International Journal of Advance Research in Engineering, Science & Technology(IJAREST),
ISSN(O):2393-9877, ISSN(P): 2394-2444,
Volume 2, Issue 4, APRIL, 2015

Re-Conductoring scenario & Payback Calculations of ACSR Moose and its Equivalents Conductors for 400 kV Transmission line[Thermal Uprating].

MARGIL THAKKAR[1], DIVYANGSINH RANA[2], CHIRAG PATEL[3], SUMIT LINGARCHANI[4]
[1]Department of Electrical engineering, Sigma Institute of Engineering, margil627445@gmail.com
[2]Department of Electrical engineering, Sigma Institute of Engineering, divyangsinh90@gmail.com
[3]Department of Electrical engineering, Sigma Institute of Engineering, cschiragpatel1007@gmail.com
[4]Electrical Engineer (HV & EHV Design),Takalkar Power Engineers & Consultants PVT. LTD., sumit.lingarchani@tpec.in

Abstract- Now a day's increase in demand for electricity is a big issue of the day in many countries. Installation of new power lines is very costly and not enough time to built new lines. It is difficult to acquire tower sites and right-of-way. So the best solution is Re-conductoring of existing transmission lines with Techno graded High Temperature & Low Sag (HTLS) Conductors.

Keywords- Techno-Economical solution in EHV transmission lines, Electrical parameters, Payback calculations, Application of New Generation HTLS Conductor in INDIAN power sector.

I. INTRODUCTION

A. Basic Comparison of HTLS Conductor with ACSR Conductor:

An attractive method of increasing transmission line thermal rating (up rating) involves replacing the original (typically) steel-reinforced aluminum conductor (ACSR) with a high-temperature, low-sag (HTLS) conductor with approximately the same diameter as the original conductor. The increase in thermal rating of existing lines reconductored with one of these HTLS conductors varies from 20% to 80% depending on whether the replacement HTLS conductor is able to reach its maximum operating temperature within electrical clearance limits.

Most existing overhead transmission lines use steel reinforced aluminum conductors (ACSR). On a continuous basis, ACSR may be operated at temperatures up to 100°C and, for limited time emergencies, at temperatures as high as 125°C without any significant change in the conductor's physical properties. These temperature limits constrain the maximum current density of ACSR to the range of 1 to 2 amps/kcmil (2 to 4 amps/mm^2). This in turn limits the thermal rating of a typical 230 kV line with a single 795 kcmil ACSR conductor per phase to about 400 MVA. In order to increase the thermal rating of existing lines, one method involves replacing its ACSR conductors with special "high-temperature low-sag" (HTLS) conductors having approximately the same diameter as the original ACSR but being capable of operation at temperatures as high as 200°C with less thermal elongation than ACSR. Ideally, these special HTLS conductors can be installed and operated without the need for extensive modification of the existing structures and foundations. As with ACSR, HTLS conductors typically consist of aluminum wires helically stranded over a reinforcing core. Most of the electrical current flows in the high conductivity, low density, aluminum strand layers. Most of the tension load is in the reinforcing core at high temperature and under high loads. The comparative performance of the HTLS conductors depends on the degree to which the aluminum strand and reinforcing core's physical properties are stable at high temperature and on the elastic, plastic and thermal elongation of the combined HTLS conductor.

B. Some of HTLS conductors:

- ACSS and ACSS/TW [Aluminum Conductor Steel Supported] – Annealed aluminum
- strands over a conventional steel stranded core. Operation to 200°C.
- (Z)TACIR [Zirconium alloy Aluminum Conductor Invar steel Reinforced)– High
- temperature aluminum strands over a low-thermal elongation steel core. Operation to 150°C (Tal) and 210°C (ZTAl).
- GTACSR ["Gapped" TAL alloy Aluminum Conductor Steel Reinforced] – High temperature
- aluminum, grease-filled gap between core and inner layer. Operates to 150°C.
- ACCR [Aluminum Conductor Composite Reinforced] – High-temperature alloy aluminum over a composite core made from Alumina fibers embedded in a matrix of pure aluminum. Operation to 210°C.
- CRAC [Composite Reinforced Aluminum Conductor] – Annealed aluminum over
- fiberglass/thermoplastic composite segmented core. Probable operation to 150°C.
- ACCFR [Aluminum Conductor Composite Carbon Fiber Reinforced]– Annealed- or
- high-temperature aluminum alloy over a core of strands with carbon fiber material in a matrix of aluminum. Probable operation to 210°C.

