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This plot can be used to prepare some data for generating the elements. Consequently the data fed to the pre–processor for generating the applied loads on the tower is quite simple regardless of the number of load cases and points of load application.

Based on the information fed by the pre–processor the main analysis program calculates the stesses in the members and also the translation of the nodes. The main analysis program considers the tower as a space structure, have an elastic and linear response.

Another program is prepared as a post processor which starts operation after receiving the analysed data from the main analysis program. This program is infact for checking the actual stesses in members as they are compared to the calculated allowable compression stresses for every member. Then, with a brief list of output, the post–processor program shows the members which requires modification. The modification can be done instantaneously for a final design result.

CHARACTERISTICS OF 230 KV STANDARD TOWERS

As a result of the study performed, the design of the standard towers of 230 KV have showed some distinguished characterstics in comparision to those already built in IRAN. Some of the characteristics are summarised below:

1. Standard towers can be manufactured from steel produced locally by about 82% of the total weight needed per 100 Km line; knowing that the suspension towers makes usually about 80–85% of the total number of towers per line. The percentage of local material in standard towers can be increased if local steel production is improved for a bigger section than 80x80x8 mm.

2. The standard 230 KV towers are lighter than those corresponding which are already built in IRAN. The weights of angles of the standard towers condsidering their normal height(Basic Body+4.5 m Body extension and 3 m leg extenstion) are listed below:

– Standard suspension tower
(0–3 deviation)for all zones in IRAN: 8.240 Ton
– Standard tension towers:

(10 deviation)	for all zones in IRAN		:11.400 Ton
(30 deviation)	for all zones in IRAN		:13.033 Ton
(60 deviation)	for Heavy and Medium zones in IRAN		:14.990 Ton
	for Light zone in IRAN		:14.390 Ton
(90 /Terminal)	for Heavy and Medium Zones in IRAN		:16.370 Ton
	for Light zone in IRAN		:15.00 Ton

3. Easy to manufacture since the number of the types of the steel section are reduced to the minimum for instance, the bracings above hamper are unified in size and length.

4. No electrical problems up to 500 m for suspension towers, and up to 550 m for tension towers.

5. Standard towers are designed for up lift by providing cross arms of reversed action.

6. For any unusual climatic and topographic condition, the sizes of the angles or the ruling spans can be adjusted using the computerised design procedure.

CONCLUSION

The standard towers which possess the charac–teristics summarised above and the advantages already illustrated, are in actual use all over IRAN. The standardization procedure is recommended for appli–cation in any of the third world countries.

under specified climatic conditions Starting by an equilibrium condition assumed at 0 C at calm with no ice. The creep of the line is also included for a better result. The calculated sag would be useful in deciding upon the ruling span in connection with the minimum and maximum heights of the tower. Also the calculated tension of the cables will be included in the calculation of loading on tower. The ice load for windy conditions is assumed as the weight of cylinder sheath with the thicknesses indicated in Table 3. The density of ice is taken to be 900 Kg m The magnitude of ice loading for calm conditions has been chosen so that the conductor stresses are the same for both ice loading and wind, as for calm conditions, i.e, the ice loading for calm condition is somewhat greater than for wind. Thus, the ice, for calm conditions is the resulting additional load of wind in combination with ice.

The wind pressure loading on cables is taken as $(V^2/16)R$. Where V is the gust wind speed at 10m height as given in (Table 3), corrected to any other height(H) of the centroids of the span under considration by the factor$(H/10)^{0.095}$ .R is a reduction factor owing to reduced gust wind influence. The value is 1.0 for wind span length$\leq$100 mand it is 0.6 for wind span length$\geq$300 m. The value of R when wind span between 100 and 300 is calculated by linear interpolation.

Loading on Tower

The above calculated tensions in conductors and shield wires are automatically fed to another program which resolve them to components in the transverse vertical and longitudinal directions at the points of cable application for any number of loading combinations. Loading combinations are: Heavy wind, Normal wind+ice, Heavy ice and also the same loading cases with the broken cables. In addition, differential ice loading and stringing are also considered. The other loads, the tower is subiected to, is wind on the body of the tower itself which is calculated by a separate computer program. The effect of the weight of the tower is considered in the main analysis program, which is not needed to be fed as an applied load.

Loading Factors

A loading factor is used for the climatic conditions which is taken as an average valve of γ=1.3 for wind and ice loading.

Another loading factor is introduced as β in order to care for the variation in material and performance. The magnitude for β is consepuently different for the different parts: e.g conductor, tower, tower foundation, insulator etc., values of β for some parts are given as:

β=1.8 for conductors, 1.2 for tower, 1.3 for steel grillage foundation and 1.5 for stresses in soil overturning moment, up lift in soil and rock.

Therefore, the total loading factors considered for the conductors and towers are (1.3X1.8) and (1.3X1.2) respectively.

