UPGRADING OF 132KV TRANSMISSION LINE INTO 220KV BY PROVIDING INSULATED CROSS ARMS - CASE STUDY

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ABSTRACT

This paper emphasises the necessity of upgradation of existing transmission lines to next higher voltages and its technical feasibility in the framework of code practices being adopted in various countries. Needless to mention that such upgradations will not only be cost effective but also save considerable time, which otherwise would be required to construct new/additional lines.

1 - INTRODUCTION

The progress witnessed in the Power Sector in India since plan development has been phenominal. Installed generating capacity of mere 2500 MW in 1950 has now crossed 45000 MW. The transmission & distribution net-work has increased from 30000 circuit kilometers to over 3 million circuit kilometers. This is due to massive rural electrification programme taken up in the country.

India has unique place amongst the developing countries due to its sound agricultural and industrial base. These sectors necessitated rapid expansion of electric power industry. During the 7th five year plan it has been programmed to add about 22000 MW of new generating capacity and to add about 15000 circuit kilometers of 400 KV AC system which will ultimately form part of the national grid. For long distance transmission of power and inter regional connection, 500 KV HVDC is also being introduced. In the process of development EHV lines of 66 KV, 110 KV, 132 KV and 220 KV have been constructed but in many cases, are inadequate to evacuate the required power. As the growth rate of the power in the country is about 9%, it requires massive investment in generation and transmission. Within the limited plan outlay on transmission in particular, there is a good scope in the country to adopt compact designs of transmission lines and also upgrade the existing lines to increase power transmission capacity. These days, transmission system planners are working for efficient use of transmission rights of way with minimal environmental impact. This has necessitated development of various new compact designs of transmission lines with insulated cross arms and solid core post insulators.

2 - GENERAL

The size of conventional transmission line towers is governed primarily by the live metal clearances required with respect to tower body under various conditions of swing of the conductors. In case of horizontal formation, the spacing between two phase conductors is the sum total of the minimum live metal clearances required by the two conductors and the width of the steel structure. In case of vertical formation, the distance between two conductors is governed again by the live metal clearance between the top conductor and the inclined member of the lower steel cross arm. In this paper an effort has been made to analyse if the electrical parameters of transmission line towers can be changed by reducing live metal clearances & phase to phase separation between conductors. This is necessary as unless the standard clearances are brought down without in any way affecting the performance of the transmission lines, upgradation of transmission lines to higher voltage will not be feasible. The present practice in this regard & relaxation which are technically possible have accordingly been discussed in this paper.

3 - STANDARD PARAMETERS FOR NEW LINES

3.1 The Table 1 gives the size of conductor, phase to phase spacing, and live metal clearances normally being provided by the utilities.

Table - 1

	66 KV	132 KV	220 KV
Conductor 'ACSR'	DOG	PANTHER	ZEBRA
Nominal Cu. eq. area in 'mm^2'	65	130	260
Phase to Phase spacing in 'mm'	2300	3900	5000
Live metal clearances for conductor swing of 10° & 45° in 'mm'	1075 760	1520 1220	1980 1680

3.2 The Table 2 gives the other standard parameters being used by utilities.

Table - 2

Voltage	66 KV	132 KV	220 KV
Angle of protection	30°	30°	30°
Minimum mid span clearance in 'mm'	3050	6100	8500
Ground clearance in 'mm'	5500	6100	7000
Nominal span in 'metres'	250	365	400

4 - TECHNICAL REQUIREMENT OF UPGRADATION OF LINE

In our country the size of conductor is fixed on the basis of power transmission requirement, power loss, and voltage regulation considerations and the structures are designed for specified wind loading & size of conductors and earth wire. It would therefore, imply that the existing transmission structures do not have much margin available to take care of extra loads by replacement of existing conductors by higher sizes unless in the original design itself such provision has been made. In majority of the proposals for upgrading the lines, replacement of existing conductors, by higher size of conductors is not feasible & therefore, the same conductor will continue in the converted line also. This however requires a check to ensure that corona effects are within permissible limits. Calculations have indicated that in our country 'Panther' ACSR conductor can be used also on 220 KV lines without any technical problems.