C. Comparative Cost Analysis (Operation Period: 30 Years):

		Build New Line	Replacement by HTLSC
Build Period	Based on 30 km route.	18 Months	6 Months (Short Period)
Construction Cost	Preliminary work	Required	Not Required
	Cost of right of way (ROW)	High Cost	Low Cost
	Tower Foundation	Required	Not Required
	Conductor & Ground wire:		
	1. Conductor Furnishing	Low price	High price
	2. Stringing	Required	Required
	3. Ground-wire Furnishing	Required	Not Required

	4. Ground-wire Stringing	Required	Not Required
	Line Accessories	Required	Partially Required
	Grounding	Required	Not Required
Operation Cost	kWh Loss	Low	High
Opportunity Cost	Cost due to Difference of Construction Period	High	Low
Maintenance Cost	-	Small	Small Cost (same as ACSR)

D. Advantages of HTLSC over ACSR Conductor:

- High conductivity
- High Ampacity transfer capacity at max. temperature
- Low Sag-Tension properties
- High ratio of tensile strength to weight
- Retention of tensile strength at high temperature
- Low plastic elongation
- High mechanical self-damping
- Low ratio of outside diameter to cross sectional area
- Easy fabrication into wire
- Weather ability (unaffected by humidity, sun, rain)

E. ISSUES RELATED WITH POWER TRAS-MISSION:

The power sector in India is undergoing tremendous growth due to statutory changes. The new electricity act 2003 & open access under the same, have paved a way for speedy development of transmission sector. Large number of private players have entered into the business. The existing state & central power utilities have to mend their ways to optimize the power transmission capability. The following issues are related to the power transmission sector of this country.

- The state utilities which came into existence after independence, have large number of transmission lines of 33 kV/66 kV/132 kV etc. These lines are very old and are not able to carry more power. Up rating of such transmission line to carry more power at the same voltage, is important for state utilities. Many of such lines which were once upon a time outside the urban boundaries are now appearing dotted on the main thorough fares of the extended urban boundaries. Changing the tower and or foundation is almost impossible in such crowded streets. The use of high ampacity conductor is therefore inevitable.
- Due to rapid urbanization, sometimes it becomes necessary to up rate the existing line to next higher voltage. In such a situation, the utility would like to transmit higher quantum of power using the same right of way (ROW).
- The bus bars in the existing substation have to be augmented for higher ampacity. Use of higher size or multiple bundle conductors may need change in the existing bus bar gantry structures (Beams & Columns) and foundations for columns. This will need a long shut down of the bus. This may not be possible if the sub-station is heavily loaded. Alternative would be to use new generation conductor with identical mechanical parameters compared to the existing conductor but having very high current carrying capacity (say 150 to 200%).
- Due to increase in urban load, the utility may have construct new substation by acquiring small piece of land in the urban area. Bringing in new transmission line with high ampacity may be a problem. The compact towers with small spans and high conductivity conductors can come to the rescue of the utility.
- Due to oceanic & or industrial pollution, the existing conductors of the line show sizable degradation. It may be necessary to replace such conductors by new generation conductors, which may be resistant to such vagaries and simultaneously can carry higher current.
- ROW is becoming difficult day by day. The cost of ROW is escalating exponentially. The government utilities & private players may like to transmit large block of power using the same ROW with higher voltage, with higher ampacity or both. The conventional conductors cannot be loaded beyond a thermal rating of 85 deg. C.
- For long river crossing spans, the valleys & major high way crossings and in ravines, the conventional conductor will sag more & result into excess height of tower & cost of foundation. If new generation low sag conductors are used, situation can be addressed.
- While constructing a new line, it now becomes absolutely essential to optimize the tower spotting, the power transfer capability & ultimately the cost of towers & foundations. This can be done by selecting the most appropriate conductor.

