Computer Aided Analysis and Design of EHV-AC Transmission line

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***Abstract* - Power demand had a drastic raise in past few decades. To fulfill the power demand, transmission line becomes a vital part of power system. The manual method of transmission line design involves tedious calculation and relies on the knowledge and experience of designer so computational design of transmission line gives faster result and wide vision of the probable solutions. This paper introduces Programmed based software to calculate all electrical parameter required for transmission line design. Software developed for single and double circuit transmission line, including up to eight sub conductor in a bundle. In this paper ACSR Moose conductor and ACCC Delhi conductor are used to transfer 600 MW power at 400 KV voltage level for 430 km long Transmission line. Three different configurations are compared Figure i.e. simple vertical, Hexa and Inverted V configuration for ACCC Delhi conductor.**

***Keywords* - Designing parameters, software, ACSR Moose and ACCC Delhi conductor**

I. INTRODUCTION

The standard transmission voltages dictated by ANSI standard C-84 of the American National Standard Institute. The sub transmission refers to a lower voltages network, 34.5-115 KV, and interconnecting bulk power and distribution substation. The voltages that are in the ranges of 345-765 are classified as extra high voltages (EHV). The EHV system dedicates a very thorough system design.[10]

Design of EHV and UHV transmission line has become essential for today's transmission engineer. Demand of power has risen to a great deal and to transmit large block of power to a long distance, high voltage transmission lines are required. Optimized design of these transmission lines does not have any unique process or standard procedure, though there are certain elements that are universal to all designs procedures. Depending on the design parameter given by the client or purchaser, there are several possible solutions to send the designated power to a distant place. Out of various possible solutions, final selection of any design is chosen according to the practical constraints such as allowable ROW, route of transmission line, height of tower, environmental conditions etc.

The manual method of transmission line design involves tedious calculation and relies on the knowledge and experience of designer. Computational design of transmission line gives faster result and wide vision of the probable solutions. According to the existing constraint variable, design parameters and solution varies. For EHV transmission line design, certain areas are given more importance, such as corona loss, electric and magnetic fields. Transmission line designing is done in such a way that conductor has low losses, high efficiency, good voltage regulation, less RI, TVI and AN. By using high order bundled conductor, corona loss, AN, RI are reduced. As these loss increases with the raise in voltage level, so in case of EHV and UHV transmission level bundled conductor are used.

II. PROBLEM FORMULATION

New planning tools introduce computers, which will permit the automating of more and more of the planning activity. The automation will proceed along with two facilities. First increased application of operations research techniques will be made to meet performance requirements in the most economical way. Second, improvements in data base technology will permit the designer to utilize far more information in an automatic way than has been possible in the recent past. In forecasting that certain practice or old tools will replace with the computer based analysis and design of EHV-AC transmission line.

Voltage level selection is the one of the most important factor to be considered. Power transfer capacity is approximately proportional to the square of the voltage. Hence higher voltage is required to transmit more power. If higher voltage is selected, then with increase in voltage level, cost of insulation along with height and weight of tower increases, resulting into overall cost escalation of the transmission line. Therefore the voltage level must be judiciously selected. Choice of conductor according to its current carrying capacity, and choice of number of circuit i.e. single circuit, double circuit or multi-circuit. Choice of number of bundles in a conductor. As number of bundle in conductor increases, GMR increases resulting into reduced inductance of the line and consequently reduced losses. With increase in bundle, mechanical design of tower changes and hardware assembly becomes complicated and expensive. Now a days transmission network is become very complex so optimal designing of transmission line is required so computer aided analysis and design is really helpful for getting optimal results. Appropriate conductor configuration must be selected, so as to minimize the inductive losses, corona loss, AN, TVI, RI, ROW, etc, while maintaining the suitable electrical clearances. According to the atmospheric condition, calculate corona loss of selected conductor for normal weather condition and critical weather condition. Corona calculation changes as per the number of bundle in a conductor and atmospheric conditions of the line. Conductors with large GMD or diameter have low corona losses but at the same time with increase in diameter, weight of line increases resulting into high cost of tower and foundation. Selection of the shortest route must be considered along with the cost required to acquire the land, for ROW.