5 - REVISED NEW RECOMMENDED PARAMETERS FOR LIVE METAL CLEARANCE & PHASE TO PHASE SEPARATION

5.1 At present phase to phase separation with standard configuration of conductors in vertical & horizontal formation are not decided on the basis of technical requirement but are governed by live metal clearances. Insulation in EHV transmission lines must be adequate to withstand over voltages due to lightning, load rejection, single phase to ground faults, switching surge transient etc. Lightning over voltages depend more on the design of overhead lines. Switching over voltage assumes special importance in deciding the insulation of EHV transmission lines when the system voltage exceeds 250 KV. The insulator string length and air clearances between transmission line conductors & tower structures are primarily governed by switching surge requirement. The insulator string's length may also be controlled by power frequency voltage, in areas where contamination is present. The phase to phase spacing based on switching surges & the normal spacings provided in conventional designs for 145 KV, 345 KV & 500 KV system voltages are given in Table 3.

Table - 3

(minimum requirement)

System Voltage in 'KV'	145	345	500
Phase to phase clearance in 'mm'	1524	2500	3800
Live metal clearance in 'mm'	915	1700	2400
Phase to phase separation (conventional) in 'mm'	3900	7600	10000

From the above table it would thus be seen that substantial reduction is possible in phase to phase & phase to tower clearances as compared to the conventional clearances being adopted. In case of transmission lines, some provision has to be made to take care of the galloping of conductors. For 345 KV system, a phase to phase separation of 2800 mm to 3600 mm is being adopted depending upon various configurations of conductors with respect to steel tower structures. Based on studies conducted in U.S.A. & Canada, it appears reasonable to adopt a minimum phase to phase separation of 3000 mm to 3250 mm for 220 KV lines. As regards live metal clearances, we should limit it to a minimum of 1700 mm which is being adopted for 345 KV systems in U.S.A. In this connection, it may be mentioned that in case of insulated cross arms, phase to earth clearance is not of any relevance as swing of conductors is fully controlled and much higher clearances are available. For a converted 132 KV & 220 KV lines with insulated cross arms or 'V' strings, the clearances as given in Table 4, appear adequate.

Table - 4

(recommended parameters)

System voltage in 'KV'	132	220
Phase to phase spacing in 'mm'	2100	3500
Live metal clearance in 'mm'	1100	1700

5.2 MID SPAN CLEARANCES

When a stroke current of high magnitude enters the mid span with ground wire having surge impedance of the order of 300 ohms, there is a possibility of extremely high voltages developing between the ground wire & phase conductors at mid span. For this reason, it has been the practice in past to maintain a very large clearance between the earth wire and conductors. In 1964, however Wagner & Hileman found that the very heavy pre-discharge current that develop, inhibit the mid span break down long enough for reflected waves from adjacent towers to arrive at mid span and thus reduce voltage below the flashover level. It has been found now that mid span flashovers rarely occur and clearance between earth wire and the top conductors is no more critical than clearances of the conductors to the tower. There is no doubt however, that from lightning performance, the angle of protection should not exceed 40° and should be kept as low as possible and the tower footing resistance are kept reasonably low. In some cases of converted lines, angle of protection may not be achieved and deliberate relaxation has to be made in this regard.

5.3 GROUND CLEARANCE

In majority of cases it would be possible to maintain the minimum ground clearance as required in IER when the conversion of line is done by adopting insulated crossarms in vertical formation. With 'V' strings, however, minimum ground clearance may not be available, unless margins are available in the original designs. In case it is preferred to upgrade lines with the help of 'V' strings some relaxation in minimum ground clearance for cross country, transmission lines will become inevitable.

6 - FEASIBILITY OF LINE UPGRADATION

There cannot be readymade designs for conversion of lines. The design has to be tailor made for each line after knowing the parameters. However, there are 4 alternatives available for upgradation of transmission lines as under :

* By adopting insulated cross arm in tie and strut 'V' formation with a provision for swing of insulator assembly under broken wire condition.
* By providing insulated cross arm in 'V' formation.
* By providing the insulated cross arms comprising of line post insulator with hinged type of fittings so as to allow swing of post insulator under conditions of conductor breakage.
* By use of fixed type of line post insulator and use of slip on or load limiting suspension clamp so that under the conductor broken wire condition, conductor slips from the suspension clamp without any damage to the conductor and to the post insulator and release conductor tension.

6.1 LONG ROD INSULATORS

Upgradation of transmission lines is feasible only by using long rod insulators. Such insulators are now being manufactured in our country by Messrs Modern Insulators Limited in technical collaboration with Messrs Siemens AG, West Germany. Various designs of these insulators to suit contaminated, light or heavy and, non-contaminated areas for different BIL are being manufactured. Tables 5 & 6 give the technical particulars of these insulators. It will be of interest for engineers engaged in power sector to know that each piece of Long Rod Insulator is routine tested upto 80% of its breaking strength & at various levels, high degree of quality control is exercised. The standard long rod insulators have high strength in compression and tension. Apart from high strength, long rod insulators are also much lighter as compared to disc insulators string and provide higher leakage distance due to less metalic parts. The profiles of sheds are such as to provide self cleaning properties. Such profiles are very advantageous in contaminated areas. For insulated cross arms it has been recommended in this paper to use long rod insulators having much higher strength as compared to normal insulator strings for suspension towers.

