The Pressure Loss Calculation Method and Application of Portable Fire Extinguishing Equipment for Power System

J.Z. Lu, T.J. Zhou, B. Li, C.P.Wu, Y. Liu
Power transmission and distribution equipment anti-icing & reducing disaster technology key lab of state grid in China
China

Abstract—**Wildfire nearby transmission has posed a serious threat on power system. Research on portable fire extinguishing equipment hasimportantsignificance to massive wildfire emergency handling. Structure of the water transfer system of the portable fire extinguishing equipmentis analysed. Pressure lossforms of the equipment are elaborated. Basing onactual instance of the water transfer system, a calculation method of pressure loss for long-distance and high-lift transmission is proposed.With the result of the test and CFD simulation, the efficiency and the practicability of the method is verified. A conclusionthat transportation distance reaches close to 3000 meterswhilehead reaches 500 meters is drawn. Finally,the application of the portable fire extinguishing equipment in fire prevention of power transmission line results show thatmassive wildfires can be extinguished quickly.By using the equipment, electric power company's ability of resisting wildfires has gained remarkable improvement.**

Keywords-wildfire;portable fire extinguishing equipment; pressure loss;transportation distance;head

I. INTRODUCTION

With complex climatic conditions, influenced by human interference activities such as spring ploughing, Chinese New Year celebrations, ceremonies during Ching Ming festival and autumn harvest, frequent occurrences of fires disasters near transmission in recent years have caused major property losses in the China's grid company.Wildfires near transmission not only harm the electric equipment, but also threaten stability of the power system. Trips caused by wildfire at the same time or in successionmay cause large area power cuttingor breakdown of power network. Control the fire as quickly as possible can stop the fire spreading to transmission.

Currently,the development and improvementof fire-fighting equipment have been paid widely attention to by researchers at home and abroad.This research results have provided effective methods for fire control[1-4]. As the wildfires disperse in many spotsand quite wide areas,combined that ashes are easy to reburnin the wild, the control of wildfires near transmission is carried into effect difficultly.In areas deficient of water, portablefire-fighting equipmentshould not be used for massive fires.Although fire trucks could carry plenty of water, they are not is unsuitable for wildfires near transmission, due to the traffic inconvenience and low outlet pressure.

Water-series extinguisheris piped tohigh pressure water mist nozzleby the high pressure piston pumpof portable fire extinguishing equipmentfor power system(referred to in this article portable fire extinguishing equipment).Security of firefighting crews will be threatenedand anti-fire efficiencyis weakif the location of fires may beyond the range oftransportation distance and head. So, transportation distance and head are the important parameters of portable fire extinguishing equipment.The pressure loss of water-series extinguisher in the pipelinesaffectedthose two parametersmarkedly. A study on the calculation methods of pressure loss is significant in improving the science and correctness of firefighting workeffectively.

II. PRESSURE LOSS FORMS OF PORTABLE FIRE EXTINGUISHING EQUIPMENT

The water conveyance system of portable fire extinguishing equipmentincludeshigh pressure piston pump, connecting pipe, pressure regulating valve, pressure relief valve, fire hose,elbows, and high pressure water mist nozzle, as shown in figure 1.

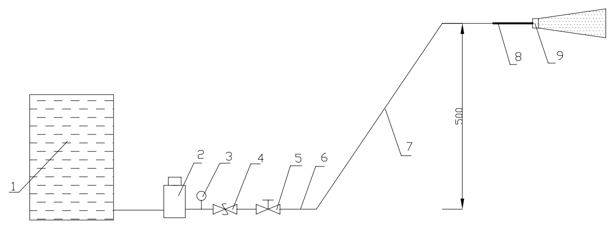

FIGURE I. STRUCTURE SKETCH OF PORTABLE FIRE EXTINGUISHING EQUIPMENT.

