Break Impact Influence Factor of Tension Composite Insulator String

Cao-Lan LIU[1,a*], Hao-Lin YANG[2,b,] Bin LIU[1,c], Xue-Ping ZHAN[1,d], Li-Xian ZHOU[1,e], Sheng-Chun LIU[1,f], Xin-Min LI[1,g] and Yu-Xian DI[1,h]

[1]China Electric Power Rese arch Institute, Beijing, 100055, China

[2]Nuclear Power Engineering co., Ltd. Beijing, 100840, China

[a]liucaolan@epri.sgcc.com.cn, [b]haolin_98@sohu.com, [c]liub1@epri.sgcc.com.cn, [d]zhanxueping@epri.sgcc.com.cn, [e]zlx@epri.sgcc.com.cn, [f]liubshengchun@epri.sgcc.com.cn, [g]lixm@epri.sgcc.com.cn, [h]diyx@epri.sgcc.com.cn

*Corresponding author

Keywords: Composite insulators; ultra-high voltage; break impact; test; dynamic impact factor; influence factor

Abstract. To guarantee the security of composite insulators as tension strings applied to ultra-high voltage engineering, it is necessary to study the mechanical properties of composite insulator regarding break impact, especially researching on key factors influencing. Study the key factors influencing by numerical calculation method, which provides reference and evidence for further study on mechanical properties of composite insulator and development of applicable design specifications.

Introduction

The composite insulator is characterized with light weight, high strength, strong anti-fouling flashover capability, convenient manufacturing and maintenance, which is extensively applied in the power transmission line in our country[1-2]. The tension composite insulation string shall withstand severe static and dynamic load during actual operation process, function of the static load is generally considered in detail during design phase, sufficient tolerance is reserved for it by the safety coefficient, which is easy to meet with actual engineering demand; for the dynamic load, no detailed technical requirement is available in current design specification in our country during design phase[3], demand that the insulator withstands various dynamic load is met through improving the safety coefficient. But the fluctuating wind, the conductor galloping and de-icing, break of the insulator etc dynamic functions will generate great dynamic load about the insulator structure under the actual conditions, which always causes enormous threaten about application safety of the tension string. Therefore break operation condition is an important dynamic load destruction way which shall be considered during designing the multiple linkage structure, it is necessary to carry out detail analysis about break impact influence factor of the composite insulator.

Some domestic and foreign scholars have carried out some study about mechanical characteristics of the composite insulator. Dynamic impact function of free falling of the conductor about the power transmission line is analyzed in document [4]. Electromechanical performance of the 220kV composite insulator which is under network operation is tested and studies in document [5]. Brittle failure mechanical performance of the composite insulator is studied in document [6] and document [7]. The existing research achievement mainly focuses on the mechanical tensile force and brittle break of the composite insulator. The research achievement which can be referred in break characteristic of the composite insulator tension string in the ultra-high voltage line is very limited, it is necessary to carry out research about break characteristic of the composite insulation tension string.

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Because break impact of the tension string is a very complicated dynamic process, structure of the line is very complicated and there is influence of non-linear factor, it isn't realistic to take advantage of the theory to analyze influence of dynamic load about the insulator. In particularly to forcing status of the local structure, theoretical analysis isn't realized at present. Even though the mature finite element software is applied to calculate, selection and taking value of the calculation model will directly affect correctness of the result, accuracy of the numerical model and numerical algorithm are firstly verified by test means. The numerical calculation method is taken advantage of to study main factor affecting break impact of the composite insulator in the line, which provides reference and basis to further study mechanical performance of the composite insulator and compile the corresponding design specification.

Dynamic Theory

According to the structure dynamic theory, instantaneous response of the structure after temporary excitation belongs to free vibration; free vibration of the structure is completely described by the mode response of the structure.

