Design aspects of high voltage transmission line

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ABSTRACT

The transmission lines are very important in the transmitted of electrical power, and the process of selecting the voltage of the line is an important task in the design and implementation process. The process of transferring electrical power from one side then onto the next place for long away. While maintaining the percentage regulation within the permissible limits is an important problem in the transfer of energy. In electrical transmission line there are important elements are resistance, inductance and capacitance. The purpose of this paper is to study and calculate economic high-tension voltage and selection of overhead line conductor ACSR.

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1. INTRODUCTION

The design of electrical transmission lines is an important factor for the success of this design and the work of the lines correctly. The transmission line are circuits with distributed constants, resistance, inductance, and capacitance and shunt conductance. The tasks of transmission lines are to send electrical power from one place to another within economic controls to achieve the design of electrical and mechanical, The Regulation factor, efficiency, and loose with limit of design. The possibility of corona losses should be another consideration. The increase in power to be transmitted over a long distance. Use of high voltages for power transmission has been developed. Choice could be made by standard voltage as in Table 1 or by calculation from formula used in the calculation. Choice of voltage is also linked with the conductor size. The final choice of the voltage and conductor size is made [1]. To predict the efficiency of the transmission line, the voltage and conductor size is decided, and the sending end voltage are calculated. The main component of the transmission line is the conductor, where the conductor the actual primary carrier of electric power. The other part of transmission line is either carry conductor or isolate from the ground. The electrical parameter of transmission lines resistance, inductance and capacitance can be determined from specifications for conductor and geometric arrangements of conductor. It lowers the inductive reactance and increases the capacitive saucepans or capacitance of the line [2]. The voltage of the transmission line must have constant along the line, and the losses of transmission line must be minimized so that the efficiency is high [3], and the cost of the line is minimum. In paper, Jyoti deep Deka1 and ANSI electrical design of 132KV transmission line are shown [4]. This paper presents the choice and calculation of high voltage line and conductor size [5-8].

2. SELECTION OF WORKING VOLTAGE

The capacity of the power line transmitted through requires an increase in the voltage, the voltage from generating station increased by step-up power transformer. Higher transmission voltage causes reducing conductor size [9-12], so conductor size decreases. The transmission line voltages in Iraq are 33KV, 132KV, 400KV. The determine of voltage line, represent major factor in the line designs. There is different voltage can be choosing from three cases [12-15].

- First case: according to the loading of the line.

The choice of voltage is also linked with the transmitting power required and distances the following Table 1 may be used:

Table 1. Loading of line

Line-to-line voltage kV	Line loading Kw x km
11	24×103
33	200×103
66	600×103
110	11×106
132	20×106
166	35×106
230	90×106

- Second case: choice of voltage with a maximum and minimum length, can see in Table 2.

Table 2. Choice of voltage with maximum and minimum length

Line-to-line voltage kV	Length of line km	
	Minimum	Maximum
66	40	120
110	50	140
132	50	160
166	80	180
230	100	300
400	400	800

- Third criteria**:** according empirical formula for high voltage is given by equations:

$$V_L=5.5\sqrt{((L/1.6) + (P\times1000/\cos\phi \times Nc \times 150))}$$

where; V_L=Transmission line voltage in kV.
L=Length of a line in Km.
P=3 phase Power to be transmitted in kW
Nc=Number of circuits.
For Nc=1 (single circuit line).
For Nc=2 (double circuit line).
Cos ø=Power factor of the load.

The various points and specification to be considered in the electrical design of transmission lines can be worked out as an illustration. Design a transmission line three-phase, 85Mw [16-17], at 0.9 power factor lagging. Over distance of 160-kM. The regulation of the line should be within 12.5% of the receiving-end voltage, efficiency 95% and corona losses not to exceed 0.6 kW/Km.