ANALYSIS AND DESIGN

The analysis has been carried out by computer so That it would be practical to try different tower configurations until an optimum shape is achieved. A pre–processor program is specially written for transmission towers. It is to prepare and deliver information to the main analysis program based on simple data. The information delivered are such as generating all the nodes of the transmission tower; also generating the elements and the forces acting on the tower. The first node generated is at the ground level with a specified number. The numbering continues in an ascending order to cover all the nodes in the specified geometry of the tower. It is performed, level by level anticlock wise in a spiral form. The pre–prossesor program could provide a plot of the four sides of the tower, showing all the nodes with their numbering.

– Minimum permissible air gap.

– Diagram of air gap for tower.

Loading Spans

For each line voltage, a ruling span, wind and weight spans are decided upon to satisfy some requirements such as kind of conductors, maximum and minimum heights of the tower, also the topography of the ground. The spans are indicated in Table 1.

Table 1. Spans at normal & broden conditions

Line KV	Ruling Span m	Normal condition		Broken condition	
		Wind Span m	Weight Span m	Wind Span m	Weight Span m
230	400	400	600 * 1000*	0.6x400	0.6x600 0.6x1000
* Suspension Towers ** Tension Towers					

Kinds of Conductors and Shield Wires

The types of conductors and shield wires for lines 63 KV to 400 KV are standardised in IRAN. They are named as in Table 2.

Table 2. Standard conductors and shield wires

Line KV	name of conductor
63	PARTRIDGE , LYNX
132	ORIOLE , HAWK
230	DRAKL , CANARY, CARDINAL
400	CURLEW „ MARTIN
For each line voltage, the standard shield wire is the core of the standard conductor.	

Climatic combinations

From the survey which has been made about the climatic conditions, three distinguished zones are accepted as Heavy, Medium and light. The climatic combinations of wind, ice, and temperature are presented in Table 3. For any unusual climatic conditions such as heavier ice than specified, the standard towers can be modified, accordingly

Table 3. Climatic combinations

Zone	Combination	Temp. C°	Wind m/sec	ice thickness mm
Heavy	Minimum Temp.	–30	0	0
	Maximum Wind	0	40	0
	Normal (Wind+ice)	– 5	24	18
	Heavy Ice	– 5	0	Equivalent to wind+ice
	Every Day Stress	15	0	0
	Maximum Temp.	65	0	after creep
Medium	Minimum Wind	–20	0	0
	Maximum Wind	0	40	0
	Normal (Wind+ice)	– 5	24	10
	Heavy Ice	– 5	0	Equivalent to wind+ice
	Every Day Stress	20	0	0
	Maximum Temp.	75	0	after creep
Light	Minimum Temp.	–10	0	0
	Maximum Wind	0	45	0
	Normal (Wind+ice)	– 5	24	0
	Heavy Ice	– 5	0	Equivalent to wind+ice
	Every Day Stress	25	0	0
	Maximum Temp.	85	0	after creep

Mechanical Design of Transmission Line

A computer program is written to calculate the sag tension of a transmission line for any range of spans under stated climatic conditions. The program solves 3 rd degree equation which includes the effects of load and temperature on the transmission line

G. Electrical utilities or organizations concerned, do usually require long time to construct a line because of their consultancy involvements with companies in connection with design, supply and even erection of towers.

In case of standard towers, where their designs are ready, and their manufacturing are done locally, it is only required to be ordered for erection in any part of this country. Even if modification is required, it can be accomplished easily using the computerised design procedure, and can be easily translated to the standard tower through altering some of the major members.

This is again an advantage, by saving the time and effort of the electrical utilities and having lines erected fast with total price less than usual.

DESIGN ASPECTS OF STANDARD TOWERS

The design of standard towers is based on unified design code, climatic and topographic data and on the computerised design procedure as will be referred to here in. Standard towers 230 KV double circuit is taken as an example.

Type of towers

Five types of towers are designed for 230 KV, double circuit. They are one suspension tower with 3° line deviation, and four tension towers with line deviations 10°, 30°, 60° and 90° Terminal.For any other line deviation, a reference could be made to an application chart for an economical use of the above standard towers.

General Configuration of Towers

In general, it is aimed that the standard towers would have similar shape. The configuration of the 230 KV standard towers are shown in Fig. 1. Each

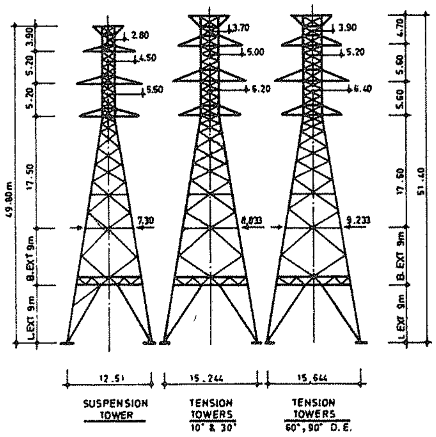

Fig. 1 CONFIGURATION OF STANDARD TOWERS 230kv DOUBLE CIRCUIT

Fig 1 Configuration of standard towers 230KV double circuit

tower is taken as a self supporting space truss structure. Where members are made of angle sections bolted at their ends. The sizes of the angles are affected by their location and function in the tower.