Because rigidity of the elastic structure is very great, the deformation caused by vibration is assumed as the small deformation, the dynamic system of the structure is linear, the dynamic characteristics of the structure are described by the vibration mode and the inherent frequency, and vibration response of the structure can also apply superposition principle at same time.

Assuming quality matrix, damping matrix and rigidity matrix of the finite element model of the structure (N free degree) are respectively M , C and K, vibration displacement of every point on the structure corresponding to time t is

$$u(t)=\left\{u_1(t),u_2(t),u_3(t)...,u_N(t)\right\}^T \tag{1}$$

Correspondingly, $u(t)$ and $\ddot{u}(t)$ expresses speed and acceleration of vibration at every point of the structure respectively, the distribution instantaneous impact load is $f(x,y,z,t)$, and differential equation of its vibration is

$$M\ddot{u}(t)+C\dot{u}(t)+Ku(t)=f(x,y,z,t) \tag{2}$$

And then assume every vibration mode of the no-damping free vibration of the structure Φ_j is

$$\Phi_j=\left\{\phi_{1j},\phi_{2j},\phi_{3j},...,\phi_{Nj}\right\}^T \quad j=1,2,...N \tag{3}$$

In which, $\left\{\phi_{1j},\phi_{2j},\phi_{3j},...,\phi_{Nj}\right\}^T$ expresses component of no j mode of the structure at every free degree.

Basic Conditions and Assumption of Numerical Calculation Model Page Numbers

In general, static force analysis and calculation of the conductor structure apply the rod or rope unit. Only the translation free degrees at three direction [9] are considered. For dynamic analysis, the torsion free degree always can't be neglected. Therefore the model of the single node with six free degrees is considered during analysis process.

The insulator and the fitting apply the traditional beam or the plate unit to simulate. In order to facilitate connection of the conductor unit and the fitting unit, the conductor also applies the beam unit to simulate. One node in the beam unit has three translation free degrees and three rotation free degrees. The U shaped ring, the bolt, the nut and the regulation connection board etc connection fittings shall be considered correspondingly.

In order to simplify calculation and improve operation convergence speed, establishment of the numerical model shall consider to neglect the secondary factors as possible because of complication of the coupling structure. Compared to the actual model, main consumption conditions which are applied by the numerical calculation model is shown as following:

(1)Neglect influence of elastic deformation of the rod tower structure about break impact, the relevant rod tower is substituted by the fixed boundary.

(2) Consider connections between the conductor and the fitting, between the insulator and the fittings and between the fittings are free hinge connection, the relevant connection also rotates freely even during break process. Because of limitation of the design shape and size of the fittings under actual conditions, the hinge point can only rotate certain angle during break process, it can’t realize free rotation. If collision force of the fitting at local hinge point is greater than impact load of the insulator during partial rotation when it is compared to complete rotation, it belongs to safety consideration if free rotation is taken.

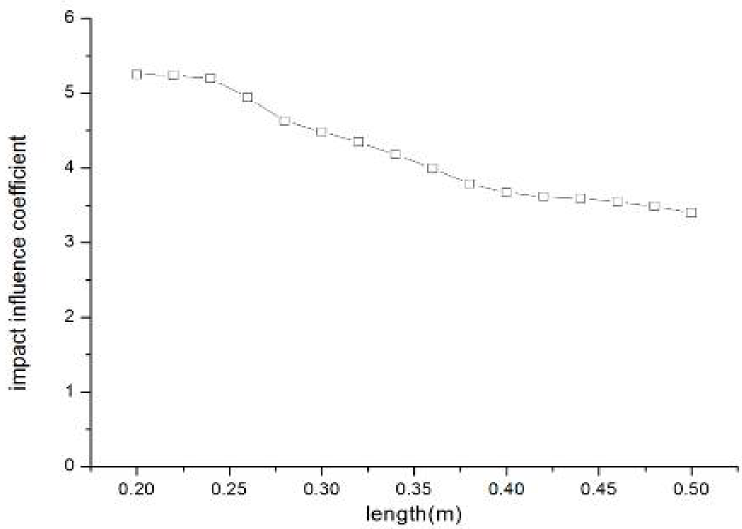
Analysis of Main Factor Affecting Break Impact of Composite Insulator

It is very important to analyze influence parameters of break impact load of the composite insulator for design of the ultra-high voltage composite insulator. Reducing effect of break impact can be realized through changing the predominant influence parameters. According to actual experience and test conditions, main parameters which affect break impact load characteristic of the insulator including: structure size, operation tension and span etc.

