Analysis on Mechanical Property of 110kV Power Transmission Line Tower under Different Wind Speed

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Abstract—**Finite element is adopted for simulating power transmission line tower, cable element is used for simulating power transmission line wire and ground wire, tower element is used for simulating insulator on the basis of finite element analytical method in the paper. A power transmission line solid model is established. Hyper-design wind speed under typhoon weather is considered according to the weather condition of power transmission line region. Tower mechanical property of strain tower and hanging tower on 110kV actual operation line under different wind speeds is analyzed. Stress growth condition in different parts of towers under different wind speeds is analyzed quantitatively. The mechanical property of strain tower and hanging tower is compared. The research results in the paper can reflect the risk level of mechanical failure on the power transmission line during typhoon.**

Keywords—component; formatting; style; finite element; hanging tower; strain tower; mechanical failure

I. INTRODUCTION

Main failure forms of overhead power transmission line under typhoon weather include large scale tower falling, tower slanting, wire breaking, etc.. Typhoon wind speed higher than design standard is the main reason of large scale tower falling and wire breaking of distribution line. The distribution line destructive failure caused by typhoon generally has large influence scope, long duration and huge economic loss on the society. In recent years, power system failure brought by strong disastrous typhoon weather is also more and more frequent with environment deterioration. Though design standard of overhead distribution line has been improved in some regions, typhoon wind speed is higher than the design wind speed sometimes. Some scholars engages in research on tower mechanical property [1-10]. However, the research on power transmission line tower mechanical analysis model under different wind speeds is relatively rare. It is necessary to analyze power transmission line tower mechanical property under different wind speeds according to actual weather information and line design condition, thereby reflecting tower falling and wire breaking probability of distribution line under real time weather conditions. Early warning information is provided for operators, emergency plans can be adopted timely, thereby ensuring safe operation of power distribution system.

II. TOWER MECHANICAL ANALYSIS MODEL

Tower mechanical analysis refers to analysis and calculation with finite element model. Beam element is generally adopted for iron tower modeling. Beam element is a 2-node three dimensional linear finite strain element. Each node has 7 freedom degrees, including 3 rotation freedom degrees, 3 translation freedom degrees and warping WARP. It has the ability to bear tension, pressing, bending, twisting and shearing. The element is based on Timoshenko beam theory, the cross section after deformation prevents the plane from being twisted. It can support elastic, creepage and plastic material models. In addition, section simulation can be realized through defining section and section direction. Sections of many materials can be simulated well. For example, steel arc section and its stiffening rib are suitable for analyzing beam structures from long and thin state to medium short and thick state. It can be used for simulating angle iron material models of iron tower. L-shaped angle iron shapes and its section dimension can be simulated during modeling through setting real constant of beam element.

Wire and ground wire are regarded as a flexible component. It is characterized by not bearing bending moment and pressure but stress. The problem should be solved accurately according to single cable structure. The cable section dimension is very tiny compared with cable length. The section flexural rigidity is low, which can be ignored. The material of the cable conforms to Hooke's law, and its geometric shape is a catenary under the effect of gravity. Wire and ground wire have relatively low rigidity, large span and deflection, and high nonlinear degree compared with general cable network structure and bridge cable dragline. The unique bilinear stiffness matrix characteristic of cable element makes it become an axial tower element with tension or compression only. When tension option is used only, the rigidity disappears if the element is compressed, thereby simulating natural relaxation characteristics of wire and ground wire. Cable element has non-linear feature, stress regasification and large deformation energy supply. It is ideal to simulate wire and ground wire of power transmission line.

The size of insulator string and wire connecting hardware is very small compared with the wire and ground wire system of iron tower, thereby little influence is produced on kinetic analysis of tower line structure. The gravity load influence of insulator and connecting hardware is ignored. The tower

element of rigid connection is used for simulating the insulator. Torque is applied through the element with 3 nodes, 3 or 6 freedom degrees, which can be used for connection, beam, sphere, hinge, globe, slot and cylinder respectively.

Beam element is used for simulating the power transmission line iron tower, cable element is used for simulating wire and ground wire, and LINK8 tower element is used for simulating the insulator string in order to effectively calculate the stress and deformation caused by span, height difference and uneven load of multi-span tower-wire system. An overall solid model is established. The beam element section of power transmission iron tower model is 'L' shape, which is eccentrically connected. Cable element suspension chain model is established for power transmission wire and ground wire, and the priestess is determined according to installation pay-off stress.

