Design and Reconductoring of A 400 K.V Transmission Line And Analysis on ETAP

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Abstract:- *The existing transmission line when subjected to actual load flows across a system of distribution and substation are restricted to various permissible limits of its line parameters limitations in terms of temperature, sag , current rating and atmospheric parameters laying of the existing line and its limitations problems and linked costs, where new generation transmission upgrades are inculcated in proximity with the load. Thus we followed this basic concept of replacing the existing conductors with the various new age conductors which have enhanced temperature, sag, current and power transfer capacity. We selected few conductor's and with their data designed a 400kv transmission line and its comparison model and thus performed the load flow analysis on ETAP which uses the Newton-Raphson and Gauss-Siedel iterations and performs the load flow analysis. Thus, reconductoring is an important cost reduction process in evaluation of the system integration, which is economical for capital improvement and better transmission capabilities.*

Keywords:- *Design, Transmission line, 400 K.V, Reconductoring, Load Flow Analysis, ETAP.*

I. INTRODUCTION

Transmission system is an integral part of distribution and transfer of power to the user end. It consists of various stages of transmission of high voltage to low voltage based on the requirement of the consumer. Various loads are connected to this system and thus every demand is to be catered thus the load flow analysis of such system gives the purview of the various parameters such as power flow, current carrying capacity, temperature range, voltage, reactive power etc. are obtained and analysis of the system is done accordingly. For laying transmission line the atmospheric parameters and the geographical location etc. are to be known before lying of the line.

The various parameter's and mathematical equations pertaining to the design of the transmission line was obtained from the [1] and [2] all the calculation parameters and tables were also been obtained from [1] and

[2] about the heat and skin effect and corona loss table and also about the atmospheric parameter's such as the wind azimuth value, solar radiation, emissivity, absorptivity etc. from [1] and [2]. The sag calculation and the data of various conductors and sequencing data was obtained by [7] and its technical chapters a brief explanation of what all consideration regarding the temperature and wind parameters are to be taken was given in[7] which helped immensely in calculating the sag in our design model. Effects of sag on the transmission line was studied in [8] and the process of reconductoring and its effect was seen in [6]

Thus we designed our transmission line model on various data's and equations obtained in excel and thus we created an excel model where various amapacity and electrical and mechanical properties of the conductor are calculated and thus we have inculcated that in our model we also made and comparison model based on the data of the various different types of conductors and its modeling is done. Based on the data obtained we have updated ETAP library with our conductors and a simple ring distribution model us created for various conductors and their load flow analysis on the software is done and thus the result obtained is thus compared from the excel model result and the best possible configuration is derived for reconductoring process.

II. DESIGN OF 400 K.V TRANSMISSION LINE

A. Parameters Calculations

The Design of the transmission line is done by calculating numerous parameters such as the A.C Resistance, Inductance, Capacitance and total line reactance etc. at various ambient conditions. The line losses mainly the I^2R losses are calculated as with change in current the I^2R are affected with increase in current high heat losses are generated with further contribute towards the temperature rise and thus stress it more. As the heat increases and exceeds a certain limit the conductor starts melting and thus it expands and elongation of the conductor takes place forming a catenary parabolic structure with more sag. The sag should be in a particular limit as exceeding that limit would cause line-ground faults. The current also contributes to various other parameters such as the inductance and capacitance of the line which plays a major role in terms of the reactance and voltage regulation of line. And also the various parameters such as the corona losses and audible as well as the radio inferences are to be calculated simultaneously.

B. Calculation of the Ampacity (Ampere-capacity)

The ampere capacity i.e. the current carrying capacity of the conductor at the ambient temperature and atmospheric condition. The maximum permissible limit that can be allowed to flow in the conductor. The current carrying capacity depends basically on the conductor resistance and the ambient conditions.

The crux of this calculation is to obtain a steady state heat balance equation i.e. the the heat gained by the conductor should be equal to the heat losses.