F. Effect on Transmission Line Components due to Change in Conductor:

Change in conductor is required if the existing transmission line is to be up-rated or up-graded. Up-rating means increasing ampacity without change in voltage. Up-gradation means increasing the voltage level of transmission line with or without increase in ampacity.

Up-rating of the transmission line by changing the conductor with higher size has the fallowing consequences:

- The clamps /connectors and insulator hardware requires change
- The conductor accessories require change
- The ground clearance may reduce which may increase the tower weight and the foundation quantity.
- If the same towers are to be used, the span may have to be decreased resulting into more number of structures per Kilometer.
- Increase in Sag will vary the insulation coordination and earthwire may have to be re-strung to maintain the shield angle in the mid span.
- The load due to wind on wire and load due to deviation will increase. This will also add to the tower weight.
- If the UTS of the proposed conductor is not higher, the insulators may have to be changed.

Up-gradation of the transmission line with/without changing the conductor with higher size has the fallowing consequences:

- If the conductor is changed, all the consequences listed above will have to, be faced by the utility.
- Insulator string will have to be changed for higher voltage. This will mean increase in height of the tower to maintain tower body clearances and phase to phase clearances.
- The statutory ground clearance will have to be increased which will again add to the tower weight in the foundation quantity.

- If the line is passing through the populated area or through forest, the width of right of way will have to be increased. This may create social and environmental hurdles.

G. Higher Ampacity Conductors – Usage and application in Indian Power Systems:

The growth of power system in India is causing a great burden on the power transmission system. The most important item of transmission network expansion is the right of way. Due to urbanization and conservation of Forest Act, acquisition of right of way is becoming extremely difficult. The open access being granted to private players has added one more dimension to this problem. The utility and the private players are now looking forward to an avenue to transmit large blocks of power using minimum R.O.W. This has resulted into a race for designing super conductor or otherwise the conductors which can operate at very high temperature without causing any break down or hazard the power system. The pros & cons of the temperature elevations in conductor are as follows:

- The use of alloy conductor makes it possible to increase the conductor temperature and transmit more power. However, such conductors are vulnerable to continuous high in velocity (as there is no steel core).
- Operating the conductor with high temperature also means that there is an increase in the line resistance. This increase in resistance also leads to increase in line losses and voltage drop.
- The increase in temperature is also resisted by environmentalists on the plea that the birds who line up on conductor may suffer from the burn injury. The line passing through the forest may also cause fire.
- The high temperature conductors are most suitable for metropolitan cities where the density of consumers is very high & is the distance of transmission line is minimum.
- The use of bundle conductors is becoming very popular for transfer of power in large block with the same R.O.W. However, this is possible only for the lines which are being planned.
- If the existing line is to be operated with bundle conductors, it will be difficult to use the same tower. However, if the R.O.W. is secured and if it is possible to lay tower in between, in will be the best alternative.
- Raising the transmission voltage beyond 400kV is yet another alternative for transmitting large block of power over long distance. However, such lines are required to be designed for a very high reliability level. This has a cost in terms of money and R.O.W. Besides, the cost of substation equipment is enormous for such extra high voltage.
- The various alloy conductors, TW conductors, Air-gap conductors

H. SELECTION OF CONDUCTOR:

The selection of conductor for overhead EHV Transmission Line is a very precise job and calls for accurate calculations. In the total construction cost of EHV Transmission Line, the conductor has a lion's share. Therefore any over estimation will result into cost escalation. On the other hand under estimation may result into inadequate power transfer capability of the lines. There are various basic considerations while selecting the conductor. The same are prescribed below,

1. Selection based on Voltage
2. Selection based on Current
3. Selection based on Strength
4. Selection Base on Environment
5. Selection Based on the span
6. Selection Base on the Production and Availability

II. White paper (Base paper) for techno-economical comparison of conventional (ACSR) with HTLS conductors

For techno-economical comparison, we have consider HTLS conductors such as STACIR, ACSS Curlew, ACCC Budapest TACSR, ACCR against conventional conductor (ACSR Moose) having same mechanical properties as that of conventional. **Table.1** shows the input parameters of HTLS conductors.