The standard configuration as an optimum shape is decided upon in the analysis by th aid of a computer program.

Electrical Detailing

From the electrical point of view, the power transmission line is checked for:

Corona, insulation and electrical arc. In particular, the insulation is further checked for lightining impulse withstand voltage, switching impulse withstend voltage and also wet power frequency. As a result of those checkings, the following information are obtained:

– Length of insulator chain
– Number of insulators per chain

elaborate study have some advantages over individual designs. The advantages are clarified by the following:

A. Usually the individual designs are based on standards which are different in approach and content. As a result; their design output would show considerable weight variation even with towers designed for the same line and area of application as clearly experienced in IRAN.

For the tower standardization, a unified design code is prepared. It considers the studies which are carried out in IRAN by SSPB(Ref. 1), and also some modified aspects of the known international standards.

The advantage of this unified code is to control the weight of the tower.

B. The environmental conditions in the load calculation as performed by individual designs are affected by the judgments of individuals. Hence, some designers may use values which are not related to this country.

For the tower standardization, a unified climatic condition is chosen. It is based on collected data and studies carried out by some firms such as SSPB(Ref.1) and the IRANIAN weather Bureau.

The advantage of this unified climatic condition is to control the loadings on tower which eventually has an influence on the weight of the tower.

C. The individual designers may choose any configuration, any arrangement of bracings and electrical clearances, which usually require long time to be decided upon. It may turn out not economical, and not easy to manufacture.

Those aspects have been considered thoroughly in the standard tower. For instance, different types of bracings are studied for 63 KV. It is found out then that the staggered bracing is more economical than nonstaggered bracing in case of ligh: loading. Also the electrical clearances are thoroughly specified and the required dimensions are accordingly fixed. The types of steel sections in the standard towers are reduced to the minimum to simplify their construction by local manufactures.

In general, determining inadvance the configuration with studied clearances would save a considerable time in comparison to individual designs, and that is infact an advantage.

D. The individual desingers may use a simplified design procedure to be able to analyse the tower. In general such a design procedure leads to strengths distribution some what different than designs based — on modern computer programs.

A unified computerised, design procedure is set-out for the standard towers, which considers the tower in its exact status as a space structure. The computerised procedure comprises the mechanical design of conductors and wires, the calculation of load on tower and the elastic analysis of space structures. Apre—processor program is provided to simplify the method of preparing and feeding the data to the computer. Also a post processor program is added to design the tower Apparently, this procedure can be used to modify the standard towers for any unusual environmental and topographic conditions.

The advantage of the unified procedure is to control the weight of the tower.

E. The individual designers may specify steel sections of strengths and sizes which are not available locally. Infact most of the steel sections used so far for tower manufacturing are inported with a very high price.

The standard towers are designed to make use of the steel sections which are produced locally.

This is infact an advantage due to considerable savings in the foreign currency.

F. Usually, long time is required for the local manufacturers to prepare shop drawings, so preparing it once for standard towers as a mass production woul(be very much easier and faster than non standard towers.

This is another advantage by saving the time and the effort of the local manufacturers.

Optimum power Transmission Line Towers

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ABSTRACT

The aim of the study is to standardize electrical power transmission line towers for the voltages 63, 132, 230 and 400KV; making use of the steel sections manufactured locally in IRAN. The standard towers are to be liable to modification to suit any unusual climatic and topographic conditions. The study has to cover many aspects such as preparation of a unified design code and a complete computerised design procedure. The towers which are already standardized have proved to be lighter and more practical than the already built towers in IRAN. This achievement is a big step forward in self reliance and independence of the foreign monopoly, and obvoiusly is of great benefit to the country. The standardization is actually implemented in IRAN; and it is recommended for the third world countries.

INTRODUCTION

The long experience in establishing electrical power transmission lines all over the country for the last three decades have urged the implementation of the standard towers for the expected advantages as will be summarised below and clarified next. The standardization of towers has to be performed through comprehensive study program which is set to cover aspects such as preparation of a unified design code, survey on climatic and topographic conditions over the whole country and establishing a computer program to perform all the calculation involved to the end of the tower design. So that it can be modified easily to suit any unusual loading. The design after such a thorough study, have showed that the standard towers are lighter in weight than those already built in IRAN, and a high percent of their weight can be provided from locally produced steel. Also it is easier and faster for local manufactures, to construet standard towers than individual towers, because the former have predetermined specified configurations which are not changing continuously.

ADVANTAGES OF STANDARD TOWERS

As introduced, the design of standard towers which are prepared through comprehensive and