V_L=5.5 √ (160/1.6)+ (85 ×1000/0.9 × Nc ×150))
For
N_C=1 (Single Circuit Line)
V_L=148 kV
The nearest standard high voltage 220 kV
For
N_C=2 (Double Circuit Line)
V_L=112 kV
The nearest standard high voltage 132 kV

3. SURGE IMPEDANCE LOADING

Surge impedance loading is a very essential parameter in power system. Its mean a maximum loading of transmission line. A transmission line loaded to its surge impedance loading [17-19], has no net reactive power flow into or out of the line.

$$V_L/V_C=I_L X_L$$

Or

$$V_{/I}=\sqrt{(L/C)}=Z0$$

$$SIL= 〖(VL)〗^2/Z0$$

where; V_L=Transmission line voltage in kV
Z_0=Surge impedance in ohm
=200 Ω (for double circuit line)
=400 Ω (for single circuit line)

The transmitted power is greater than actual power, hence double circuit power transmitting capability of the system is higher than the real power to be transferred [16], hence, Double Circuit, 132Kv line is selected and the value of MF equal 2.5 from Figure 1.

For Double Circuit Line:-

$SIL= 〖(VL)〗^2/Z_0= 〖(132)〗^2/200 =87$ MW

$P\ t=SIL \times MF=87\times2.5=217.5$ MW

This power transmitting capability of the system is greater than the actual power to be transmitted; hence, double circuit, 132Kv line, is selected.

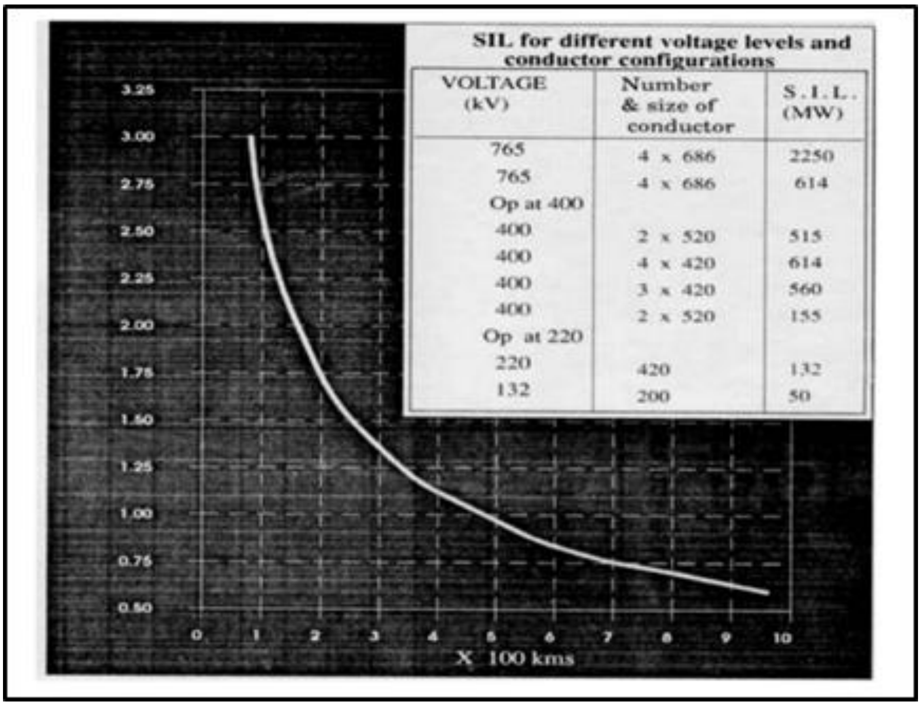

Figure 1. Capability curve

4. STANDARD CONDUCTORS USED FOR TRANSMISSION LINE

The significant cost segment of the line's configuration reply to the conductor. Here are four sorts of overhead transmitter utilized for electrical transmission line and circulation. ACSR conductors are generally used for high voltage work [18-22]. The size of conductors chose upon the length of the transmission line, load on hold and the voltage of the line, ACSR conductor is most commonly usedas shown in Figure 2 and Table 3 represent geometric mean radius (GMR) values as function of conductor radius r.