III. CCC OR AMPACITY OF CONDUCTOR

Current carrying capacity (CCC) of any conductor is the ampere it can carry before damaging the conductor. Amount of current that can be carried by a conductor is determined by the temperature withstand capacity of the conductor. Ampacity of a conductor must be more than the normal rated current to be transmitted, so as to carry the overload current without any damage.[16]

Conductor carrying current cause I^2R loss that contributes in the increased temperature of conductor. Solar radiation is the other factor that raises the temperature of the conductor. Steady state temperature rise of a conductor is attained whenever the heat gained by the conductor from various sources is equal to heat losses. This is express by heat balance equation.

$$P_J + P_{sol} = P_{rad} + P_{conv} \quad \text{..........……..(1)}$$

Where, Pj: Heat generated by joule effect (W), Psol: Solar heat gain by conductor surface (W), Prad: Heat loss by radiation of the conductor (W), Pconv: Convection heat loss (W)

Now, CCC of any conductor can be obtained using above equation:

$$CCC = \sqrt{\frac{P_{rad} + P_{con} - P_{sol}}{R_{ac}}} \quad \text{…… ……………...(2)}$$

Conductor is chosen as per CCC of the conductor (in Amp), for transmitting power at different voltage levels.

Table:1 Input data for calculating Ampacity of ACSR moose conductor

Description	Unit	ACSR
Conductor Diameter	Mm	31.77
Temperature	^{0}C	20
DC resistance at 2000C temperature	Ω/km	0.05595
Constant of mass temperature coefficient of resis. per ^{0}C	Ω/0C	0.004
Ambient Temperature	0C	48
Final Equilibrium Temperature	0C	65.45
Wind velocity	m/s	0.6
Emissivity coefficient in respect to black Body	––	0.6
Solar radiation absorption coefficient	––	0.5
Intensity of solar radiation	W/m2	1200
Stefan-Boltzmann constant	W/(m2 * K4)	5.67 *10−8
Thermal conductivity of air film in contact with conductor	W/(m *K)	0.02585
Frequency	Hz	50
Permeability	––	1

Computational calculation using software: Sub modules contains editable text, users can fill the data into edit text and final result will generated into the string after pushing the CALULATE AMPACITY push button. Calculation of Ampacity of conductor as per.[2] As mentioned previously the software ESGSD has been developed using MATLAB as mathematical computing tool and programming environment as well [19]