1-water tank; 2-high pressure piston pump; 3-piezometer; 4-safety valve; 5-pressure regulating valve; 6- truck-mountedconnecting pipe; 7-fire hose; 8-lance; 9-high pressure water mist nozzle

By applying the Bernoulli equation, which is shown as formula (1),pressure loss of portable fire extinguishing equipmentincludesthe route loss and the local loss.

$$z_1 + \frac{p_1}{\rho g} + \alpha_1 \frac{v_1}{2g} = z_2 + \frac{p_2}{\rho g} + \alpha_2 \frac{v_2}{2g} (1)$$

From formula (1) and figure 1, the pressure loss forms of the equipment can be drawn, as shown in figure 2.

$$h_{sd} = \lambda \times \frac{L}{d} \times \frac{1}{2g} \times v^2 + \sum \varsigma_i \times \frac{1}{2g} \times v_i^2 \quad (2)$$

Where, L is the length of fire hose, d is internal diameter of fire hose, $\lambda$is the friction factor, ς_i islocal drag coefficient and vdenotes a mean velocity of the fluid in the conduit.

III. PRESSURE LOSS CALCULATION AND SIMULATION OF PORTABLE FIRE EXTINGUISHING EQUIPMENT

A. Flow Analysis ofWater-series Extinguisher

Reynolds number is an important parameter reflecting the fluid flow characteristics in the pipe.When the Reynolds number is small, viscous forces plays host tothe force between liquid particles and a fluid flows in parallel layers, with no disruption between the layers.While if the Reynolds number is large, the flowing liquid is in a turbulence state, thusinertiaforces plays host tothe force between liquid particles.

The sectional areaand velocityequals everywherealong the fire hose.Formula 3is commonly used for calculationof velocity of flow.

$$v = \frac{4Q}{\pi d^2} \quad (3)$$

So, if the average flow of fire hose is 20.3 litres per minute and the diameterof pipeline is 16mm, thenvelocity of water-series extinguisher is 1.659m/s.

At 20℃, the dynamic viscosity of water-series extinguisheris $1.005 \times 10^{-3} pa \cdot s$.According to the formula of calculationof Reynolds number,it can be deduced thatthe Reynolds number is 26411 and the flowing liquid is in a turbulence state,

B. Calculation of the Route Loss

The inner surface roughness of the fire hosemeasures0.010mm and the relative roughness is 0.000625.Thicknessviscous sub-layer is calculated using semi-empirical correlation, as shown in formula4.

$$\delta = \frac{34.2\mathrm{d}}{\mathrm{Re}^{0.875}} = 7.39 \times 10^{-2} > \Delta = 0.010\mathrm{mm} \quad (4)$$

This shows that the fire hose is hydraulic smooth pipe at this condition. So, the water-series extinguisher flow conditioncorresponds tothe third interval of Nicholas' curve.Iterative method was used to calculate the friction factorin Prandtl-Schlichtingformula which is shown in formula 5.

$$\frac{1}{\sqrt{\lambda}} = -2.01\mathrm{g}\left(\frac{2.51}{\mathrm{Re}\sqrt{\lambda}}\right) \quad (5)$$

Take the Reynolds number Re into (5) perform iterative calculation, then get that λ=0.0241.

Using formula (2) gains that the frictional head loss of 3000m pipe is 621m(water column height) , that is the frictional head loss of 3000m pipe is 6.21MPa.

Simulate the waterdelivery system of portable fire extinguishing equipment based on Fluent6.3.26, use periodic boundary conditions[5], calculate the pressure loss of unit length of water pipe under a certain flow, then, we can get the frictional pressure loss of 3000m pipe. Aiming to the Reynolds number Re of fluid flowing in the pipe, calculate by using Spalsrt-Allmaras model and $\kappa-\varepsilon$ model[6,7] respectively, and compare the result of numerical modelling with that of calculation following Nikuradse experience curve method.