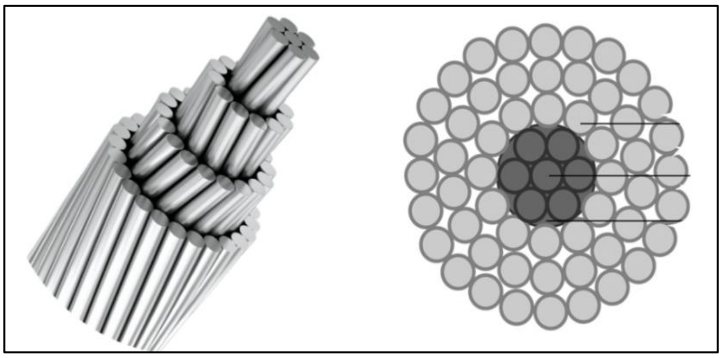

Figure 2. Stranded aluminum conductor with stranded steel core (ACSR)

Table 3. Geometric mean radius values as function of conductor radius r

All aluminum or all copper conductor		ACSR	
Number of stands	GMR	Number of all stands	GMR
7	0.736 r	6	0.768 r
19	0.758 r	12	0.859 r
37	0.768 r	26	0.809 r
61	0.772 r	30	0.826 r
91	0.774 r	54	0.810 r
127	0.736 r		
169	0.779 r		
Sold	0.779 r		

5. SPACING OF CONDUCTORS

An empirical formula Many factors is taken when calculating the spacing between conductors in TL, no exact calculation was developed for calculating spacing between phases because of the complicated situation, like function of many things [16, 17], and there are many empirical formulas that we come up with and is used to determine the spacing between the conductors. Empirical formulas that are used:

Spacing=√S+V/150 meters

where; S is a sag in meter.
V is a line voltage in kV.
The spacing arrangement may be horizontal or vertical is given in Table 4.

Table 4. Spacing of conductors

The line to line voltage kV	Equivalent spacing (m)
11	1
33	1.3
66	2.6
110	5
132	6
166	8
230	10.2

6. TRANSMISSION LINE CONFIGURATION

As Figure 3 shows the transmission line configuration for 132 kV, is show an overhead transmission line used to transmit electrical energy across alarge distances, it consists of three double circuit nductors. Overhead transmission is generaly the lowest cost methed of power transmission for alarge quantities oe electric energy.

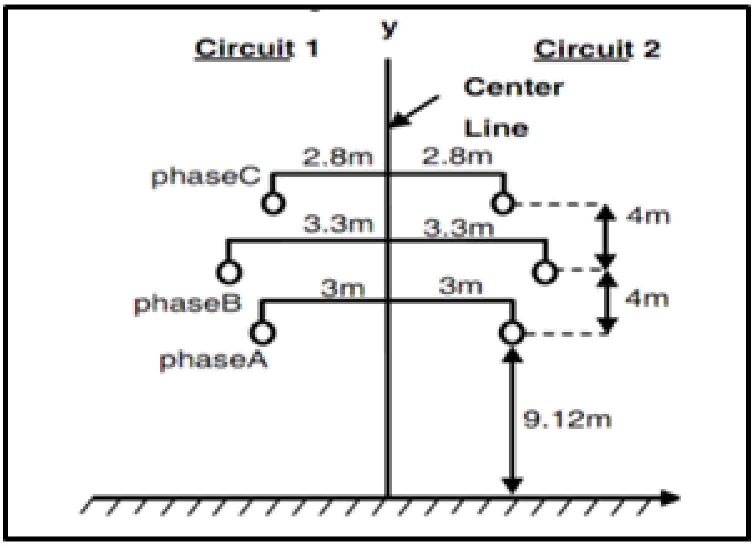

Figure 3. Conductor arrangements for 132 Kv overhead double circuit overhead transmission

7. EFFICIENCY TRANSMISSION LINE

From suitable conductor for this current is ACSR (30/7/2.59) mm conductor. It is necessary to calculate the line losses and the efficiency to check the suitability of this conductor [10-13].

Losses=$3Ir^2R$

where; R=total resistance per phase at 75^o
For
ACSR (30/7/2.36) mm.
Resistance at 20^o is 0.222 Ω/Km.
To calculate the resistance at 75^o .

$$\frac{R75}{R20} = \frac{\frac{1}{\alpha o} + 75}{\frac{1}{\alpha o} + 20} = \frac{228 + 75}{228 + 20}$$

$$R75 = 0.222 \times \frac{308}{228} = 0.299\Omega/km$$

$$R75 = 0.299 \times 160 = 47.98\ \Omega$$

$$The\ \text{efficiency of the line} = \frac{85\times10^6}{85\times10^6+3\times414^2\times47.98} = 77\%$$

The efficiency very poor; hence, the conductor size is not suitable [16]. The same calculation can be done for another ACSR conductor as shown in Table 5. Figure 4 showed the relation between conductor diameter and efficiency when the conductor size increased, efficiency of overhead transmission line increased also.

