Original Article: Evaluation of Shielding Failure in UHV Transmission Lines by Improving the Simulation in the Corona Phenomenon

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ABSTRACT

Corona phenomena are usually ignored in the numerical helical analysis of transient electromagnetic states or as a phenomenon that negatively affects power systems in analyses. In this study, we intended to evaluate the positive effects of corona on lightning strikes in the power system and show that the corona plays an important role in improving the reduction of the overvoltage range of lightning and improving the BIL size of transmission lines. In a high-pressure transmission line, when the voltage amplitude exceeds the intensity of the refractive field that surrounds the air, it occurs in the air around the ionization line, causing a corona to form around the transmission line and increasing the conductor radius. This paper investigates the improvement of the corona model in high-pressure alternating current transmission lines.

Introduction

According to research, light is the main reason for transmission line travel [1-4]. Studying the transient electromagnetic trend of high voltage transmission lines caused by lightning can play an important role in analyzing the level of lightning stability in high voltage transmission lines. The shock wave process is affected when a light shock occurs at a high voltage level above the transmission lines. This is why the frequency-dependent parameters of high voltage transmission lines and impact shock can affect the transient development of electromagnetic and shock plays a major role [1-5]. The effect of the shock wave process will become more apparent with

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increasing voltage levels [6-9]. As for the establishment of the first ultra-high voltage transmission line, the 1000 kV transmission and transmission project can gather experience working in a UHV transmission project in special circumstances [10-14].

When conducting a study on a UHV transmission line, electromagnetic space is a major technical problem that must be considered. The electromagnetic environment is related to the corona characteristics of the high voltage transmission line. Corona discharge can have consequences such as loss of impact corona, audible sounds, the electromagnetic field of electric frequency, DC electrical effect, and wireless ripples [15-19]. For this reason, in the insulation design of electrical equipment, the effect of the impact crown against the lightning penetration wave is always ignored. The need to insulate electrical equipment without calculating the effect of the lightning strike crown is very severe, so the cost of power grid equipment increases [20-23].

Impulse corona is not only an issue that should be studied at the level of lightning resistance of the UHV transmission line but also a fundamental issue that should be considered in the design, construction, and operation of the UHV transmission line. So in the existing impact corona models, most of them do not consider the connection and the impact crown branch is located directly in the position between the wire and the ground and the space between them. In fact, such a model is not appropriate. Therefore, it is necessary to revise the corona model of the lightning strikes to have more real wave conditions [24].

Grounding conductor capacity

Increasing the conductor radius due to the corona reduces the wave of internal impedances and the wave of reciprocal impedances around the conductor remains unchanged [25-28]. It also increases the capacitance and conduction of the ground line and increases the coupling coefficient around the conductors. But the conductor inductance parameters remain unchanged. It occurs in the air around the ionization line and causes the formation of a corona around the transmission line and increases the conductor radius, as shown in Figure (1).

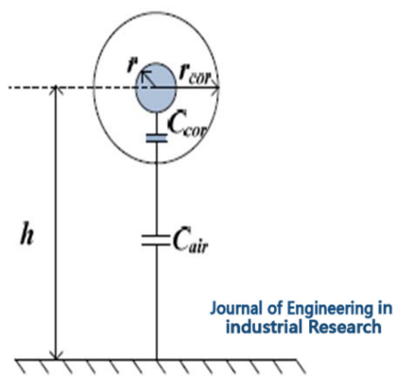

Figure 1. Grounding conductor capacity

The corona (Q-V) curve profile is a standard measure for evaluating the damping of waves. Curve characteristic (Q-V) is a process of wave transients that shows the relationship between the instantaneous value of the voltage shock in the conductor and the electric charge charged by the impulse corona. Figure (2) shows the characteristic curve (Q-V). The OA part is a response to the characteristic curve wave (Q-V) which is linear and its slope is the geometric capacitance of the conductor. Section AB is the answer to corona expansion. The characteristic curve (Q-V) in these conditions is simulated nonlinearly with the dynamic capacitance of the conductor [29-32]. The BC segment represents the AB wave sequence and is somewhat parallel to the OA segment. Corona electrical discharge is a process with a series of nonlinear states with hysteresis characteristics that can change the grounded capacitance and conduction parameters relative to the voltage, and generally investigates the characteristic OB (Q-V) and corona effects [33-36]