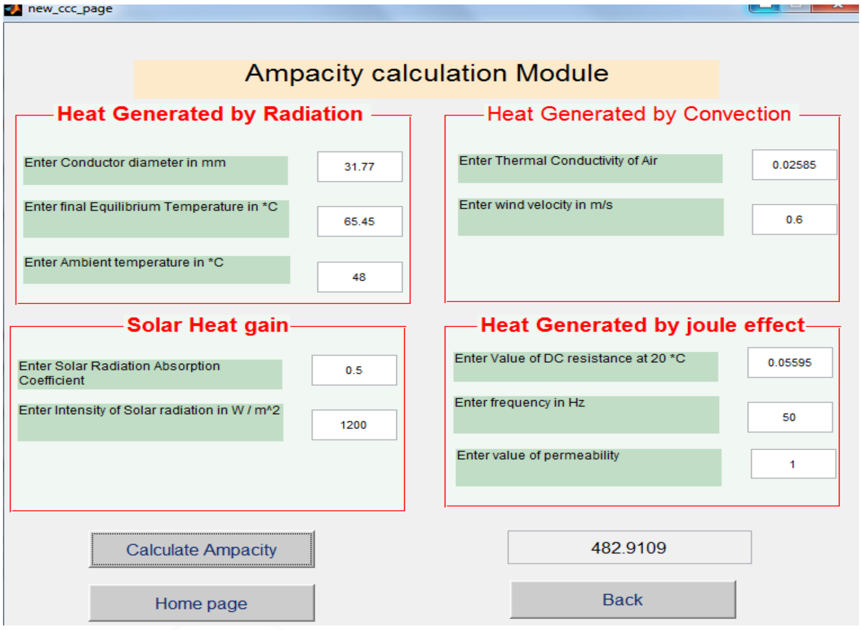

Figure 1: Ampacity calculation module

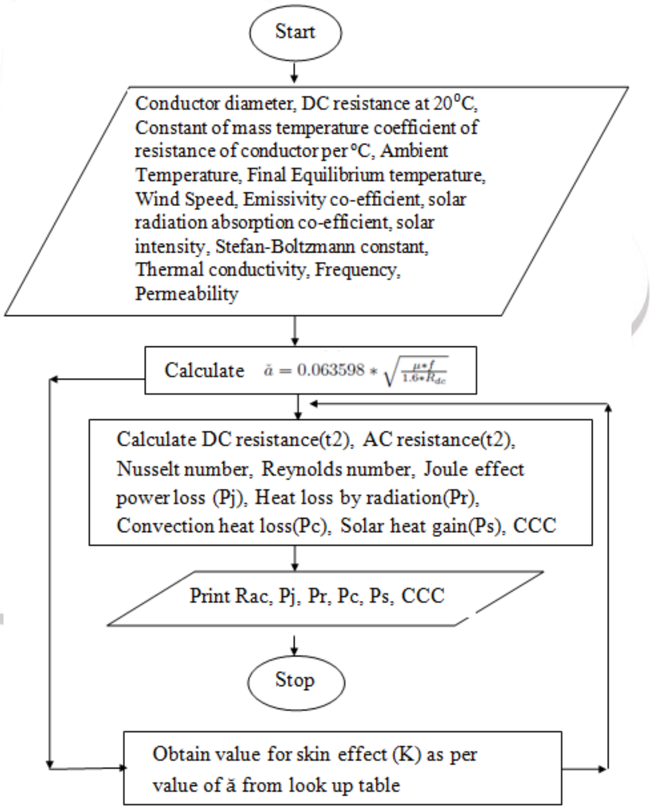

Figure 2: Flowchart for Ampacity calculation

IV. ELECTRICAL CALCULATION FOR DOUBLE CIRCUIT CONFIGURATION

The flow chart is given for the calculation of all necessary design parameters for single circuit and double circuit calculation. Electrical calculation for the double line circuit is given in the figure.

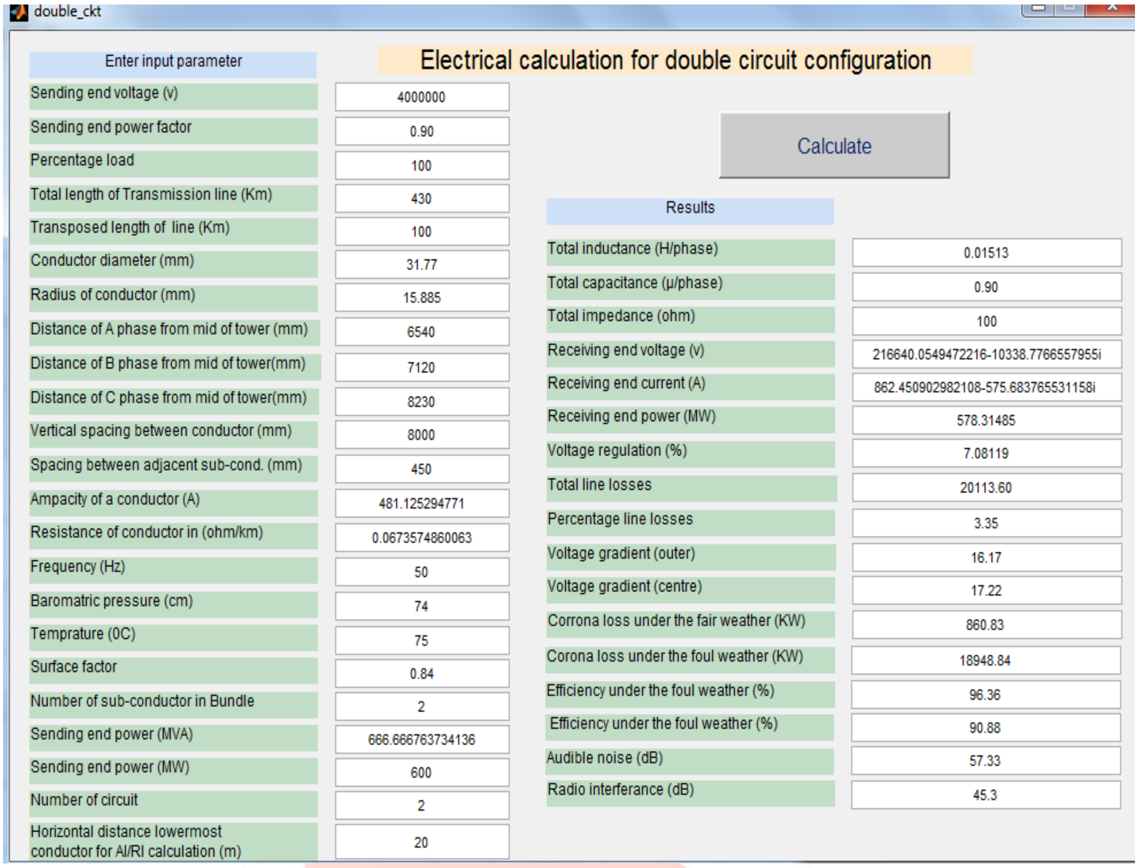

Figure 3: Screen for Electrical calculation for double circuit configuration using ACSR Moose conductor