Vertical weight (Kg/Km) of STACIR is 0.5489 % less than conventional, ACSS Curlew is 1.1477 % less than conventional, ACCC Budapest is 0.0698 % less than conventional, TACSR is 8.6327 % less than conventional, ACCR is 17.4151 % less than conventional.

DC Resistance (ohms/Km) of STACIR is 3.5567 % less than conventional, ACSS Curlew is 2.3413 % less than conventional, ACCC Budapest is 24.2180 % less than conventional, TACSR is 8.5075 % higher than conventional, ACCR is 4.5576 % less than conventional.

Maximum continuous operating temperature of HTLS conductors are in the range of 150-210˚C that is quite high as compare to that of conventional (75˚C) i.e. we can boost more current within the same Row & Power structure.

CASE-1:- The purpose of this case is to mark the difference in line losses when same current (i.e. 350Amp) is passes through all the conductors, STACIR is 3.4468 % less than conventional, ACSS Curlew is 2.2708 % less than conventional, ACCC Budapest is 23.4387 % less than conventional, TACSR is 1.1330 % higher than conventional, ACCR is 4.4606 % less than conventional. **Table.2** shows the calculations on this case.

CASE-2:- This case shows the maximum continuous operating capacity of individual proposed conductor as shown in **Table.3**.

