromagnetic fields.

3. Computational methodology

For the calculation of the electric field intensity on conductor's surface of the OHL different numerical techniques and analytical formulas can be applied. Charge Simulation Method (CSM) is one of the most commonly used methods for calculation the electric field intensity on surface of high voltage OHL. In modern literature there are different formulation of the CSM method for calculation transmission line electric field intensity, based on the type of analyzed problem and desired accuracy [8–10]. In this paper for calculating of the electric field intensity on the stranded conductor surface and in the immediately vicinity of the OHL, two slight modified CSM method for this type problem, based on the 2D CSM method are given. One slight modified CSM method for calculating of the electric field intensity on the surface and in the vicinity of bared stranded conductor of three-phase transmission lines and a slight modified CSM method calculating the electric field intensity on the surface and in the immediate vicinity of the insulation coated stranded conductors of three-phase transmission lines. The heights of conductors and ground wires to ground relate to the midspans and the voltage values corresponds to the voltage values in analyzed period.