[Internal heat developed I²R (Wi)] + [External Heat supplied by Solar Radiation(Ws)] = [Heat lost by convection of air(Wc)] + [Heat lost by radiation(Wr)]

Wi+Ws = Wc+Wr

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I = Current

qs = Heat gained by conductor by solar radiation per linear meter, Watts/m

qc = Heat lost by conductor by convection per linear meter, watts/m.

qr = Heat lost by conductor by radiation per linear meter, watts

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R(Tc) = A.C Resistance at Temperature(Tc).
TLOW = Minimum Temperature.
THIGH = Maximum Temperature.

C. RLC Parameters

The parameters such as the Conductor Capacitance and Inductance are calculated mainly. And also the voltage regulation corona and various interference line GMD and GMR based on the spacing and length of the line is taken and calculation based on its value is done. Also the type of circuit and its configuration is taken into the account. Here the inductance and capacitance of the line require the GMD calculation as for its calculation as well as the line length and its transposition based upon which the whole calculation is taking place. Also we find the corona losses and also the audible and radio interference which is permissible only upto a certain limit. Voltage regulation is also obtained and used in various parts of calculations and the design of conductor and its distance span and structure and the type of circuit plays a key role in here.

D. Sag tension Calculation

Each type of conductor has a specific weight. When the conductor is strung on the tower, they form catenaries and follow a parabolic curve. The lowest point of the conductor catenaries is called a "Null-Point". The vertical distance between the point of fixity on tower and the null point is called "Sag". The sag is worked out by a simple equation as follows:

$S = WL^2 / 8T$

Where, S=Sag in Meters.

W= Weight of Conductor per Meter.

L = Span between two towers in Meter. &
T = Tension of the Conductor in Kg.

Thus the various conductors have various values and its withstand capacity we have a certain permissible limit of the line to ground clearance that has to be maintained for the safety and line to ground fault clearance based on that the comparison between the various conductors and its load bearing capacity is done. This plays a vital role in the calculation and also in the reconductoring process.

E. Recondcutoring

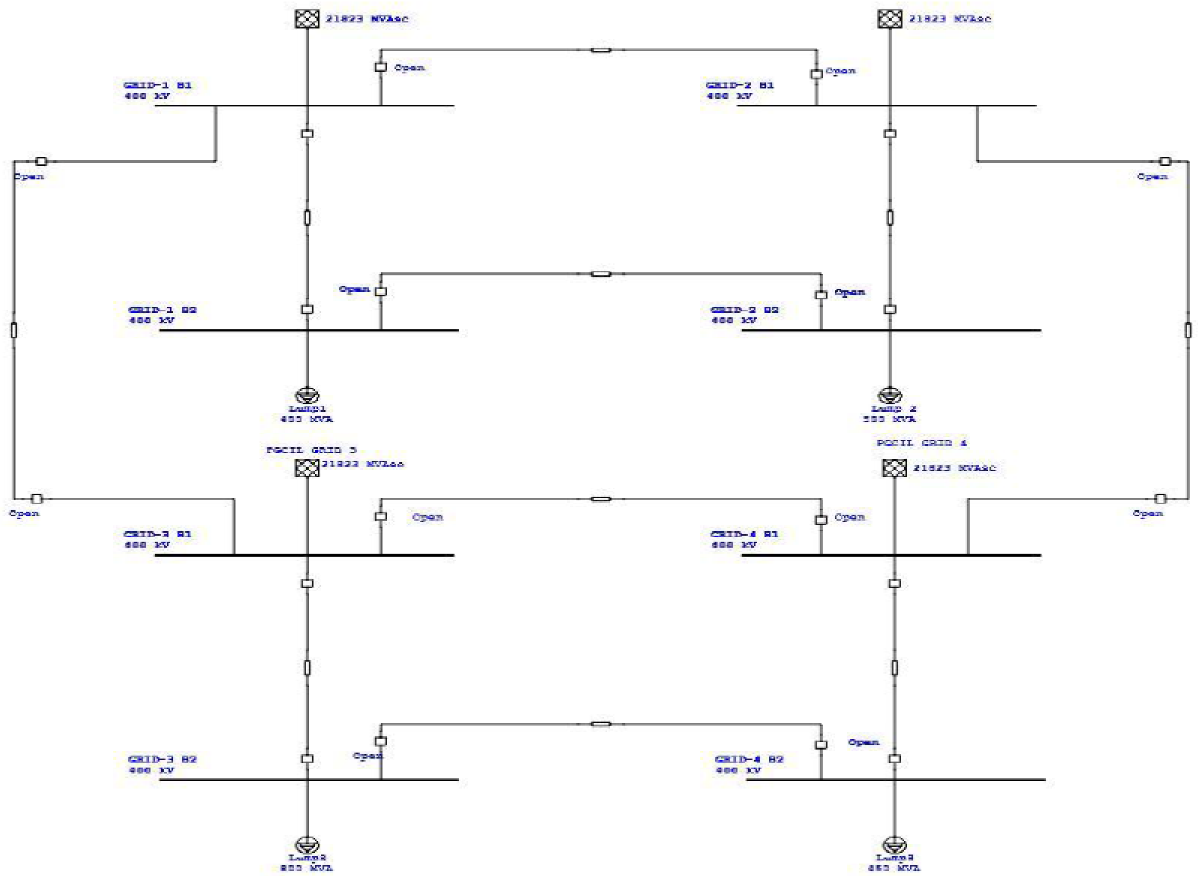
Reconductoring is a simple process of replacing the existing conductors with new generation high performance conductors(HPC) as the existing conductors causing high losses in transmission due to increasing load growth and requirements and thus the process is evolved when the existing conductors are no longer optimum and feasible in catering our requirements.