III. Graphical representation of SAG-POWER for HTML conductors:-

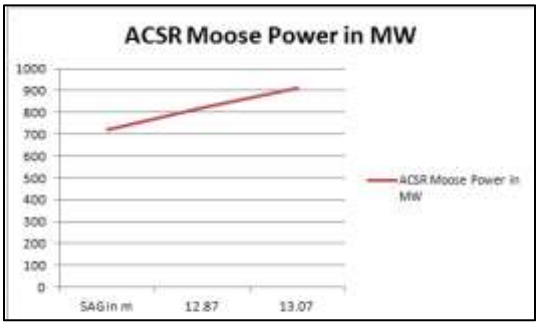

Figure.1- Sag vs. Power Curve in ACSR Moose

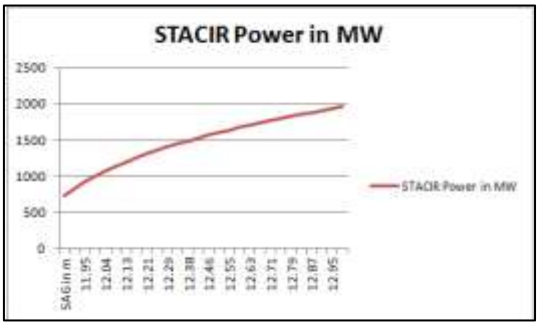

Figure.2- Sag vs. Power Curve in STACIR

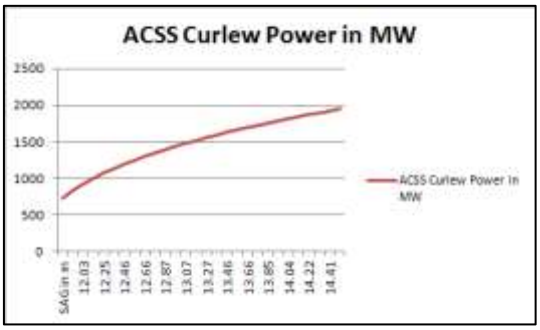

Figure.3- Sag vs. Power Curve in ACSS

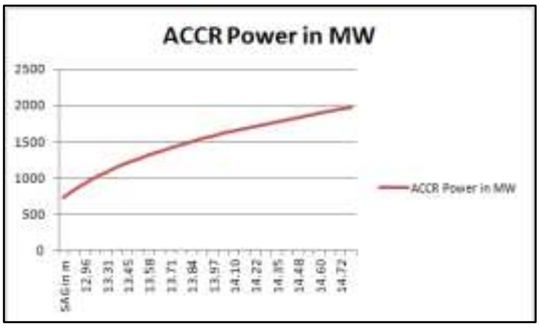

Figure.4- Sag vs. Power Curve in ACCR

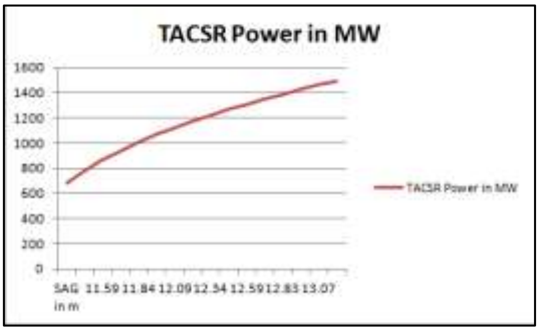

Figure.5- Sag vs. Power Curve in TACSR

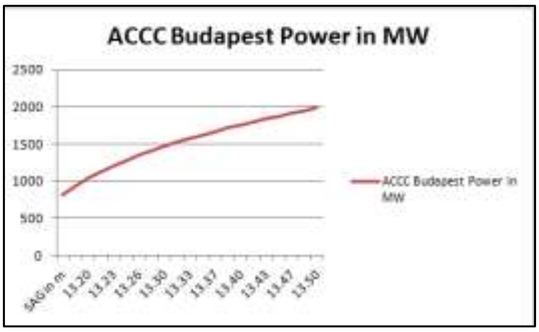

Figure.6- Sag vs. Power Curve in ACCC

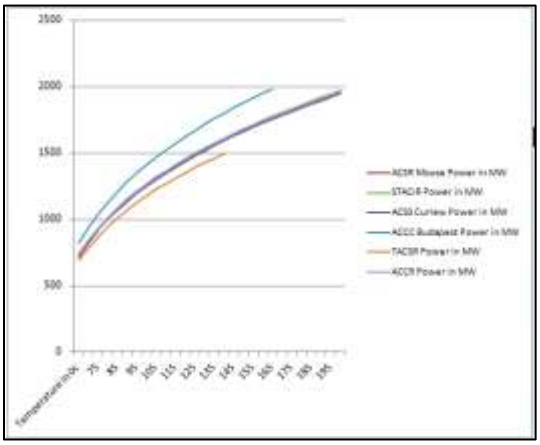

Figure.7- Temperature-Power for HTML conductors

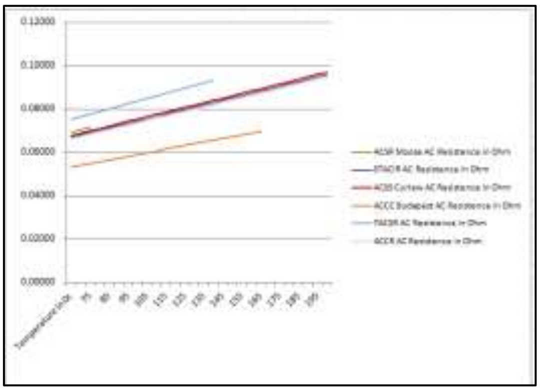

Figure.8- Temperature-AC resistance for HTML conductors

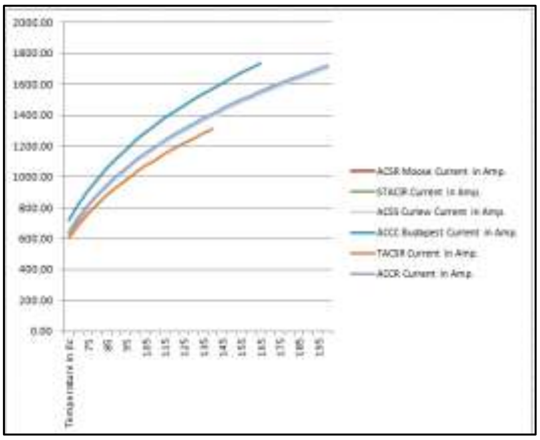

Figure.9- Temperature-Current for HTML conductors

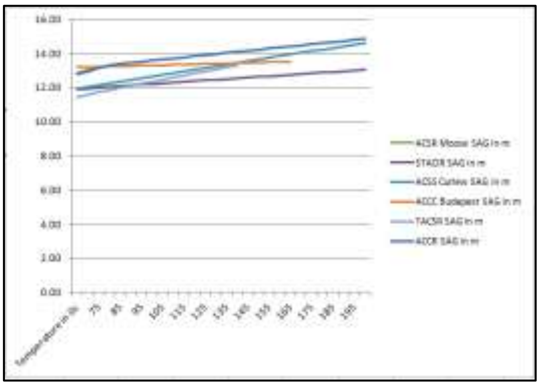

Figure.10- Temperature-Sag for HTML conductors

IV. Payback for Re-conductoring Scenario: Power conductor, Conductor accessories, Insulator hardware, Destringing of conventional power conductor & Re-stringing of HTLS conductors & Re-conductoring design engineer charges are to be considered.

Availability factor of 80% of the year for 400 MW, 15% of the year for 800 MW and 5% of the year for 1200 MW is considered for payback calculations. **Table.4&5** shows the Payback calculations.

"Table.1- Input parameters"

Technical Comparison of ACSR Moose and its Equivalents Conductors for 400 kV Transmission line						
