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ELECTRICAL POWER ENGINEERING

Design and Analysis of Three-phase 230 kV Transmission Line in the North-East of Myanmar

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Abstract— **Long transmission lines are required to transmit power from hydroelectric power stations to the places of load, as the sites of water power would be far away from the load centers. In this paper, it designed and analyzed three-phase 230 kV transmission line for the North-East of Myanmar. Shweli hydroelectric power station generates the power of 90 MW for Shweli-Mandalay (Shwe Sar Yan) transmission line portion. The length of the transmission line from Shweli to Shwe Sar Yan is 287.93 km. It aims to distribute electricity to Lashio and Kyaukme districts, Northern Shan State and to transport electricity to Mandalay (Shwe Sar Yan) by using 230 kV Twin Bundle Double Circuit transmission line. The purpose of this paper is to transmit optimum power at a given power factor, over a given distance and regulation, efficiency and losses.**

Keywords— **electrical design, hydroelectric power station, mechanical design, transmission line.**

I. Introduction

Electricity is the only form of energy. Electricity consumption per capital is the index of the living standard of people in a place or country. Therefore, electrical energy becomes most essential item for modern human beings. Day by day increase in demand of electrical energy places depletion of fossil fuel sources in alarming rate. An electric power system consists of three principle components: (i) generation system, (ii) transmission line and (iii) distribution systems

The power transmits from the power station to the customers by using the transmission line. Transmission lines are also required for interconnecting power systems having a number of power stations for transfer of power or energy.

II. OBJECTIVES

This paper aims to provide the optimum design and calculation for Shweli-Shwe Sar Yan transmission line portion, to provide the efficiency of the transmission line and to provide the electric power necessary in rural and urban area.

III. TYPES OF TRANSMISSION LINE

There are two types of transmission line. They are;

(i) Overhead transmission line and (ii)Underground transmission line

An overhead power line is an electric power transmission line suspended by towers or poles. Since most of the insulation is provided by air, overhead power lines are generally the lowest-cost method of transmission for large quantities of electric power. Line-supporting towers are made of wood, steel, concrete, aluminium and occasionally reinforced plastics.

A Comparison between Overhead and Underground Transmission Line

Transmission and distribution of electric power can be carried out by overhead as well as underground systems. Comparison between the two is given below:

(i) Public Safety: Underground system is safer than overhead system.
(ii) Initial Cost: Underground system is more expensive. For a particular amount of power to be transmitted at a given voltage the underground system costs almost double the cost of overhead system.
(iii) Flexibility: Overhead system is more flexible than underground system. In overhead system new conductors can be laid along the existing ones for load expansion. In case of underground system new conductors are laid in new channels.
(iv) Working Voltage: The underground system can not be operated above 66 kV because of insulation difficulties but overhead system can be designed for operation up to 400 kV.
(v) Maintenance Cost: Maintenance cost of underground system is very low in comparison with that of overhead system.
(vi) Damage due to Lighting and Thunder Storm: Underground system is free from interruption of service on account of thunder storm lighting and objects falling across the wires.

IV. CLASSIFICATION OF OVERHEAD TRANSMISSION LINE

Generally overhead transmission lines are classified into three types such as;

(i) Short transmission lines
(ii) Medium transmission lines
(iii) Long transmission lines

A Short Transmission Line

Transmission lines having length lesser than 60 km and operating voltage lower than 20,000 volts fall in first category i.e. short transmission lines. Due to smaller distance and lower line voltage, the capacitance effects are extremely small and, therefore, can be neglected. Hence the performances of short transmission lines depend upon the resistance and inductance of the line. Though in an actual line, the resistance and inductance are distributed along the whole length, but in case of short lines, the total resistance and inductance are assumed to be lumped at one place.

B Medium Transmission Line

Transmission lines having length between 60 km and 150 km and line voltage between 20 kV and 100 kV fall into second category i.e. medium transmission lines. The shunt admittance, usually pure capacitance, is included in the calculations for a line of medium length. If the total shunt admittance of the line is divided into two equal parts placed at the sending and receiving ends of the line.

C. Long Transmission Line

The transmission lines length above 150 km and line voltage 100 kV fall into third class i.e. long transmission lines. The long line constant (resistance, inductance, capacitance and conductance) of a transmission line are uniformly distributed over the entire length of the line. The performance calculations of long transmission lines are made with line constants uniformly distributed over the entire length of the line so that the results with fair degree of accuracy are obtained.