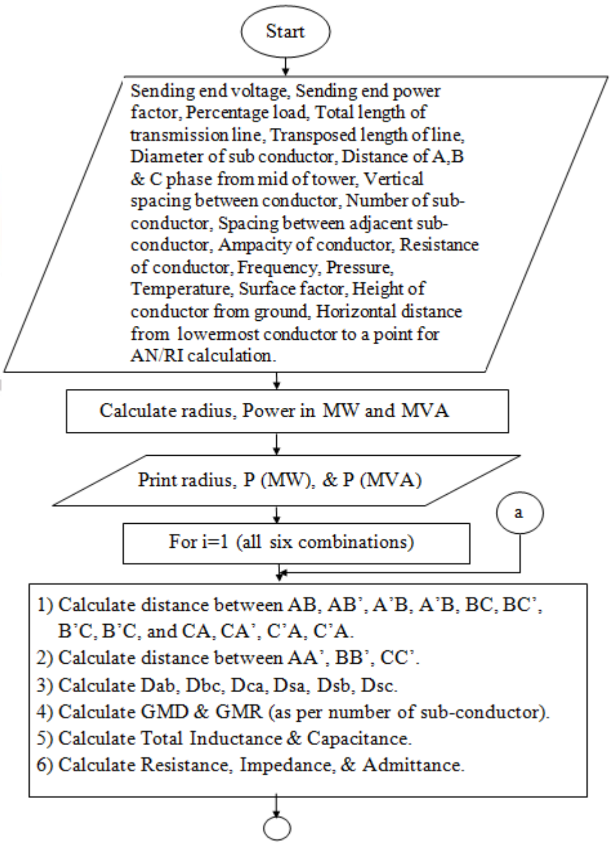

Figure 4: Flow chart for Electrical calculation

V. INPUT DATA AND OUTPUT RESULT FOR ACSR MOOSE CONDUCTOR AND ACCC DELHI CONDUCTOR

Here two conductors: Twin ACSR Moose conductor and twin ACCC Delhi are considered for 600MW power transfer at 400KV.[18]

Table 2: Input data for ACSR moose and ACCC Delhi conductor

Description	ACSR Moose	ACCC Delhi
Sending End Voltage (V)	4000000	4000000
Sending End Power Factor	0.90	0.90
Percentage load (%)	100	100
Total length of Transmission Line (Km)	430	430
Transposed Length of line (Km)	100	100
Diameter of conductor (mm)	31.77	31.40
Distance of top conductor from mid of tower (mm)	6540	6540
Distance of mid conductor from mid of tower(mm)	7120	7120
Distance of bottom conductor from mid of tower(mm)	8230	8230
Vertical Spacing between conductor (mm)	8000	8000
Spacing between adjacent sub-conductor (mm)	450	450
Ampacity of conductor per phase per circuit(A)	962.25	962.25
Resistance of conductor at operating temp(Ω/Km)	0.06736	0.050317
Frequency (Hz)	50	50
Barometric Pressure (cm)	74	74
Temperature (^{0}C)	65.5	63.47
Surface Factor	0.84	0.84
Number of sub-conductor in bundle	2	2
Sending End Power (MVA)	667	667
Sending End Power (MW)	600	600
Height of conductor from ground (m)	15	15
Horizontal distance from bottom conductor (m)	20	20

Table 3: Output result for ACSR moose and ACCC Delhi conductor

Description	ACSR Moose	ACCC Delhi
Power handling capacity for single circuit (MW)	568.95	568.95
Current per single circuit (kA)	0.866	0.866
Number of circuit	2	2
Total Inductance (H/phase)	0.05134	0.0514
Total Capacitance (µ/phase)	2.22	2.218
Impedance (Ω)	7.24+16.13i	5.41+16.15i
Receiving End Voltage-Magnitude (KV)	216.89	218.50
Receiving End Voltage-Angle	-2.73	-2.96
Receiving End Current-Magnitude (A)	1036.85	1036.80
Receiving End Current-Angle	-33.73	-33.75
Receiving End Power (MW)	578.31	583.80
Voltage regulation (%)	7.08	6.29
Total Line loss (KW)	20113.60	15025.27
Percentage Line loss (%)	3.35	2.50
Max. outer surface Voltage gradient (KV)	16.15	16.31
Max. center surface Voltage gradient (KV)	17.23	17.39
Fair weather corona loss (KW)	1721.67	1717.46
Foul weather corona loss (MW)	37.90	38.81
Efficiency under fair weather (%)	96.36	97.21
Efficiency under foul weather (%)	90.88	91.56
Audible Noise (dB)	57.33	57.49
Radio Interference (dB)	45.30	45.65

VI. COMPARISON OF DIFFERENT CONFIGURATION OF ACCC DELHI CONDUCTOR

Here three different configurations are compared Figure i.e. simple vertical, Hexa and Inverted V configuration. All input considered here are same except the distance of conductor from mid of the tower.