7 - INSULATED CROSS ARMS

The transmission lines in our country are designed for broken wire conditions & therefore, in the alternative for insulated cross arm, it is necessary to make arrangement for smooth swing of the insulated cross arm under broken wire conditions. The VEE assembly of insulated cross arms normally used are free to rotate about the axis between the attachment point of the suspension insulator to the structure and the attachment point of rigid insulators (strut) to the structure as shown in fig.1 below :

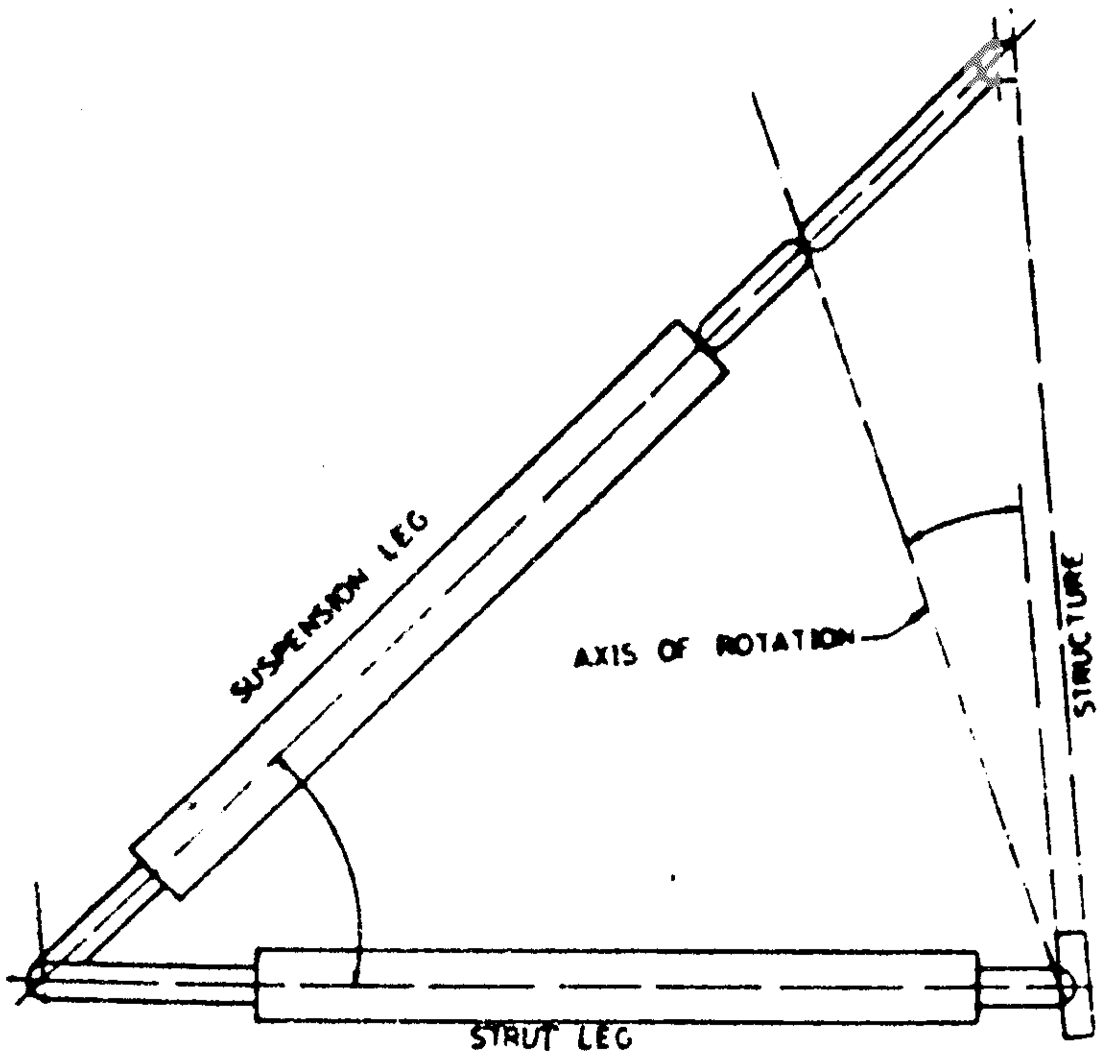


Fig.1

Should unbalanced longitudinal load occur, the insulators will tend to rotate about an axis which is 6° to 10° inclined to the tower under normal condition, the strut insulator works in compression or tension depending upon the direction of wind. The points of attachment to the structure are designed to provide freedom of movement thus preventing bending & torsional loading of strut.