Its is relevant for the developing conductors as the process is very economical and the capital cost revenue generated is more. Here replacing the existing conductors with HPC conductors on the same structure and mounting would not add to the cost and thus we have taken this as a major prospect for optimization of line.

III. SYSTEM IMPLEMENTATION

A. Distribution System

Here we have selected a simple 8 Bus interconnected distribution system with 4 utility grid connected to it as given one of the case studies of PGCIL we have estimated the length of various lines and the parameters as per the case are given has been entered in our ETAP model.



B. Various Conductors for Reconductoring

The various New Age conductors are being considered in our project and the data obtained from various manufacturers are being used in computing the load flow analysis of the line with them.

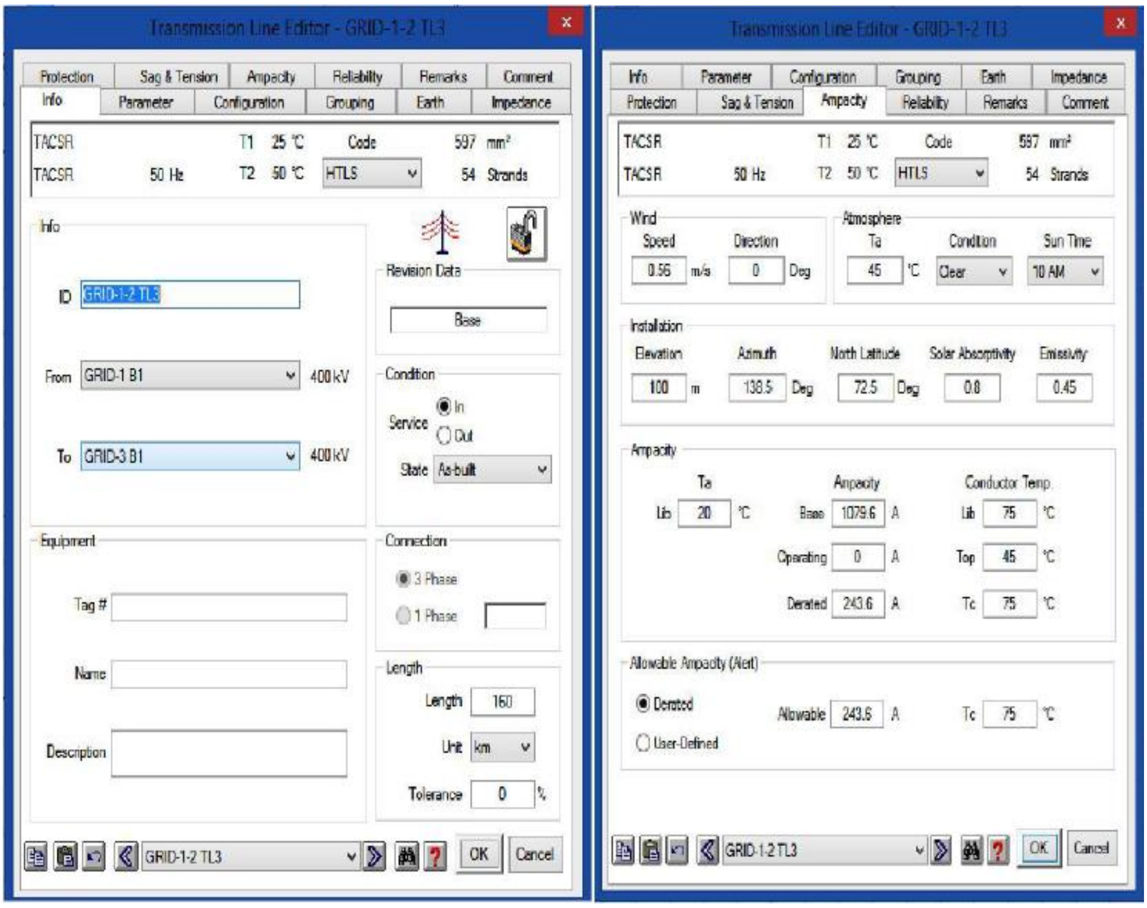
The conductors that we used for analysis are as follows:

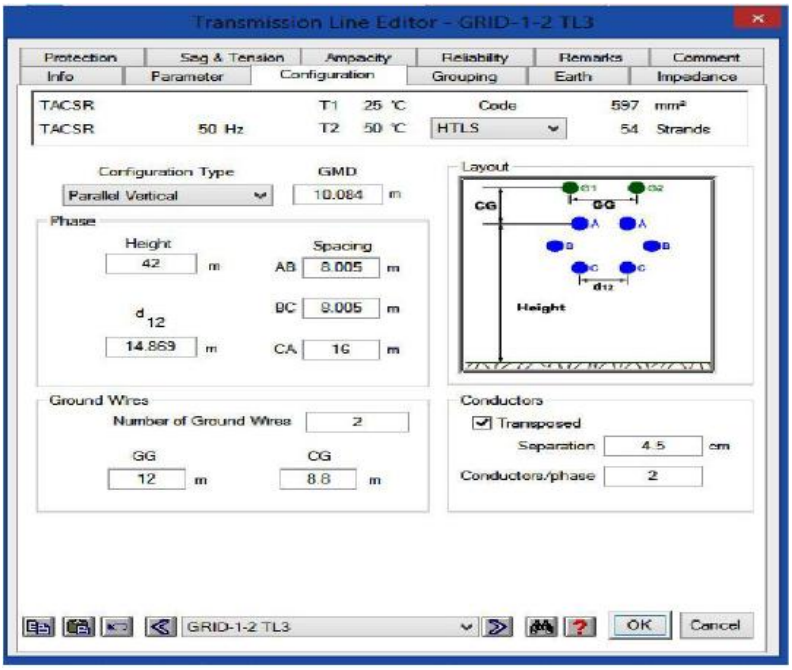
- ACSR- (Aluminum Conductor Steel Reinforced) Moose configuration (Existing).
- AL-59

- ECO
- ACCC- (Aluminum Conductor Composite Core)- Budapest
- ACCC- (Aluminum Conductor Composite Core)-Rome
- TACSR- (Thermal Resistant Aluminum-alloy stranded conductors Steel Reinforced)
- GZTACSR- (Galvanized Ultra Thermal Resistant Aluminum-alloy stranded conductors Steel Reinforced)-520
- GZTACSR- (Galvanized Ultra Thermal Resistant Aluminum-alloy stranded conductors Steel Reinforced)-620