V. DESIGN AND RESULTS

The design criteria of a transmission line set the detailed design characteristics. The design criteria are critical as it will be instrumental in conductor and structure design. The primary components of design criteria are the electrical and mechanical loading is a result of loads generates by weather and construction activities. Electrical loading is a result of the manner in which the line is operated and lightning events and dicates electrical clearances insulation levels and grounding.

A. Design Specifications

The specifications for the calculation of electrical design are,

Power rating	= 90 MW
Voltage	= 230 kV
Power factor	= 0.85 (lagging)
Line distance	= 287.93 km
Frequency	= 50 Hz

B. Choice of Voltage

The choice of voltage is also linked with the conductor size, the performance of the line as expected within permissible percentage losses and the regulation of the lines or the receiving end voltage in relation to sending end voltage, when transmitting the required power.

Loading power rating = Power rating × Line distance

$$= 90000 \times 287.93$$

$$= 25.91 \times 10^6 \text{ kW km}$$

According to loading power,

The selected line voltage = 230 kV

The equivalent spacing, D_m = 10.2 m

Current rating, in three-phase,

$$P = \sqrt{3} E_L I_L \cos\varphi$$

$$I_L = I_R = \frac{P}{\sqrt{3} E_L I_L \cos\varphi}$$

$$= \frac{90{,}000}{\sqrt{3} \times 230 \times 0.85}$$

$$= 265.788\angle -31.79 \text{ A}$$

$$= 225.9157 - j140.0191 \text{ A}$$

C. Choice of Conductor

The conductors available are hard drawn copper or stranded conductors or aluminum core steel reinforced (ACSR) conductors. They are used for high voltage work. The size of the conductors are selected depends on the length of the transmission line, load on the line and voltage of the line.

Current carrying capacity, = 350 A

In accordance with current carrying capacity;

Copper equivalent cross-sectional area = 0.9675 cm^2

Approximate Overall diameter, D = 1.814 cm

Required radius, $r = \frac{D}{2}$

$$r = \frac{1.814}{2}$$

$$= 0.907 \text{ cm}$$

Resistance per km, $R = 0.1832\ \Omega/\text{km}$

According to the above calculation, ACSR 605 (DUCK) conductor is choose.

D. Corona Losses

When corona occurs, it produced loss of power. The formula for the power losses due to corona under fair weather condition is

$$P_c = \frac{21 \times 10^{-6} \times f \times E^2}{\left(\log \frac{D}{r}\right)^2} \times F \text{ (W/km)}$$

$$F = 0.08$$

$$P_e = \frac{21 \times 10^{-6} \times 50}{\left(\text{Log} \frac{1020}{0.907}\right)^2} \times (132.79)^2 \times 0.08 \times 3$$

$$= 0.51220 \times 287.93 \text{ km}$$

$$= 137.45 \text{ W}$$

In general, the corona losses per km should be limited to 0.6 W under fair weather conditions. Bundled conductors are used for high voltage lines particularly above 230 kV lines bundled conductors are the best solution for reducing corona loss in transmission of power over the high voltage lines.

E. Regulation

When the load is supplied, there is a voltage drop in the line due to resistance and inductance of the line end, therefore, receiving end voltage V_r is usually less than sending end voltage Vs. The voltage drop i.e. difference of sending end voltage and receiving end voltage expressed as a percentage of receiving end voltage is called the regulation.

$$\% \text{ V.R} = \frac{(V_s - V_r)}{V_r} \times 100$$

$$\text{V.R} = \frac{142.17\times10^3 - 132.79\times10^3}{132.79\times10^3} \times 100\%$$
$$= 7.064\%$$

Regulation is nearly ± 5% of declared voltage.

F. Efficiency

Efficiency of a transmission line is defined as the ratio of power received to the power send out.

Output power, P_r = 90 MW
Input power, P_s = 95.48 MW
The efficiency is;

$$\eta = \frac{\text{Output power}}{\text{Input power + Coronal loss}} \times 100$$
$$= \frac{90\times10^6}{95.48\times10^6 + 137.45} \times 100$$
$$= 94.26\%$$

TABLE I
RESULTS OF ELECTRICAL DESIGN

Line Voltage (kV)	Current (A)	Spacing (m)	Copper section area (cm^2)	Current carrying capacity (A)	Percentage regulation (%)
230	265.788	10.2	0.9675	350	7.064

G. Specification for the Calculation of Mechanical Design

The factors of affecting the sag in an overhead line are;

(i) Weight of Conductor
(ii) Length of the Span
(iii) Working Tensile Strength
(iv) Temperature