As the axis of rotation is inclined at an angle from vertical, the line rises when assembly rotates. The normal conditions, the conductor weight and tension stabalise the assembly in its normal position.

Rotational freedom is provided between the conductor & insulated assembly by standard suspension fitting. If the conductor breaks, the horizontal VEE assembly adjacent to the break will swing in line with the conductor and act as a dead-end assembly. The horizontal strut insulator is kept at an angle of 0° to 5° to provide a smooth swing of VEE assembly.

Insulated cross arms of the type described above have been used in new designs of transmission lines to reduce right-of-way problem as also to reduce cost of structure. Insulated cross arms are now being used for upgrading of existing lines to higher voltages. This is a very attractive alternative both in respect of cost & time as compared to new construction. Incidently the overturning moment of the structure is reduced because of the load is transmitted through the strut to tower structure at a lower point than with conventional construction.

Insulated cross arm as suggested above can also be used conveniently with steel & PCC supports. There will be considerable saving in construction of a 66/132 KV line on single steel or concrete support with insulated cross arms with lighter conductors when it is possible to adopt compact designs with single insulated cross arm with slip on type of suspension clamps. There can be various economical alternatives of constructing 66/132 KV lines with long rod insulators or a combination of long rod & line post insulator.

8 - UPGRADING 132 KV EXISTING LINE TO 220 KV- A CASE STUDY

We have carried out two alternative studies of converting an existing 132 KV line with Panther 'ACSR' conductor to 220 KV :

* By dismantling existing cross arms & by providing insulated cross arms as shown in Fig.4.

* By providing insulated cross arm for the top conductor and 'V' strings for bottom two conductors as shown in Fig.5.

8.1 ALTERNATIVE - 1

In this alternative it has been possible to maintain phase separation of 4 meters as some margin in ground clearance is available in the existing transmission line. The available clearance is 6.75 meters as against 6.1 meters required for a 132 KV line. The bottom insulated cross arm has been located below the original cross arm but at a level higher than the suspension clamp so as to get additional advantage of higher ground clearance. Similarly the top insulated cross arm has been located below the original steel cross arm but at a level slightly lower than the suspension clamp. This alternative enables us to provide all the clearances, as required. These are :

* Live metal clearance about 3000 mm against 1980mm required, even for a conventional 220 KV line.

* Ground clearance of 7 meters as required under IER.

* Angle of protection 32° as against recommended value of 30°.

* Mid span clearance of 7.5 meters which is considered quite adequate.

The compression load on strut insulator and the load in tension on the suspension insulator has been worked out for maximum wind loads. These values are :

* Compression load in strut 10 KN as against compressive strength of about 500 KN and tensile strength of 150 KN.

* Load in tension in suspension insulator 7 KN as against breaking strength of 100 KN.

It would thus be seen from above that the insulator have much higher strength than what is required under normal working condition. Even in the broken wire condition the pull on the insulator assembly is only of the order of 25 KN which is much lower than the guaranteed strength of the insulators.

As regards modification at tension point is concerned, the existing strings with addition of more discs or replacement by long rod insulators should be adopted to provide for proper insulation for the higher voltage. This will require resagging of the conductors at the tension points. In order to improve clearance from jumpers under swing condition, a long rod insulator at a suitable inclination as shown in fig.2 below may be provided so that the swing of jumpers is limited.