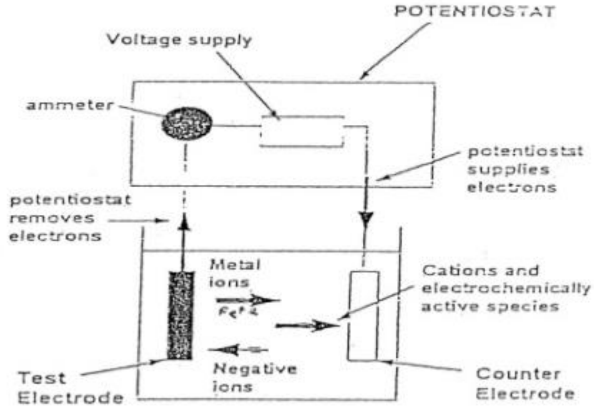

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Figure 2. Characteristics of a curve (q-v) with a corona

Corona circuit equivalent

As clear from Figure (1), the radius of the alternating current transmission line changes with the effects of corona and grounded capacitance. In Figure (1), r is the radius of the conductor, rcor is the radius affected by the corona, and h is the height of the conductor to the ground. The capacitance of some parts of the air ionization increases due to constant dielectric changes and air loading. Therefore, the capacitance of conductors in the transmission line despite the corona can be considered in two parts, cair and ccor in series. Therefore, the corona equivalent circuit in the transmission line is shown in figure (3) below [37-40].

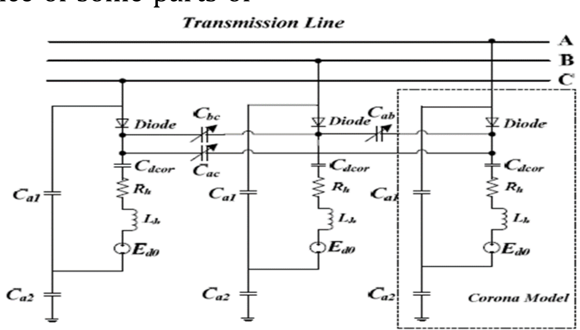

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Figure 3. Corona equivalent circuit of single phase 3-phase AC transmissio

Transmission model calculations with corona

C_{ab}, C_{bc} and C_{ac} in the form of coupling show the capacitance between different phases of the conductor due to the corona. C_{a1} shows the air capacity between the conductor radius and the radius created by the corona. C_{a2} represents the air capacity between the radius created by the corona and the earth. L_h and R_h are connected in series. E_{do} is the initial corona impulse voltage. Before the voltage of the UHV transmission line reaches the initial voltage of a corona, the diode does not conduct any conduction and is off, which is the same characteristic (q-v) of the corona in the OA section. And when the voltage of line reaches the initial corona voltage, a diode conducts its conduction [41-45].

Multi-wave impedance model of the tower

Lightning waves reflect reflection and refraction in a high pressure transmission line rig. The multi-wave impedance model for a high-pressure transmission line tower with ground resistance is shown in Figure (4).

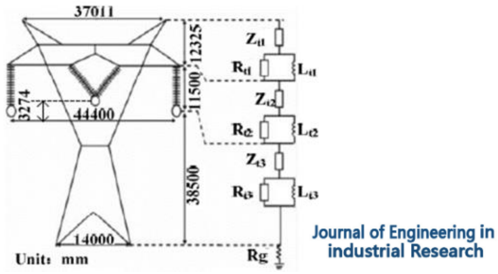

Figure 4. Multi-wave impedance model of high pressure transmission line tower

Each part of the multilayer transmission line tower includes a part of the parallel branches of the distribution parameters that cover the line losses and the resistance and inductance losses. These parallel branches reflect the damping phenomenon in the transmission line tower. In a transmission line mast, each voltage impulse has a grounding resistance value (R_0), and when this transmission line tower resistance exceeds R_0, the level of stability and lightning resistance in the transmission tower is obtained by the earth resistance [46-49].