B. Load Flow Analysis

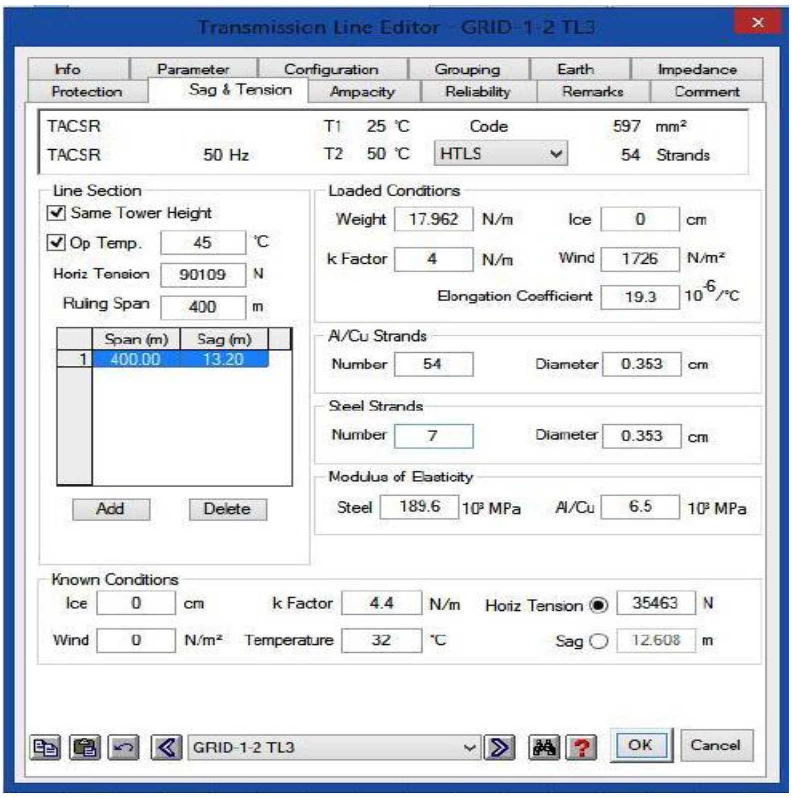
Thus on the one line diagram we have used different types of conductors on same ambienyt conditions and temperature with same loading nd line length for same amount of power tarsnfer and current carrying capacity and thus based on that ETAP for load flow calculations uses the newton raphson and the gauss seidel method for the calculation of the load flow at various points we also have made the arrangement for the marginal and critical loading capacity of the line for the same analysis perspective. Thus the value and the losses obtained are being compared and verified with the excel model calculation and thus the best possible configuration with the maximum possible power transfer capability and revenue generating conductor is to be selected based on the requirement of reconductoring.





Thus we update the ETAP library with our conductors and thus make use of that in our modeling.

Thus these are the parameters we put in our calculation for ETAP and its load flow analysis. And selection of our transmission line from ETAP updated Library with our conductor data i.e. calculated based on the requirement of the software and calculated in excel based on the information data provided by the manufacturer on dc resistance etc.



And after this the load flow is performed and report is generated which is further analyzed based on the loading and load flow calculation.