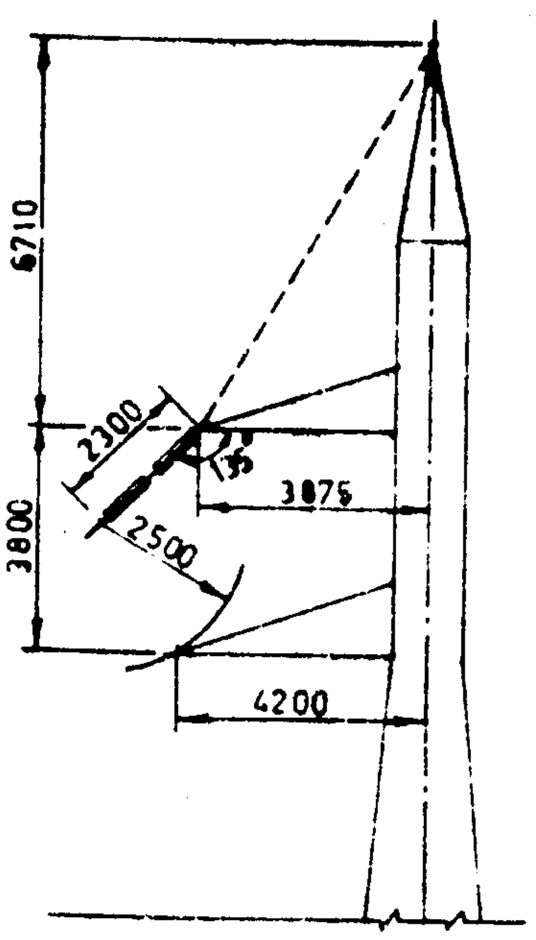


Fig.2

8.2 ALTERNATIVE - 2

In this alternative the top cross arm has been replaced by an insulated cross arm & 'V' strings have been provided on the lower cross arm for the conductors. A live metal clearance of 2000 mm has been maintained under this alternative although as discussed earlier this can be brought down to about 1700 mm.

In this alternative the phase to phase separation has automatically increased to 4500 mm. However, there is reduction in ground clearance. As against 7 meters a ground clearance of about 6.6 meters will be available. In actual practice this ground clearance may be slightly higher as majority of span lengths may be lower than the normal span of the line. This however, requires a check in the field. Some relaxation in ground clearance can be considered.

8.3 CORONA, RIV AND AN

Existing 132 KV lines with 'Panther' ACSR conductor when converted to 220 KV will give the following corona losses, radio interference & audio noise level:

* Corona loss - about 100 KW per 160 Km of length of line. This is about 5% to 10% of I^2 R losses depending upon quantum of power to be transmitted.

* Radio interference - 49 dB against allowable of 70 dB.

* Audio noise level - 14 dB against allowable maximum of 55 dB.

* The maximum surface potential gradient will be within the range of 18-20 KV/cm.

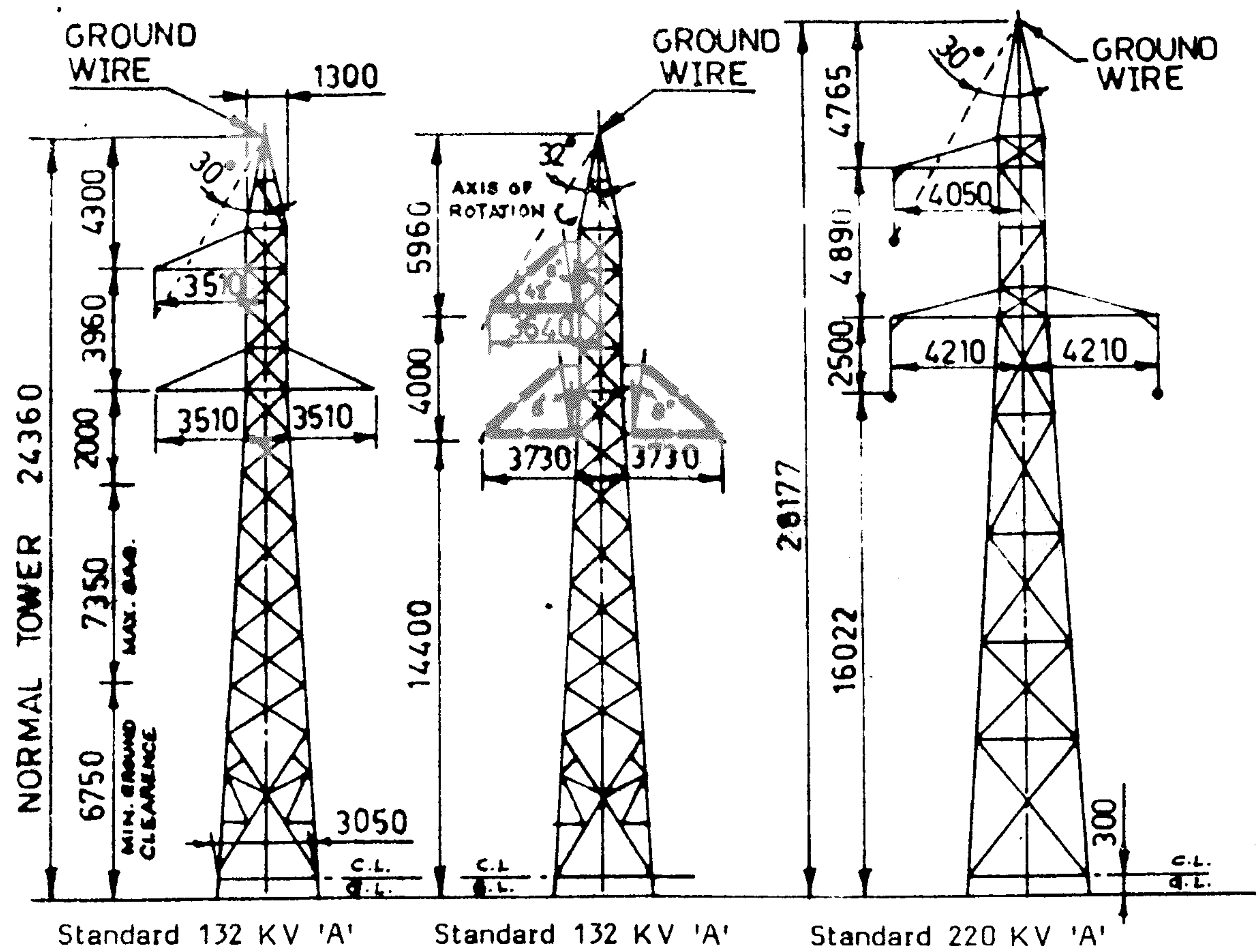
Therefore, there is no technical problem in using 'Panther' ACSR conductor on 220 KV lines.