Table 5. Summarizing the results of 132kv lines with the size of ACSR

Line voltage in kV	Size of ACSR conductor mm	Current carrying capacity A	Resistance at $R75C^{\circ}$ in Ω	Efficiency%
132	30/7/2.36	400	47.98	77
	30/7/2.59	455	39.85	80.5
	30/7/3.99	800	16.8	90.8
	30/7/4.27	850	14.4	92.02

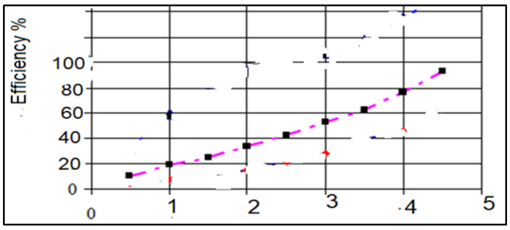

Figure 4. Dimeter of conductor

8. PARAMETERS OF TRANSMISSION LINE

The ACSR conductor (30/7/4.27) mm has much a higher current rating than the rated current of proposed line [2]. The number of aluminum strands 30 [3], each having a diameter 4.27 mm. Number of steel strands 7, overall diameter=29.89 mm, Weight 1977kg/km. Ultimate strength 178.8. In Table 4 an interphase spacing of 6 m is suitable for a 132 kV

$$L = 0.4605\, log\, \frac{Dm}{Ds}\, mH/km$$

$$c = \frac{0.024}{ln\frac{Dm}{Ds}} \mu F/km$$

$$\mathrm{Vs} = \mathrm{Vr}A + \mathrm{BIr}$$

$$\text{Voltage regulation} = \frac{\mathrm{Vs-Vr}}{\mathrm{Vr}} 100\%$$

$$\mathrm{Is} = \mathrm{VrY}\left(1 + \frac{\mathrm{ZY}}{4}\right) + \mathrm{Ir}\left(1 + \frac{\mathrm{ZY}}{2}\right)$$

9. CORONA LOSS

Some ionization is always present in the air due to cosmic rays, ultra-violet radiation and radioactivity. Therefore, under normal conditions, the air around the conductors contains some ionized particle conductor and by using steel-cored aluminum conductors (ACSR) conductors. The breakdown strength of air at 76 cm of mercury is directly proportional air density [23-27]. Table 6 show the ratio of V and Vd where F is the factor, which are, varies with the ratio. Thus, the breakdown strength of air at a barometric pressure of b cm of mercury and temperature of t°C become:

$$\delta = \frac{3.86 \times \mathrm{b}}{273 + \mathrm{t}}$$

The disruptive critical voltage V_d is given by,

$$V_d = 21.1 \times r\, m.\delta\, Ln\frac{D}{r}$$

$$\mathrm{Vd} = 21{,}1 \times 14.945 \times 10^{-3} \times 0.82 \times 0.88\, \mathrm{Ln}\frac{7.55}{14.945 \times 10^{-3}}$$

$$Vd = 143.\mathrm{kV}$$

$$\frac{V}{Vd} = \frac{132}{143} = 0.92$$

Table 6. Ratio (V/Vd) and factor F

V/Vd)	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.2
F	0.012	0.018	0.05	0.08	0.3	1.0	3.5	6.0	8.0

From Table 5, F=0.05

$$\text{Corona loss} = \frac{21 \times 10^{-6} \times f \times V^2}{\left(\log \frac{Deq}{r}\right)^2} \times F$$

$$\text{Corona loss} = \frac{21\times10^{-6}\times50\times(132000)^2}{\left(\log\frac{7.55}{14.945\times10^{-3}}\right)^2} \times 0.05 = 0.04 \text{ Kw/ph/kM}$$

The voltage regulation is with a permissible limit of 12.5%. Therefore the size of conductor and voltage is suitable for the line [20-22, 28], and the summating the results as shown in Table 7 and Table 8.