IV. RESULTS AND ANALYSIS

The various results obtained based on the calculations that we have observed in excel model and also analyzed on ETAP was compared with the existing ACSR conductor line and various parameters based on that we have obtained these graphs on comparison of various parameters:
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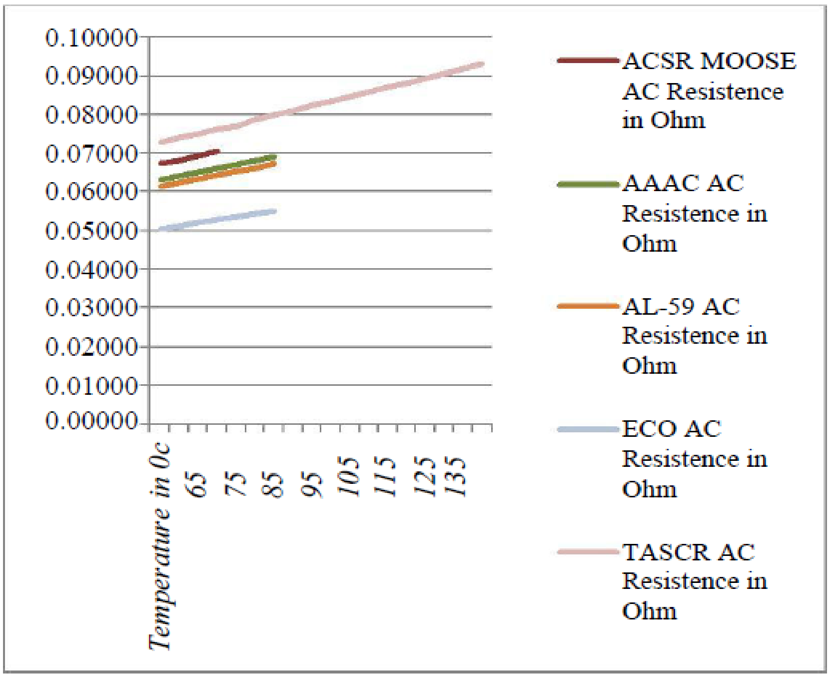
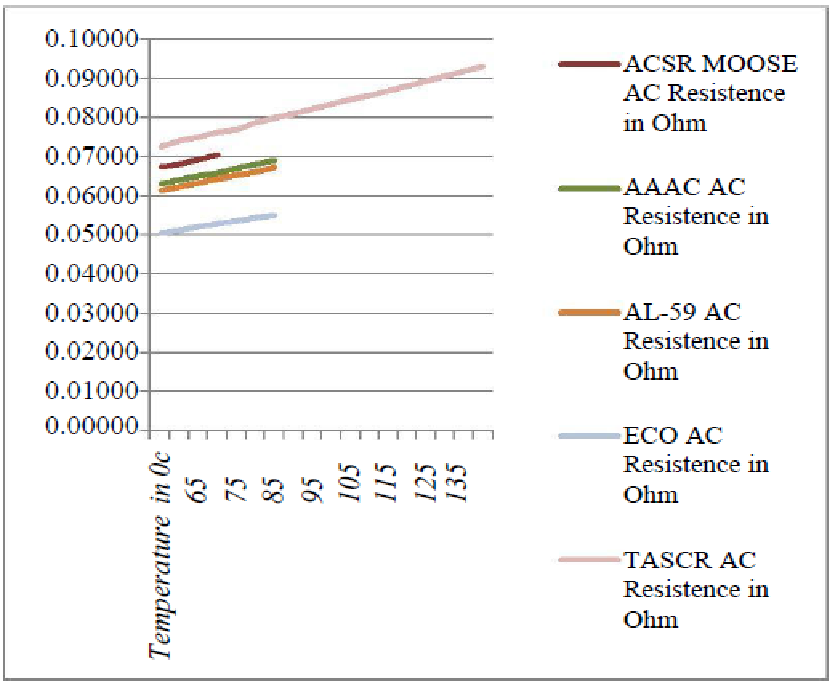
A. Temperature Vs A.C Resistance



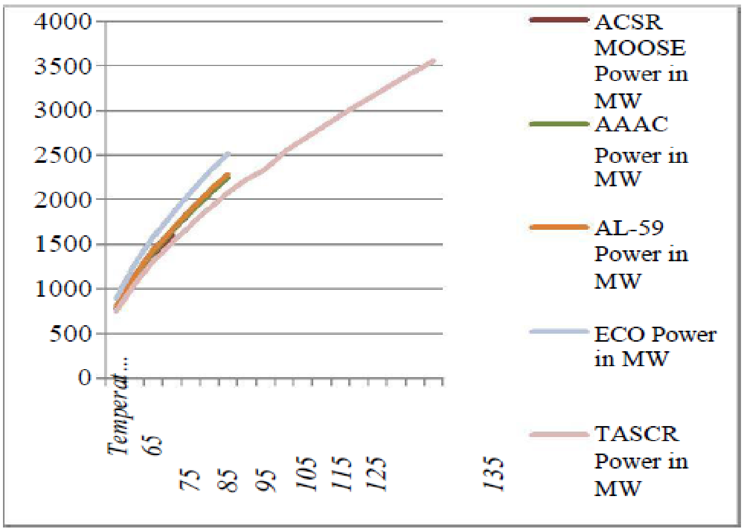
Thus we observed that as the temperature increases the ac resistance of the line increases.