The power transmission capacity of 'Panther' conductor for same percentage loss will be about 110/125 MW at 220 KV as against 150/160 MW with standard 'ZEBRA' ACSR conductor. There is, however, enormous increase in power transmission capacity of converted line from 40/45 MW to 110/125 MW.

For conversion of 66 KV lines to 132 KV there will absolutely be no technical problem as Corona effects are much less pronounced.

8.4 COMPARATIVE COST OF TWO ALTERNATIVES

Alternative 2 is economical and will take less time. Some relaxation in ground clearance under worst



Standard 132 KV 'A' Type Tower Configuration.

Standard 132 KV 'A' Type Tower converted to 220 KV By Cross Arm.

Standard 220 KV 'A' Type Tower configuration.

Fig.3

condition of temperature may, however, be advisable There is no doubt that alternative 1 will provide much high clearances and the designs will be more robust.

9 - COMPARATIVE DIMENSION OF CONVERTED 220 KV LINE WITH STANDARD 220 KV LINE

Fig.3 gives overall view of the size of intermediate tower of a converted & a conventional 220 KV line.

As compared to conventional 220 KV line the towers with insulated cross arms will be lighter as insulated cross arms are located at lower levels and are shorter in length. It is estimated that saving in tower weight on this account may be 15% to 20%.