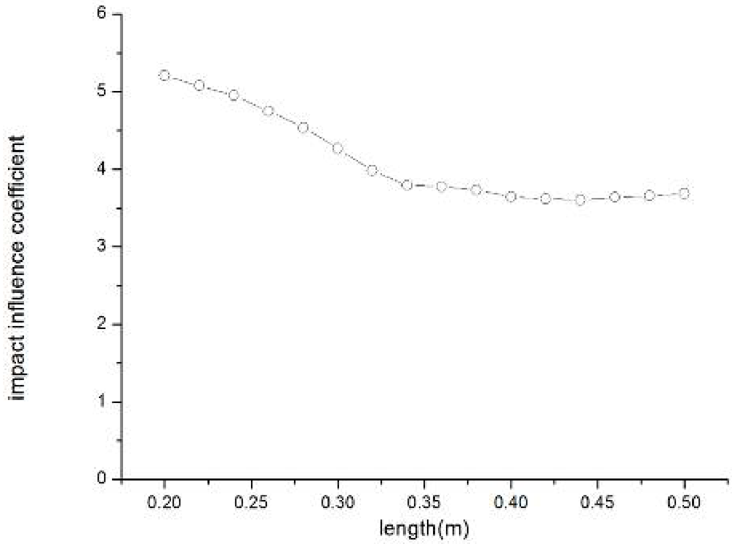
Influence of tension and size of connection board on break

For analysis of influence of different tension, different size of the connection board about break of the insulator under three span conditions, the continuous three spans of the actual conductor parameters are selected to calculate. Parameters and calculation model of the line are same as these of section 3. Initial tensions are 25%, 30%, 35% and 40%RTS respectively. Width of the L shaped connection board is 600mm, width keeps unchanged. Heights are 0.20m, 0.22m, 0.24m, 0.26m, 0.28m, 0.30m, 0.32m, 0.34m, 0.36m, 0.38m, 0.40m, 0.42m, 0.44m, 0.46m, 0.48m and 0.50m respectively.

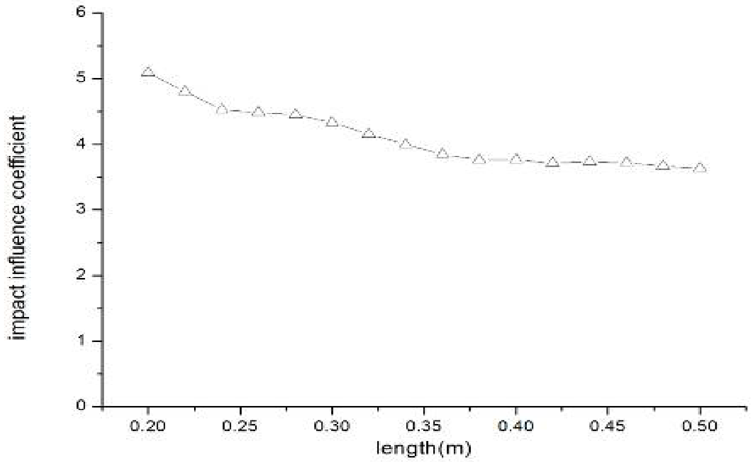
Refer to figure 1 for calculation results. Learn from the figure, influence of initial tension about result isn’t obvious when size of the connection board is same; when initial tension is same, the impact coefficient is reduced following height increase of the connection board.