Table 7. Parameters of transmission line

Conductor ACSR	R (Ω)	XL (Ω)	Ys Siemens	Z $\Omega/phase$	A = D (Ω)	B (Ω)
30/7 /4.277	14.4	65.1	4.28×10^{-4}	$66.7\angle 77.5$	0.994 0.179	$67.5\angle 75$

Table 8. Result calculation of sending voltage and percentage regulation

V_R (v)	V_S (v)	REG %	Is (A)	Ps (MW)	Corona losses Kw/ph/kM
76210	96336 12.79	2.3%	$397.52 \angle -21.44$	88.112	0.04

10. VOLTAGE FLOW LIMIT DESIN SYSTEM PLANNING

Since the desin of high voltage are depend on different parameters it is necessary to make throw analysis while planning desin system [23-26, 29]. The problems to be stusied in the total system are (i) selection of the economical of high voltage (ii) determination of the economical size of ACSR conductor and (iii) comparison of voltage regulation [27]. The flow diagram of the transmission planning as shown in Figure 5.

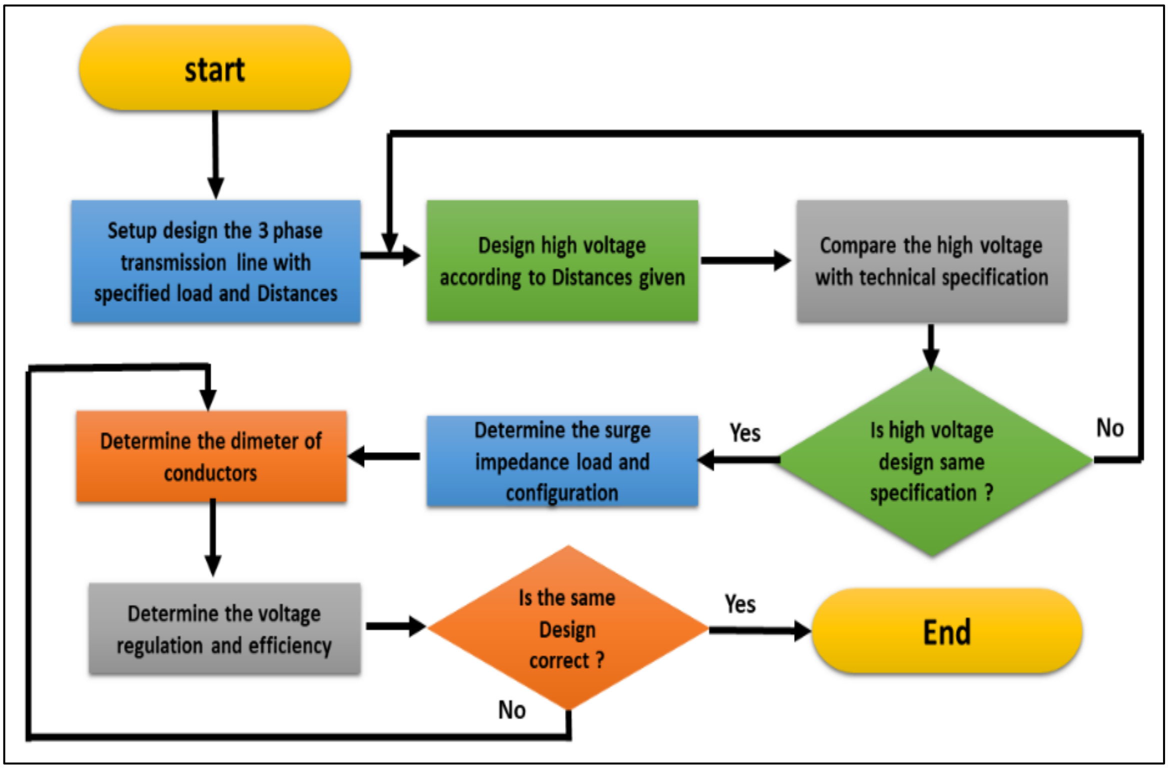

Figure 5. Flow diagram of the transmission planning

11. CONCLUSION

The conductor is a major component of the overhead transmission; the calculation was carried out for 132 kV at different sizes of conductors to make compact design of overhead transmission line. The electrical design involves selection of voltages, selection of conductors, voltage regulation, and efficiency. The conductor resistance determines the conductor losses and limits the maximum allowable current carrying capacity of the conductor. Therefore, the size of conductor and voltage is suitable for the line, and the summating the results as shown in Tables 7 and 8.

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