III. CALCULATION CONDITIONS

110kV Tangnan II line lasts from 220kV Tangmei Transformer Substation 110kV, fishponds and paddy fields are mainly distributed along the line, which is dotted with down-lands rarely. The altitude of the highest point is 23 meters. The whole line passes through Doushan Town and Guanghai Town of Taishan, which belongs to the jurisdiction scope of Jiangmen.

30-year return period 10-min average maximum wind speed is 29.9m/s in the area 10cm higher than the group in Taishan. 30-year return period 10-min average maximum wind speed in the area 15m higher than the group is 31.9m/s according to

conversion according to data provided by meteorological departments, such as Guangdong Climate Application Research Institute, etc. The maximum design wind speed is 35m/s according to meteorological data of meteorological departments, meteorological condition design standard of existing 35~220kV line in the region and operation experience over the years. 110kV Tangnan II line maximum design wind speed is 35m/s according to data of meteorological department and existing line without regelation.

FXBW4-110/100 composite insulators are used for suspension string and jumper string of wires in 110kV Tangnan line (minimum mechanical damage load: 100kN, minimum arc distance: 1100 mm, minimum creep age distance: 3200 mm). A tension-resistant string is additionally added on the upper end and the lower end respectively. FC70P/146 glass insulator is recommended as wire strain insulator-string (minimum mechanical damage load: 70kN, creepage distance: 450mm). 8 insulators are used for each string of grade 3 pollution zone, the creepage distance of the whole string is 3600mm. 9 insulators are used for each string of grade 4 pollution zone, the creepage distance of the whole string is 4050mm. Single-connection string is used for all suspension strings except large span, important span, etc. with double-connection strings. Double-connection string is used for all strain insulator-strings except incoming and outgoing lines of transformer station with single-connection strings. JLB2-40 Al-clad steel stranded wire is selected for shunting ground wire of 110kV Tangnan Line. Please see Table I for wire structure and physical parameters.

TABLE I. WIRE STRUCTURE AND PHYSICAL PARAMETERS

Wire category / Item	Wire	Ground wire
Name	LGJX	Al-clad steel stranded wire
Model	LGJX-240/40	JLB2-40
Total section (mm 2)	277.75	90.4
Total diameter (mm)	21.66	12.2
Breaking tension (N)	83370	97610
Allowable stress (N/mm2)	33348	308.5
Annual average operation tension (N)	20842.5	24402.5
Safety coefficient	2.5	3.5
Average operation tension /Breaking tension	0.25	0.25
Weight of unit length (kg/km)	964.3	541.1
Technical standard	GBll79-83	GBll79-99

Tower shaped design drawings are respectively selected for 110kV Tangnan Line according to whole line topography, geology and use meteorological conditions. Tower models are selected for single-loop linear iron towers, such as cat-head type tower ZM4, Z8, etc., drum-shaped ZGU3 tower models are selected for double-loop linear iron towers, JG3 tower models are adopted for single-loop corner strain insulator, JGU3, JGU6 and other tower models are adopted for double-loop corner strain insulator. The following technical measures are adopted in order to improve the technical and economic indicators of iron towers during iron tower design for the above tower models: Q345 (Mn16) steel is adopted as main materials for steel pipe tower and tower body during design. Other components are made of Q235 (A3F) steel, M16 bolts are made of grade 4.8 steel, and M20 bolt are made of grade 6.8

steel.

IV. CALCULATION RESULTS AND DISCUSSION

Tower stress percentage of JGU6 tower models at different positions under different wind speeds is shown in Table II. The analysis results show that tower stress is relatively low during 35m/s wind speed, the component meets requirements on strength and stability. 50m/s wind speed is used for checking calculation, crossarm main material is increased by 7.4%, main material of tower body is increased by 27.5%, main material of tower leg is increased by 29.1%, diagonal member of tower body is increased by 18.3%, diagonal member of tower leg is increased by 23.4%; the components meet requirements on strength and stability. 60m/s wind speed is used for checking

calculation, crossarm main material is increased by 14.1%, main material of tower body is increased by 51%, main material of tower leg is increased by 53.8%, diagonal member of tower body is increased by 34%, diagonal member of tower leg is increased by 43.3%; components meet the requirements on strength and stability; JGU6 tower belongs to anstrain tower, component is controlled mainly by line tension. Therefore, component meet the requirements on strength and stability under the working condition of 50m/s 60m/s wind speed.