B. Temperature Vs A.C Resistance



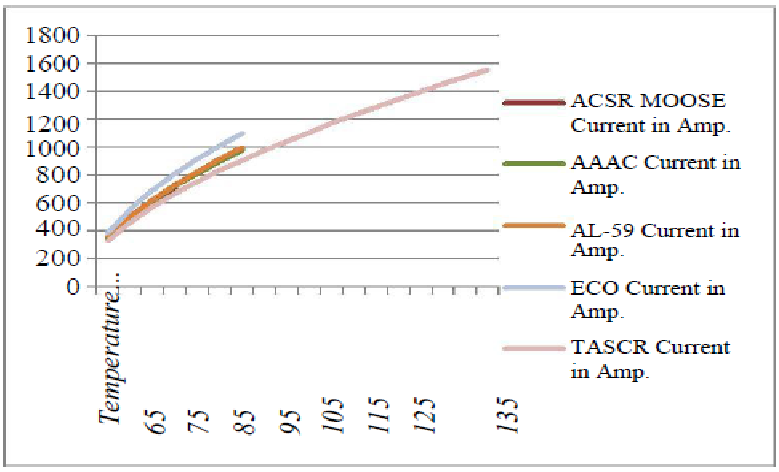
Thus we observed that as the temperature increases the ac resistance of the line increases.

C. Temperature VS Power



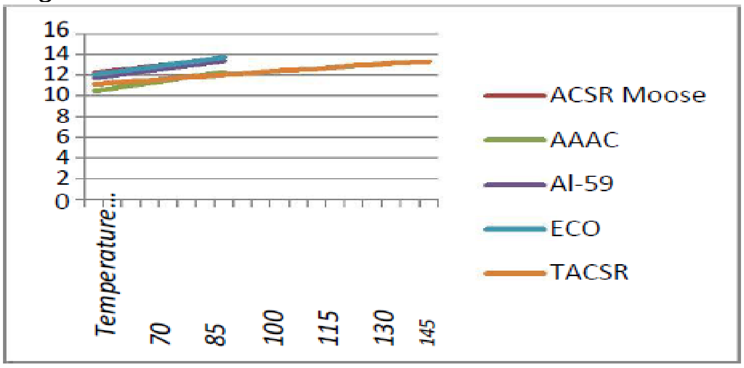
Thus the power transfer capabilities of various conductors can be observed.

D. Temperature VS Current



Thus from the graph we can observe the current carrying capacity of the various conductors and temperature rating.

D. Temperature VS Sag



Thus Temperature VS Sag i.e. the line to ground clearance capacity of various conductors are compared.

V. DISCUSSION

Thus from the result and ETAP analysis report we have seen that the existing conductor have a certain amount of limitation a d due to which there is loss of power and revenue. Thus by performing the reconductoring process and costing of laying the new conductor and its revenue generation certain calculations based on recent costing of power is performed and its revenue generation within 3 years and losses optimization are being compared.

Based on this the reconductoring with new generation HPC conductor was done and value were analyzed on the excel model for costing and losses. On the ETAP model we have performed load flow analysis which gives us the detailed over view of the amount of the losses that the existing system would give on using that conductor and observation are made accordingly. Thus what we have observed that loss are minimized by approximately by 25-30% by reconductoring which varies differently based on the conductor selection.

Revenue and power calculation of various conductors are shown below:

We have mainly taken three major cases for this

i. **Case 1:** Maintaining same Current as that of ACSR Moose at its maximum operating temperature in all proposed conductors.

ii. **Case 2:** Maintaining same Sag as that of ACSR Moose at its maximum operating
iii. temperature in all proposed conductors.

iv. **Case 3:** Current in Amp at maximum continuous operating temperature in all proposed conductors

Properties	**ACSR Moose**	**AAAC (61/3.45)**	**AL-59 (61/3.5)**	**ECO**	**TACSR**
Calculations for Double Circuit & Twin per Bundle Configurations					
Case 1 : Maintaining same Current as that of ACSR Moose at its maximum operating temperature in all proposed conductors					
The following calculations are carried out at temp stated besides:	75	74.10	73.67	71.22	76.39
Current to be maintained:	601	601	601	601	601
AC Resistance (ohms/km)	0.0750	0.0701	0.0683	0.0561	0.0811
Line losses in kW/ckt	325	304	296	243	352
Power Factor	0.85	0.85	0.85	0.85	0.85
Power Transferred in MW/ckt	1373	1373	1373	1373	1373
Sag at above mentioned temp & 0% wind	12.86	11.27	12.42	12.65	11.65
Tension to be maintained at 32 0C & 100% wind	8544.57	8942.70	9160.29	8906.08	8480.52