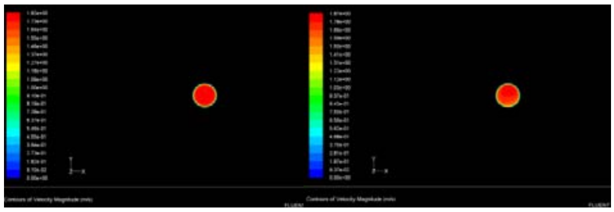

FIGURE II. VELOCITY DISTRIBUTION THROUGH ANALOG CALCULATION BY USING S-A MODEL AND $\kappa-\varepsilon$ MODEL.

TABLE I. PRESSURE LOSS UNDER DIFFERENT TURBULENCE MODEL.

calculation model	Pressure Lose	Error
Nikuradse Curve	6.21MPa	
Spalsrt-Allmaras Model	7.20MPa	15.9%
$\kappa-\varepsilon$ Model	8.40MPa	35.26%
RNG$\kappa-\varepsilon$ Model	7.25MPa	16.7%

Table 1 indicates that Spalsrt-Allmaras Model is more accurate to simulate the pressure loss of the portable fire extinguishing equipment than others, whose calculation accuracy could satisfy the requirement of design and application of portable fire extinguishing equipment. The reason is that Spalsrt-Allmaras Model is effective to simulate low Reynolds number flow, and its' demand on grid partition is not high. According to Fig3, the velocitygradient near wall in Spalsrt-Allmaras Model is smaller than that in $\kappa-\varepsilon$ Model. Turbulent fluctuation contributes to dramatic power exchange among the particle of fire extinguishing agent and uniform distribution of velocity, which better meets the velocity distribution formula 6 of fluid in the core of turbulence in hydraulically smooth region.

$$\frac{u}{u_*} = 2.5 ln \frac{u \cdot y}{\nu} + 5.5 \quad (6)$$

C. Local Loss Analysis

The local loss is due to the change of the water hose sectional area, which causes the change of flow direction, the redistribution of velocity and the loss resulting from the momentum exchange among mass points by collision. The local loss of the water delivery system of mobile fire-fighting platform includes 5 forms, among which are sudden expansion, sudden contraction, bend, folded hose and sluice valve.

TABLE II. LOCAL LOSS CALCULATION OF PORTABLE FIRE EXTINGUISHING EQUIPMENT.

No.	form of Loss	Local loss coefficient	local pressure loss
1	Diameter expanding	$\varsigma_1 = (1-\frac{A_1}{A_2})^2$	$h_1=\varsigma_1\times\frac{1}{2g}\times v_1^2$
2	Diameter reduction	$\varsigma_2=\frac{1}{2}(1-A_2/A_1)$	$h_2=\varsigma_2\times\frac{1}{2g}\times v_2^2$
3	Pipe bending	$\varsigma_3=\left[0.131+0.163(\frac{d}{R})^{7/2}\right]\left(\frac{\theta}{90}\right)^{1/2}$	$h_3=\varsigma_3\times\frac{1}{2g}\times v^2$

According to the values of the coefficients of local loss in Table 2 and combined with the calculating expression (2) for route loss and local loss, the local pressure loss of mobile fire-fighting platform is negligible compared with the route pressure loss. While dealing with the urgency of transmission line mountain fire, the safety and rapidity of mobile fire-fighting platforms can be fulfilled by only calculating the route pressure loss.

IV. PORTABLE FIRE EXTINGUISHING EQUIPMENT FIELD TEST

A. *Test Condition*

Thelocationofthetestis in the Xiaoshajiangtown,Longhuicountry,HunanProvince,locatedinthenorthwestofLonghui, in the middleeastoftheXuefengmountain.ThemovingfireplatformteststartingpointischosenatthefootofthemountainofthePufotemple,thealtitudeofwhichis1123metersabovesealevelmeasuredbyGARMINGPS60.Theendofthetestisatthetopofthemountain,nearthePufotemple.Thealtitudeis1623metersabovesealevel.Andthedifferenceofthealtitudeofthetestis500meters.Measurementofthegunheadoutletatomizationstateandpressureofdifferentaltitudecanbecompletedinthemovingfireplatformunderdifferentoutputpressure.