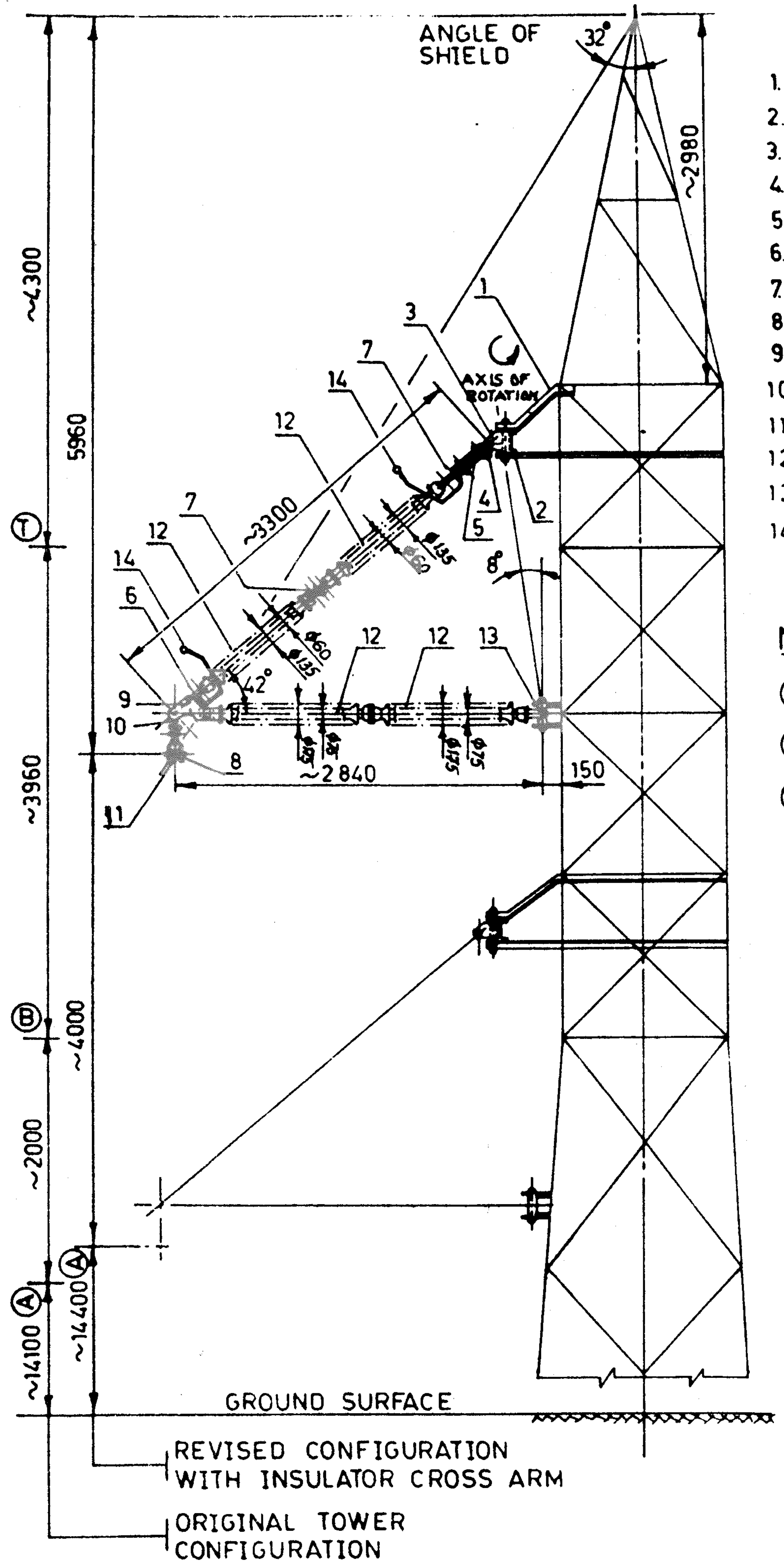
10 - COST & TIME FOR LINE CONVERSION

The approximate cost of conversion of 132 KV line single circuit to 220 KV is estimated at US $ 6000 per KM which is about 11% of the cost of new 220 KV line. The conversion of 100 KM of line can be done in about 3 months time provided ofcourse shutdown of the line is given at one stretch. In case continuous shut down of line is not possible, the work of conversion can be organised in such a way that the line is available to be charged during night and the work of conversion is carried out only during the day.

Table - 5

220 KV INSULATORS CROSS ARM PARTICULARS

	Strut	Guy
Type of Insulator	LG/75/27/1278 LG/75/27/1247	2 x LG/60/26/1200
No.of units per string	2	2
Creepage distance	6500 mm	5300 mm
Total length of insulator	2525 mm	2400 mm
Weight of insulators	87 Kgs.	40 Kgs.
Minimum failing load	150 KN	100 KN
24 hours load test	120 KN	80 KN
Routine test load	120 KN	80 KN
Impulse withstand voltage	1100 KVP	1050 KVP
Power frequency withstand voltage (wet)	490 KV	480 KV
Puncture voltage	Puncture proof	Puncture proof
Visible discharge voltage	175 KV	175 KV



PART - LIST

1. ANGLE IRON
2. I-SHB=150
3. STRAIN HINGE
4. SHACKLE
5. EXTENSION LINK
6. DOUBLE EYE TWISTED
7. DOUBLE EYE
8. OSCILLATING TYPE SUSPENSION CLAMP
9. YOKE PLATE
10. BALL EYE
11. SOCKET EYE
12. INSULATOR
13. EYE
14. ARCING HORN

Note:—

(T) ℄ OF ORIGINAL TOP CROSS ARM

(B) ℄ OF ORIGINAL BOTTOM CROSS ARM

(A) GROUND CLEARANCE PLUS SAG.