Insulation string electric discharge model

This paper focused on the improvement of the electrical discharge model of insulating filaments and the effects of corona shocks that can represent real conditions. Figure (5) shows the model of electrical discharge of insulating fibers. This model is done by ATP software, which includes three input signals and one output signal. The next topic in this article is the simulation of the protective layer failure model. Because the insulation string level of high-pressure transmission lines is very high, the probability of electrical discharge is relatively low [50-53]. Therefore, a level of lightning resistance in the high-pressure transmission line mainly indicates the level of resistance and stability of lightning in the failure of the protective layer. And part of the protective layer failure is simulated by ATP-EMTP as shown in Figure (6).

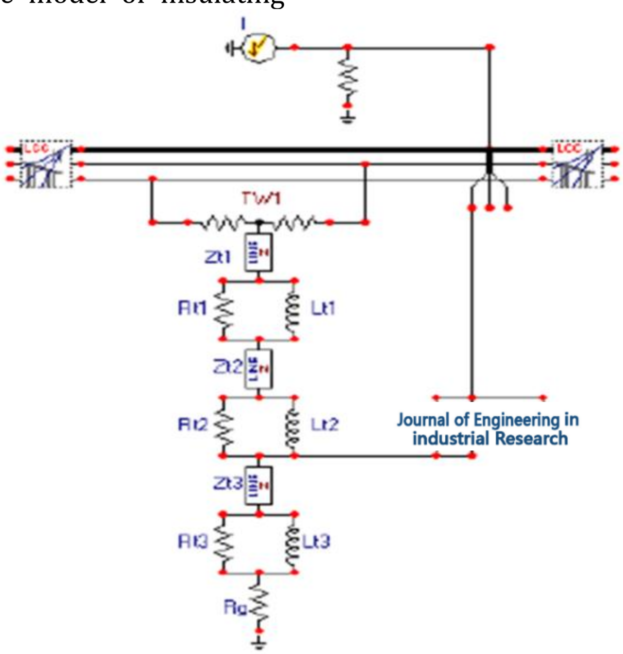

Figure 5. Electric discharge model of insulating filament

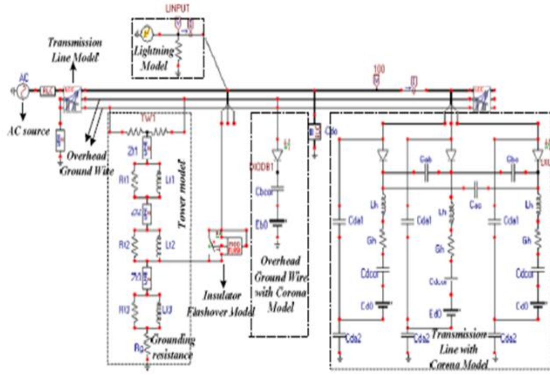

Figure 6. Simulated model of protective layer failure in high voltage transmission line by ATP-EMTP

Evaluation of the output of the simulation

According to the simulated corona model of the line, we can see its effects on the voltage waveform and the process of propagating the current wave due to corona shocks. The current sources of the lightning impulse model are 40KA at different distances of the lightning point due to corona shock generated in the failure of the protective layer of phase A-line. Also, the voltage sources of the lightning impulse model are 6000kv at different distances of the lightning point due to corona shocks produced in electrical discharge [54-57].