Properties	**ACSR Moose**	**STACIR**	**ACSS Curlew**	**ACCC Budapest**	**TACSR**	**ACCR**
Cross Sectional Area (mm^2)	597.00	597.00	591.00	746.30	597	591
Conductor Diameter (mm)	31.77	31.77	31.62	31.50	30.42	31.7
Modulus Of Elasticity (kg/cm^2)	704000.00	674100 below Thermal knee point (50 ^{0}C) and 1549968.64 above Thermal knee point	704000 below Thermal knee point temperature (32 ^{0}c) & 2110091.74 above Thermal knee point temperature	1149847.09 above Thermal knee point(80 ^{0}C) & 632008.15 below Thermal knee point.	725600	1193067.96
Co-efficient of Linear Expansion (/^{0}C)	$19.3*10^{-6}$	$18*10^{-6}$ below Thermal knee point (50 ^{0}C) and $3.7*10^{-6}$ above Thermal knee point	$19.46*10^{-6}$ below Thermal knee point temperature (32 ^{0}C) & $9.1*10^{-6}$ above Thermal knee point temperature	$1.61*10^{-6}$ above Thermal knee point(80 ^{0}C) & $19.3*10^{-6}$ below Thermal knee point	$11.5*10^{-6}$	$16.5*10^{-6}$ for temp below 90 degC(Knee Point Temp) and $6.3*10^{-6}$ for temp above knee point Temp
Weight (kg/km)	2004.00	1993.00	1981.00	2002.60	1831	1655
UTS (kgf)	16432.00	14641.00	15936.80	19551.48	15932.00	15835.70
DC Resistance @ 20° C Temp (ohms/km)	0.05595	0.05396	0.05464	0.04240	0.06071	0.0534
Maximum Operating Temperature (°C)	75	210	210	175	150	210
Voltage Level (kV)	400	400	400	400	400	400
Nos. of conductor per phase	2	2	2	2	2	2
Nos. of Circuits	1	1	1	1	1	1
Line length (km)	50	50	50	50	50	50
Span in Mtrs.	400	400	400	400	400	400

"Table.2- Calculations on case-1"