Weight of conductor, W = 1.159 kg/m
Area, A = 346.7 mm^2 = 3.467 cm^2
Diameter, D = 24.21 mm = 2.421 cm
Young modulus, E = 7000 kg/mm^2
Linear Expansion, $\varepsilon_t = 19.3 \times 10^{-6}$ /C °
Ultimate Tensile Stress, UTS =10212.24 kg
Conductor maximum temperature = 60°C
Conductor minimum temperature = -10°C
Everyday Stress at temperature 24°C= 4.93 kg/mm^2
Ruling span; 2L = 200m

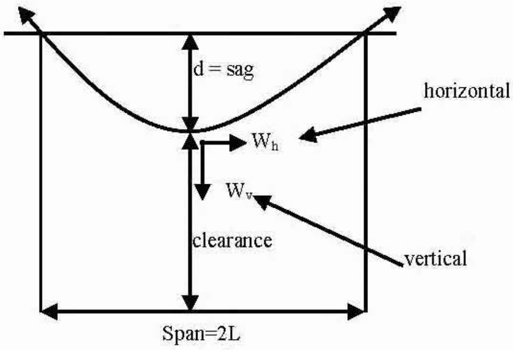

Fig. 1 Sag for Same Level

Horizontal Component of Tension
H = stress × conductor area
= 3.788 kg/mm^2 × 346.7 mm^2 = 1313.299 kg

$$d = \frac{H}{w}\left(\cosh\frac{wl}{H} - 1\right)$$

$$d = \frac{1313.299}{1.159}\left(\cosh\frac{1.159\times100}{1313.299} - 1\right)$$
$$= 4.4126\,\text{m}$$

TABLE II
SAG FOR SAME LEVEL

Ruling Span (m)	Tension (kg) (Max: Temperature, 60° C)	Sag (m) (Max: Temperature, 60° C)
200	1313.299	4.4126
250	1406.56	6.43
300	1593.43	8.19
350	1650.64	10.65
400	1691.89	13.69

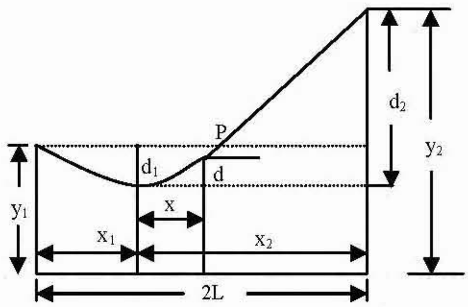

Fig. 2 Sag for Different Level

Weight of conductor, W =1.59kg/m
Span = 284 m
Tension, T = 1699.9kg

Sag $$d = \frac{WS^2}{8T},$$
$$= \frac{1.159 \times 284^2}{8 \times 1699.9}$$
$$= 6.8739 \text{ kg}$$

In this paper, it used 230kV Twin Bundle Double Circuit transmission tower. There are 955 towers between Shweli and Shwe Sar Yan dividing into six different kinds of towers; F, G, H, J, K and transposition tower. Of them, H and J fall in tension tower type and F, G and K are suspension tower type.

TABLE III
RESULTS OF MECHANICAL DESIGN

Tower Number	Type of Tower	Height of Tower	Wind Span(m)	Level Difference between Adjacent Tower(m)	Actual Span(m)	Ruling Span(m)	Tension (kg)	Sag(m)
SM23	F	24	268	-33	252	382.38	1697.95	5.4184
				11	284	382.38	1699.9	6.8739
SM24	G	18	382					
				-57.8	480	382.38	1714.81	19.4653
SM25	G	21	307					
				-14.5	134	382.38	1693.67	1.5359
SM26	F	18	304.5					
				-8	475	382.38	1714.33	19.0672
SM27	G	18	352					
				-80.5	229	382.38	1697.1	4.4767

Fig. 3 Tension Tower

Fig. 4 Suspension Tower

Fig. 5 Transposition Tower

IV. CONCLUSION

In this paper, the design and calculation of 230 kV transmission line is presented. Both of the electrical and mechanical designs are also considered. In the electrical design, it considered choice of voltage, size of conductors, spacing of conductors, corona losses, regulation and efficiency of the line. In the mechanical design, it included types of poles or tower, span to be used, number of insulators in string, towers, and permissible tension in stringing the conductors, sags for different spans with poles at equal or unequal height.

For developing power systems and transmission lines, particularly an economical transmission of large blocks of power over long distances, it is necessary to go in for higher and higher transmission voltages. Also, in localities hydro energy is plentiful but far away, so long-distance transmission has to be used. In evaluating the transmission system from economical point of view, a number of factors can be considered. The cost of the transmission line comprises the cost of conductors, towers and insulators. Technical considerations such as the voltage regulation and system-stability are also important in a transmission system.

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