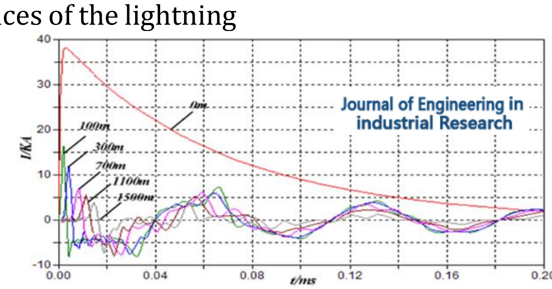

Figure 7. Phase A currents at any distance from the point of lightning when the lightning protection layer without corona breaks

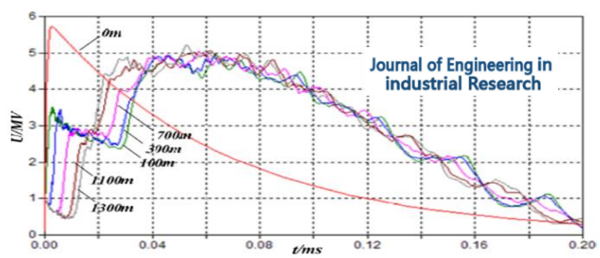

Figure 8. Phase A voltage at any distance from the lightning point when the lightning current shield breaks at 40 kA despite the corona

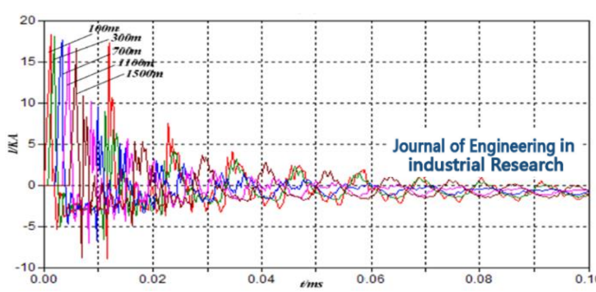

Figure 9. Phase A current at any distance from the point of lightning when the protective layer of lightning current breaks despite the corona

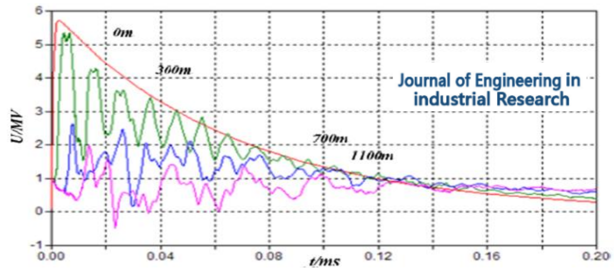

Figure 10. Each voltage of the overhead conductors with a corona in the lightning voltage of 6000 kV where the electrical discharge occurs

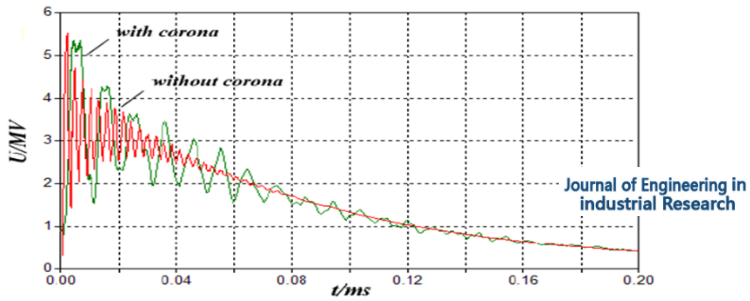

Figure 11. Indicates voltage in the presence or absence of a corona that is 300m away from the point of lightning with a voltage of 6000kv when an electrical discharge has occurred

Conclusion

Analysis and simulation results show that corona can affect the distortion and attenuation of waves in the transmission line and ameliorate the protective layer of the lightning resistance level in the transmission line. In case of failure of the protective layer, if we consider the corona in the analysis, the level of lightning resistance will be 13.5% higher than the case without considering the corona. Also, in electric discharge, considering the corona, the level of lightning resistance increases by about 3.7% compared with the absence of corona.

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