Distance of phase A, B, C from mid of tower for Vertical configuration are 7120 mm Distance of phase A, B, C from mid of tower for Hexa configuration are 6540, 7120 and 6540 mm respectively. And distance of phase A, B, C from mid of tower for Inverted V configuration are 6540, 7120 and 8230 mm respectively.

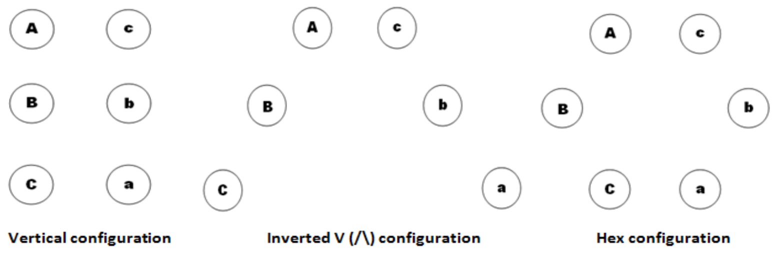

Figure 5: Various conductor configuration

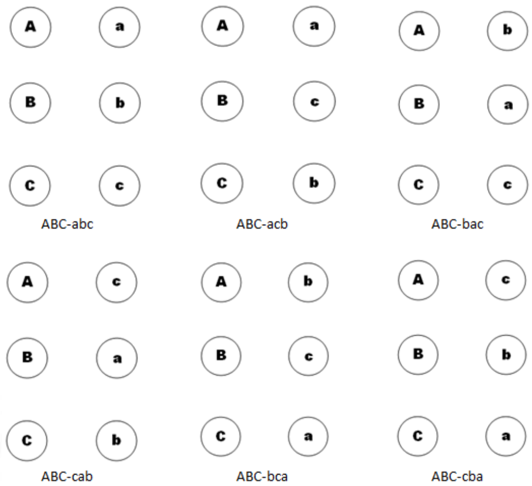

Figure 6: Different combination of double circuit vertical configuration

Table 4: Output result for different configuration of ACCC Delhi conductor

Description	Vertical	Hexa	Inv.V
Total inductance (H/phase)	0.05139	0.05165	0.051397
Total Capacitance (μ/phase)	2.21790	2.20663	2.21775
Impedance (Ω)	5.41+16.1456i	5.41+16.2260i	5.41+16.1467i
Receiving End Voltage-Magnitude (KV)	218505	218475	218505
Receiving End Voltage-Angle	-2.96	-2.97	-2.96
Receiving End Current-Magnitude (A)	1036.81	1036.36	1036.80
Receiving End Current-Angle	-33.75	-33.72	-33.75
Receiving End Power (MW)	583.8026	583.8095	583.8027
Voltage regulation (%)	6.288	6.303	6.288
Total Line loss (KW)	15025	15025	15025
Percentage Line loss (%)	2.50	2.50	2.50
Max. outer surface Voltage gradient (KV)	16.315	16.307	16.307
Max. center surface Voltage gradient (KV)	17.42	17.39	17.39
Fair weather corona loss (KW)	1771.85	1770.55	1717.46
Foul weather corona loss (MW)	38.958	38.865	38.812
Efficiency under fair weather (%)	97.203	97.204	97.212
Efficiency under foul weather (%)	91.54	91.55	91.56
Audible Noise (dB)	57.62	57.65	57.49
Radio Interference (dB)	45.92	46.02	45.65

VII. CONCLUSION

In this paper Ampacity of conductor computational calculation for transmission line design is given ACSR Moose and ACCC Delhi are compared. Software is developed for easy calculation of current carrying capacity of conductor and electrical calculation of Double circuit transmission line. In this software nearly all electrical designing parameters are considered. ACSR Moose conductor is a standard conductor which is used for 400 KV transmission line. This conductor can be considered where operating temperature doesn't exceed beyond 75^0C and where initial cost has to be kept minimum. ACCC Delhi conductor has less line losses, have more capacity build towards future demand and are ideal for reconductoring. Maximum operating temperature of ACCC conductor is180^0C which is much higher as compared to ACSR Moose. Cost of this conductor is 4 to 5 times higher then ACSR conductors. Out of three considered configurations, inverted V configuration is chosen as it gives higher efficiency and low AN and RI.

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