Properties	ACSR Moose	AAAC (61/3.45)	AL-59 (61/3.5)	ECO	TACSR
Case-2 : Maintaining same Sag as that of ACSR Moose at its maximum operating temperature in all proposed conductors					
The following calculations are carried out at temp stated besides:	75	NA	95.00	95.00	150.00
Current to be maintained:	601	NA	968	1070.7	1452.48
AC Resistance (ohms/km)	0.0654	NA	0.0682	0.0560	0.0810
Line losses in kW/ckt	283	NA	767	770	2051
Power Factor	0.85	NA	0.85	0.85	0.85
Power Transferred in MW/ckt	1373	NA	2212	2446	3319
Sag at above mentioned temp & 0% wind	12.86	NA	12.86	12.86	12.86
Tension to be maintained at 32 0C & 100% wind	8544.57	NA	9160.29	8906.08	8480.52

Properties	ACSR Moose	AAAC (61/3.45)	AL-59 (61/3.5)	ECO	TACSR
Case-3 : Current in Amp at maximum continuous operating temperature in all proposed conductors					
The following calculations are carried out at temp stated besides:	75	95	95	95	150
Current to be maintained:	601	601	968	1071	1452
AC Resistance (ohms/km)	0.0654	0.0700	0.0682	0.0560	0.0810
Line losses in kW/ckt	283	303	767	770	2051
Power Factor	0.85	0.85	0.85	0.85	0.85
Power Transferred in MW/ckt	1373	1373	2212	2446	3319
Sag at above mentioned temp & 0% wind	12.86	12.33	13.44	13.77	13.41
Tension to be maintained at 32 0C & 100% wind	8544.57	8942.70	9160.29	8906.08	8480.52

Thus based on these cases we have made certain estimation on the cost of the conductor and its laying and revenue generation.

Based on Case-1:

Properties	**ACSR Moose**	**AAAC (61/3.45)**	**AL-59 (61/3.5)**	**ECO**	**TACSR**
Saving per single circuit as in case-1:					
Cost of power loss in INR 4/- per kW	11388000	10652160	10371840	8514720	12334080
Cost of Power transferred without losses in INR 4/- per kW	48109920000	48109920000	48109920000	48109920000	48109920000
Revenue generated in INR 4/-	48098532000	48099267840	48099548160	48101405280	48097585920
Additional Revenue generated as compared to ACSR in INR	-----------------	735840	1016160	2873280	-946080
Additional Revenue generated as compared to ACSR in INR (Crore)	-----------------	0.07	0.10	0.29	------------

Based on Case-2.

Properties	**ACSR Moose**	**AAAC (61/3.45)**	**AL-59 (61/3.5)**	**ECO**	**TACSR**
Saving per single circuit as in case-2:					
Cost of power loss in INR 4/- per kW	9916320	NA	26875680	26980800	71867040
Cost of Power transferred without losses in INR 4/- per kW	48109920000	NA	77508480000	85707840000	1.16298E+11
Revenue generated in INR 4/-	48100003680	NA	77481604320	85680859200	1.16226E+11
Additional Revenue generated as compared to ACSR in INR	-----------------	NA	29381600640	37580855520	68125889280
Additional Revenue generated as compared to ACSR in INR (Crore)	-----------------	NA	2938.16	-----------------	6812.59

Based on Case-3.

Properties	ACSR Moose	AAAC (61/3.45)	AL-59 (61/3.5)	ECO	TACSR
Saving per single circuit as in case-3:					
Cost of power loss in INR 4/- per kW	9916320	10617120	26875680	26980800	71867040
Cost of Power transferred without losses in INR 4/- per kW	48109920000	48109920000	77508480000	85707840000	1.16298E+11
Revenue generated in INR 4/-	48100003680	48099302880	77481604320	85680859200	1.16226E+11
Additional Revenue generated as compared to ACSR in INR	----------------	-700800	29381600640	37580855520	68125889280
Additional Revenue generated as compared to ACSR in INR (Crore)	----------------	-0.07	2938.16	3758.09	6812.59

Thus the cost and revenue generation of reconductoring is observed.

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