TABLE II. JGU6 TOWER CALCULATION RESULT COMPARISON

Segment number	Position	Stress percentage (%)			Stress ratio increment during 50m/s wind (%)	Stress ratio increment during 60m/s wind (%)
		Wind speed 35m/s	Wind speed 50m/s	Wind speed 60m/s		
1	Ground wire cross arm top main material	15.5	22.9	29.6	7.4	14.1
1	Ground wire cross arm bottom main material	4.9	4.9	4.9	0	0
2	Upper wire cross arm top main material	14	15.3	16.3	1.3	2.3
3	Middle wire cross arm top main material	17.7	19.1	20.3	1.4	2.6
4	Lower wire cross arm top main material	14.6	15.4	16.1	0.8	1.5
2	Upper wire cross arm bottom main material	15.1	20.6	25.5	5.5	10.4
3	Middle wire cross arm bottom main material	17.1	22.1	26.3	5	9.2
4	Lower wire cross arm bottom main material	15	20	24.1	5	9.1
5	Main material of tower head	26.4	46.4	63.7	20	37.3
6	Main material of tower head	28.8	52.2	72.2	23.4	43.4
7	Main material of tower body	29.6	54.6	75.8	25	46.2
8	Main material of tower body	32.5	60	83.5	27.5	51
9	Main material of tower leg	34.6	63.7	88.4	29.1	53.8
7	Diagonal member of tower body	18.5	35.2	49.5	16.7	31
8	Diagonal member of tower body	19.1	37.4	53.1	18.3	34
9	Diagonal member of tower leg	23.7	47.1	67	23.4	43.3

The tower stress percentage of Z8 tower models at different positions under different wind speeds is shown in Table III. Analysis results show that tower stress is relatively high under working condition of wind 35m/s, however component meet the requirements on strength and stability; tower stress is relatively high under working condition of wind 50m/, component can not meet the requirements on strength and stability, main material of tower head is increased by 83.4%, main material of tower body is increased by 94.8%, main material of tower leg is increased by 89.2%, diagonal member of tower body is increased by 75.9%, diagonal member of tower leg is increased by 76.4%; tower stress is relatively high under the working condition of wind 60m/s, component can not meet the requirements on strength and stability, main material of tower head is increased by 153.6%, main material of tower body is increased by 174.7%, main material of tower leg is increased by 164.7%, diagonal member of tower body is increased by 139.1%, diagonal member of tower leg is increased by 140.7%; Z8 tower belongs to a hanging tower, and component is mainly controlled by tower body wind load. After the wind speed is increased, its influence on component is prominent. component exceeds limit seriously, which can not meet the requirements on strength and stability, and it is not suitable for working condition of 50m/s 60m/s wind speed.

TABLE III. CALCULATION RESULT COMPARISON OF Z8 TOWER

Segment number	Position	Stress percentage (%)			Stress ratio increment during 50m/s wind (%)	Stress ratio increment during 60m/s wind (%)
		Wind speed 35m/s	Wind speed 50m/s	Wind speed 60m/s		
1	Main material of tower head	55.1	118.5	170.3	63.4	115.2
2	Main material of tower head	58.5	113.9	160.4	55.4	101.9
3	Main material of tower head	86.7	170.1	240.3	83.4	153.6
4	Main material of tower body	76.5	155.7	222.5	79.2	146
5	Main material of tower body	91.4	186.2	266.1	94.8	174.7
6	Main material of tower body	90.8	184.8	264.1	94	173.3
7	Main material of tower body	83.9	170.5	243.6	86.6	159.7
8	Main material of tower leg	87	176.2	251.7	89.2	164.7
4	Diagonal member of tower body	49.5	105	150.6	55.5	101.1
5	Diagonal member of tower body	54.7	116.2	167.1	61.5	112.4
6	Diagonal member of tower body	68.3	144.2	207.4	75.9	139.1
7	Diagonal member of tower body	61.8	129.7	186.5	67.9	124.7
8	Diagonal member of tower leg	69.9	146.3	210.6	76.4	140.7

V. CONCLUSION

Tower mechanical failure is a common reason why typhoon brings disasters to power system. A tower mechanical analysis model is established in the paper in order to analyze the mechanical property at different parts of the tower under different wind speeds quantitatively. The model is applied for practical 110kV power transmission line for analyzing the mechanical property of different tower models under different wind speeds. The analysis results show that tower main material stress is increased by 150% maximally when the wind speed is increased from 35m/s to 60m/s aiming at the same tower model; component of hanging tower exceeds standard seriously under the working condition of wind (50m/s, 60m/s) compared with strain tower among different tower models, and they cannot meet the requirements on strength and stability.

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