Case 1 : Maintaining 400 MW power to be catered in all the power conductors						
Electrical Properties	**ACSR Moose**	**STACIR**	**ACSS Curlew**	**ACCC Budapest**	**TACSR**	**ACCR**
The following calculations are carried out at temp stated besides:	64.23	64.07	64.11	63.13	64.52	64.02
Current to be maintained:	350	350	350	350	350	350
AC Resistance (ohms/km)	0.0671	0.0648	0.0656	0.0514	0.0727	0.0641
Line losses in kW/ckt	2466	2381	2410	1888	2671	2356
Power Factor	0.85	0.85	0.85	0.85	0.85	0.85
Power Transferred in MW/ckt	400	400	400	400	400	400

"Table.3- Calculations on case-2"

Case-2 : Maximum power to be catered from all the power conductors						
Electrical Properties	**ACSR Moose**	**STACIR**	**ACSS Curlew**	**ACCC Budapest**	**TACSR**	**ACCR**
The following calculations are carried out at temp stated besides:	75	210	210	175	150	210
Current to be maintained:	350	1717	1704	1736	1308	1725
AC Resistance (ohms/km)	0.0651	0.0959	0.0970	0.0699	0.0932	0.0949
Line losses in kW/ckt	2394	84788	84535	63205	47841	84692
Power Factor	0.85	0.85	0.85	0.85	0.85	0.85
Power Transferred in MW/ckt	400	1962	1947	1983	1494	1971

"Table.4- Payback Calculations"

Re-Conductoring (Uprating) Cost Estimation & Payback Calculations for 400 kV S/C Transmission line of 50 kM length with Tower Structures using ACSR Moose and its equivalent HTLS Power Conductor(STACIR, ACSS CURLEW)									
line Length in kM				1	50	1	50	1	50
Description	Qty per kM	Unit	Unit Rate per kM in INR	Single ACSR Moose Line Cost in INR per kM	Single ACSR Moose Line Cost in INR for Complete 50 kM length	Single STACIR Line Cost in INR per kM	Single STACIR Line Cost in INR for Complete 50 kM length	Single ACSS CURLEW Line Cost in INR per kM	Single ACSS CURLEW Line Cost in INR for Complete 50 kM length
Towers	37	MT	70,000	0	0	0	0	0	0
Conductor	6.6	km	--------------	1593900	79695000	6853770	342688500	2709630	135481500
Insulators of 33kV	210	Nos	800 per Disc	0	0	0	0	0	0
Tower Accessories	Approx	Approx	35000	0	0	0	0	0	0
Conductor Accessories	Approx	Approx	80000	80000	4000000	108000	5400000	98400	4920000
Insulator Hardware	Approx	Approx	115000	115000	5750000	138000	6900000	126500	6325000
Earth Wires	2.2	km	57,500	0	0	0	0	0	0
Earth Wire Accessories	Approx	Approx	35000	0	0	0	0	0	0
Foundation	3	Nos	125000	0	0	0	0	0	0
Erection of Tower	37	MT	55000	0	0	0	0	0	0
Stringing (conductor+ EW)	1	km	115000	115000	5750000	138000	6900000	126500	6325000
R.O.W	1	km	100000	0	0	0	0	0	0
Design Engg. & Misce.	L.S.	LS	1000000	1000000	1000000	300000	300000	300000	300000
Estimated Cost of New 400 kV D/C line with Twin conductor				2903900	96195000	7537770	362188500	3361030	153351500
Saving in Initial Cost							265993500		57156500
Additional Revenue Generated as compared to ACSR for 1							283963722		283227444
Additional Revenue Generated as compared to ACSR for 1							266074008		57211944
Ultimate Savinag at the end of years mentioned besides							549957222		340383944
Pay back Period (YEAR)							0.937		0.202
Pay back Period (DAYS)							342.005		73.730

Notes:-
(1) The Total length of the line is assumed to be 50 kM. Actual span is considered as 400 M. Numbers of Towers comes out to be125, out of which 75Towers are assumed to be Suspension and rest are assumed Tension.
(2) Cost of 1MT of Steel is considered as Rs 70,000.
(3) The Price of 1 kM ACSR Moose conductor is considered as Rs. 241500, while that of STACIR, ACSS CURLEW, ACCC BUDAPEST, TSCAR, ACCR Conductors are 4.3, 1.7, 2.6, 1.3, 3.8% higher respectively as compared to ACSR Moose Conductor.