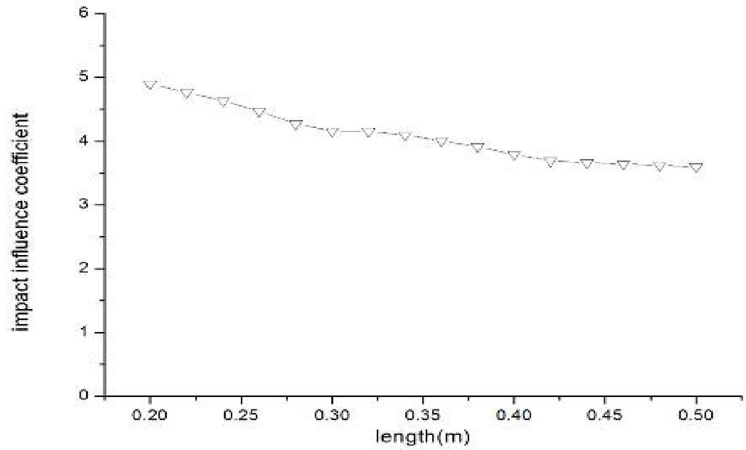
(a) Tension is 25%RTS



(b) Tension is 30%RTS



(c) Tension is 35%RTS



(d) Tension is 40%RTS

Fig.1 The results of calculation will be disconnected conditions of different initial tension, connecting plate under the condition of different size

Analysis of Height of Connection Board Structure about Break

Take advantage of test operation conditions to analyze influence of the fitting size of two connection insulator fittings about break dynamic load. There are two main size parameters of the fitting according to calculation model, one is width between two parallel insulators, i.e., width of the connection board structure; second is distance between the connection insulator and the conductor, i.e., height of the connection board structure.

Figure 2 shows correspondence relationship between height of the different connection board structure and brake dynamic influence coefficient of the insulator when width of the fixed connection board structure is 0.45m.

Learn from figure 2, after width of the connection board structure is determined, great is height of the connection board structure, corresponding break dynamic influence coefficient is reduced.

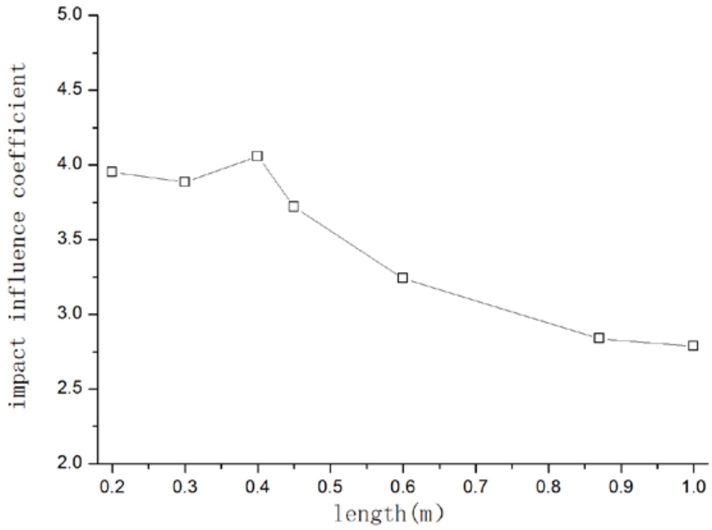


Fig.2 The relationship between dynamic impact factor and L-type junction length (width is constant)

Conclusion

Following conclusions are obtained through test, value analysis and comparison:

(1)Analyzing main parameters affecting tension string break dynamic load of the composite insulator shows size of the connection board has obvious influence on break impact load.

(2)Dynamic influence coefficient is ratio between maximum impact load of the single string of the insulator and initial tension of the single string of the insulator. If the dynamic influence coefficient exceeds design safety coefficient, strength of the insulator is ensured to meet with requirements through improving safety coefficient of the insulator at static or changing size of the connection board two ways.

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