B. *Test Data and Analysis*

TABLE III. TEST DATA OF PORTABLE FIRE EXTINGUISHING EQUIPMENT WATER PRESSURE LOSS.

head (m)	Water delivery distance(m)	Flow(L/min)	rotational speed of water pump (r/min)	Pressure of water pump(MPa)	Water gun range(m)
500	3200	20.12	628.8	10.0	12
325	2400	32.74	525.1	9.0	15
201	800	37.93	474.7	8.0	12
0-5	30	20.29	418.8	6.0	18

Table3datashowsthatwhenmobileplatformfirepumpoutletpressureis10.0MPa,theconveyancedistancereaches3200m,verticalliftreaches500mandtipsexporthassomeatomizationpressure.Thus,themethodofmobileplatformfirepressurelosscalculationthatthispaperusedis-consistentwiththeresultsofthefieldtest,hasaccuracycalculation,andcanmeettheneedsofplatformdesignandtest,andbeabletoguidethemobileplatforminthepracticalapplicationoffirefightingfires.Thispapersaidmobileplatformusesatomizationtipstoimprovefireextinguishingeffect,whenusing10MPapressurewatertotransmit3200mandtheverticalliftis500m,thepressurecannotcompletelyatomizeextinguishingagent.Extinguishingwaterdropletsparticlesisaffectedlittlebyairresistance,itsrangereaches18m.Whenusing8.0MPaand9.0MPatotransmitwater,theresidualpressurewhoseliftreaches201mand325mcompletelyatomizedextinguishing.Influencedbyair resistance,itsrange decreasesinstead.

V. APPLICATION OF PORTABLE FIRE EXTINGUISHING EQUIPMENT IN POWER SYSTEMS

According to the history statistics of wildfires, massivemountain fires often occurred during the period of Tomb-sweeping Day all around China, which resulted in the trips of transmission lines and the severe threat to the safe operation of the grid[8]. During the period of Tomb-sweeping Day in 2014, State Grid Hunan Electric Power Company deployed fiveportable fire extinguishing equipment, and the total area of extinguished open fires was 3,500m^2 in April 4-5. The lines of 110kV and above of the Hunan grid did not suffer from the accidents of mountain fire trip, which set a record that there was no trip occurring in the Hunan grid during a no-rain Tomb-sweeping Day, marking a great breakthrough of the technology against wildfires of the grid, and ensured a strong support for the safe and stable operation of the large power grid. The application of the portable fire extinguishing equipment means that the characteristics of the equipmentincludes safe drive, long water-delivery distance, high lift and good performance for fire-fighting, which can solve the problems of the bad traffic at the sites of transmission line mountain fire and the tough access to water, and fill up the gap of equipmentfor transmission line mountain firefighting in China.

FIGURE III. WILDFIRES EXTINGUISHING NEARBY TRANSMISSION LINES.

VI. CONCLUSION

Aiming at the existing problem that forest firenear transmission line, water delivery distance and lift, this paper analyzes the pressure loss of portable fire extinguishing equipment through the combination of theoretical calculation, wild field test and numerical simulation, which effectively guides the design and field application of portable fire extinguishing equipment and has made the conclusion that the water delivery distance of portable fire extinguishing equipment can reach 3000m and the vertical lift of that can reach 500m at the same time. The practical application ofportable fire extinguishing equipment in power system indicates that the equipment possesses several advantages including safety driving and user-friendly control, which has settled the problem that it is difficult for us to get water in the process of handling forest fire near transmission lines. At the meantime, it dramatically reduces the number of trip caused by forest fire related about transmission lines and has obviously enhanced the ability to defending forest fire, which has a broad application and dissemination value.

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