"Table.5- Payback Calculations continued"

Re-Conductoring (Uprating) Cost Estimation & Payback Calculations for 400 kV S/C Transmission line of 50 kM length with Tower Structures using ACSR Moose and its equivalent HTLS Power Conducto(ACCC BUDAPES, TACSR, ACCR)									
line Length in kM				1	50	1	50	1	50
Description	Qty per kM	Unit	Unit Rate per kM in INR	Single ACCC BUDAPEST Line Cost in INR per kM	Single ACCC BUDAPEST Line Cost in INR for Complete 50 kM length	Single TACSR Line Cost in INR per kM	Single TACSR Line Cost in INR for Complete 50 kM length	Single ACCR Line Cost in INR per kM	Single ACCR Line Cost in INR for Complete 50 kM length
Towers	37	MT	70,000	0	0	0	0	0	0
Conductor	6.6	km	--------------	4144140	207207000	2072070	103603500	6056820	302841000
Insulators of 33kV	210	Nos	800 per Disc	0	0	0	0	0	0
Tower Accessories	Approx	Approx	35000	0	0	0	0	0	0
Conductor Accessories	Approx	Approx	80000	104000	5200000	92000	4600000	92000	4600000
Insulator	Approx	Approx	115000	143750	7187500	120750	6037500	151800	7590000
Earth Wires	2.2	km	57,500	0	0	0	0	0	0
Earth Wire Accessories	Approx	Approx	35000	0	0	0	0	0	0
Foundation	3	Nos	125000	0	0	0	0	0	0
Erection of Tower	37	MT	55000	0	0	0	0	0	0
Stringing (conductor+ EW)	1	km	115000	149500	7475000	120750	6037500	155250	7762500
R.O.W	1	km	100000	0	0	0	0	0	0
Design Engg. & Misce.	L.S.	LS	1000000	300000	300000	300000	300000	300000	300000
Estimated Cost of New 400 kV D/C line with Twin conductor				4841390	227369500	2705570	120578500	6755870	323093500
Saving in Initial Cost					131174500		24383500		226898500
Additional Revenue Generated as compared to ACSR for 1 year					296641194		276561522		284564220
Additional Revenue Generated as compared to ACSR for 1 year					131412049		24613975		227082248
Ultimate Savinag at the end of years mentioned besides					427815694		300945022		511462720
Pay back Period (YEAR)					0.443		0.089		0.798
Pay back Period (DAYS)					161.695		32.485		291.270

Notes:-
(1) The Total length of the line is assumed to be 50 kM. Actual span is considered as 400 M. Numbers of Towers comes out to be125, out of which 75Towers are assumed to be Suspension and rest are assumed Tension.
(2) Cost of 1MT of Steel is considered as Rs 70,000.
(3) The Price of 1 kM ACSR Moose conductor is considered as Rs. 241500, while that of STACIR, ACSS CURLEW, ACCC BUDAPEST, TSCAR, ACCR Conductors are 4.3, 1.7, 2.6, 1.3, 3.8% higher respectively as compared to ACSR Moose Conductor.

V. FOOTNOTE

After Re-conductoring design of HTLS conductors we conclude that ACCC Budapest conductor is best suited for the purpose as it provides, 23.4387 % reduction in line losses, 0.0698 % reduction in weight, 24.2180 % reduction in DC resistance thus boosting up the power in the range of 4-4.5 times to that of conventional ACSR conductor & providing 1m less sag as compare to ACSR moose conductor.

VI. REFERENCES

1. CBIP MANUAL ON TRANSMISSION LINE.
2. TAKALKAR POWER ENGINEERS & CONSULTANTS PVT. LTD.