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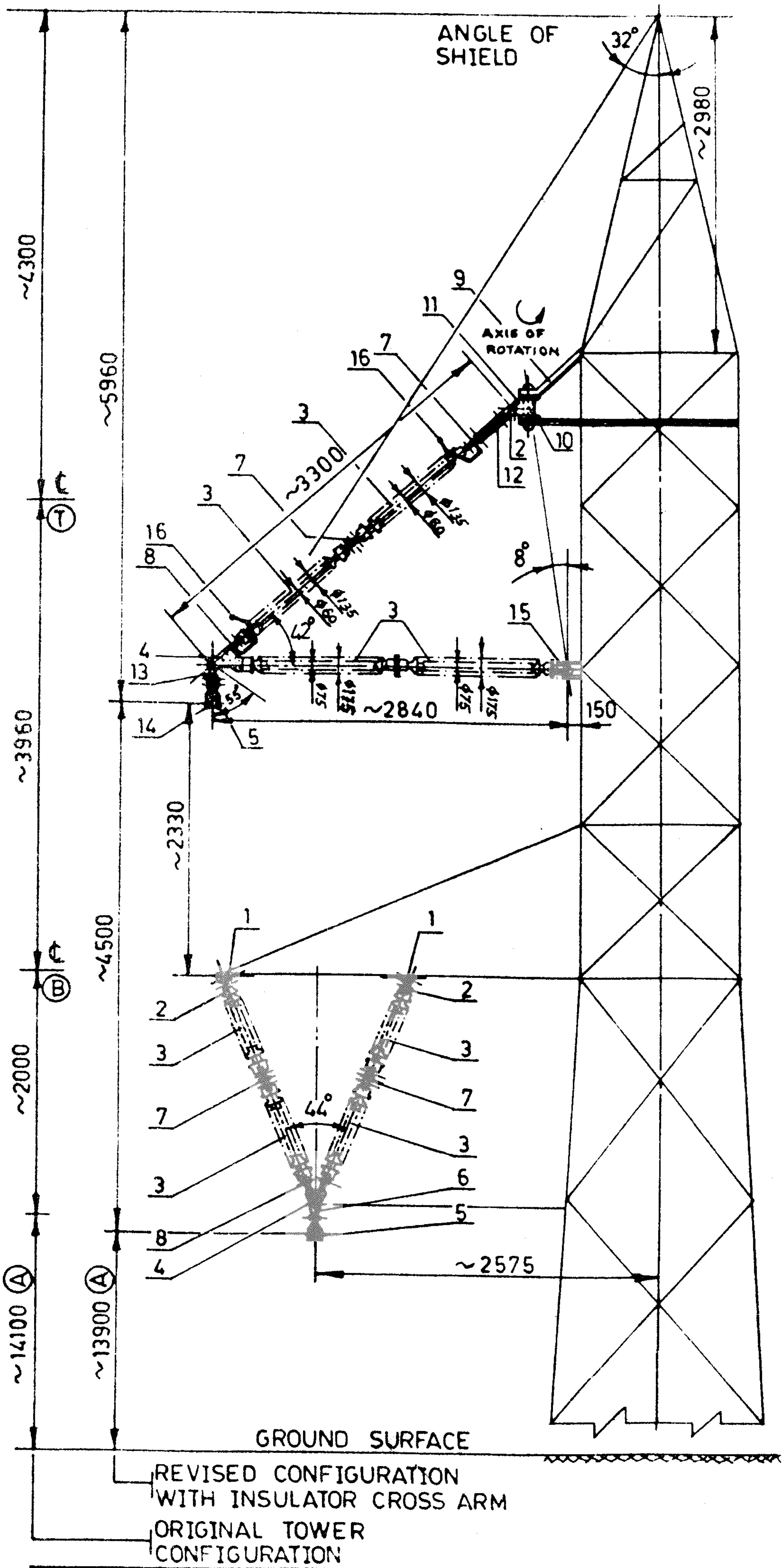
Fig.4



PART-LIST

1. STRAIN HINGES
2. SHACKLE
3. INSULATOR
4. YOKE PLATE
5. SUSPENSION CLAMP
6. CLEVIS STRIP TWISED
7. DOUBLE EYE
8. DOUBLE EYE TWISED
9. ANGLE IRON
10. I-SHB=150
11. STRAIN HINGS
12. EXTENSION LINK
13. BALL EYES
14. SOCKET EYE
15. EYE
16. ARCING HORN

Note:—

(T)÷℄ OF ORIGINAL TOP CROSS ARM

(B)-℄ OF ORIGINAL BOTTOM CROSS-ARM

(A)÷GROUND CLEARANCE PLUS SAG.

TITLE		
CONVERSION OF 132KV. LINE TO 220KV. LINE BY CHANGING TOP CROSS ARM ONLY.	DRN.	Dixit
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Fig.5