THE REPRESENTATION OF AN EHV TRANSMISSION LINE DESIGN PROCESS THROUGH THE USE OF DECISION TABLES

by

Guy VAN UYTVEN

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CLAIM OF ORIGINALITY

The representation of an EHV transmission line design process through the use of decision tables is, to the best of the Author's knowledge, an original contribution.

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ABSTRACT

After a broad analysis of present extra-high-voltage (EHV) transmission line design methods, some improvements on these methods are suggested. The improved design methods, which are of a highly logical nature, are best represented through the use of the decision table technique. The decision tables can be automatically converted into a source language. This manner of proceeding will result not only in engineering time and cost savings, but can conceivably lead to a better and more economical design.

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INTRODUCTION

When an electrical designer is confronted with a transmission line design, very often, the problem will be set in the following form: transfer a load of X MVA at voltage Y over a distance of Z miles. Once this basic data has been given by the systems people, studies can be initiated by the designer in order to determine some, or all of the following parameters:

1. <u>Tower Data</u>

   Tower type

   Conductor-structure clearance

   Phase spacing

   Crossarm height

   Applied conductor loads

2. <u>Conductor Data</u>

   Size and type

   Maximum tension

   Every day tension

   Bundle configuration

3. <u>Insulator Data</u>

   Quantity and type

Mechanical strength

String arrangement

4. Line Data

Tower quantity

Span and sag

Right-of-way width

RI^2 losses

Corona losses

Electrical gradients

RI and audible noise levels

Reactance

5. Cost Data

Tower cost

Conductor cost

Insulator cost

Right-of-way cost

Annual charges on capital and losses

This list is not necessarily complete. Other parameters may be of interest in the course of a transmission line design.

Very often, apart from trying to come up with the most economical solution, the designer will be expected to tackle some special problem which is of some particular concern to the systems people. This might be an upper limit of the line reactance where stability is of prime concern, it might be audible noise of the line in so-called "high-complaint" areas, it might be corona losses which, when occurring during power peaks, can be a big nuisance. The designer should try to cope with these special problems, and find a solution to them, while all the time keeping the overall economic picture in mind. This is not an easy job. Especially since when, after much hard labor, a solution to the special problem has been found, the satisfaction of having succeeded might induce the designer to relax his search for the most economical design.

Giving the designer the benefits of a versatile computer program would greatly enhance his possibilities. Ideally, this program should be able to perform all logical decisions, while going through all the routine calculations. It should start anew with another set of input data, in order to find the most economical solution, which conforms to the special criteria set forward at the start. Unfortunately these special criteria can not be anticipated in the program and this certainly explains why the transmission line design field has, except for certain parts of the design, been relatively impervious to the computer revolution which has invaded other fields. The emphasis will, with each special problem, lie on another part of the design, and this would require each time a different program, unless the precaution was taken to put the program in a modular form, i.e., a form in which the program is divided into different interconnected parts (1). A program change would then act on some of the parts without affecting the others.

The complexity and highly logical nature of the transmission line design makes the choice of the decision table representation a very attractive one (2). This representation is in modular form and is problem oriented. This makes it very easy to change a program. Furthermore, once the decision tables have been written, they can easily be converted into a high level computer language such as Fortran, Algol or Cobol (3). This conversion can be done either automatically or by hand.

This thesis will be an attempt to describe the EHV transmission line design process using the decision table technique.

In Part I, the design problem will be analysed without going into the mathematical formulae. The interaction between the different design parameters will be emphasized and design procedures will be discussed.

In Part II, improvements on the above design procedures will be treated. Some of the improvements are possible due to the use of the computer as a design tool.

This allows investigation of possibilities which were until then left aside because of the time consuming nature of these investigations. Other improvements are due to a thoughtful construction of the transmission line design logic. The different design areas will be detailed as flow-charts.

Part III, will detail the decision table technique and show the advantages in their use. In this part we will also represent the design process using this technique.

Part IV will show the conversion of decision tables to computer program form and an application to a specific EHV transmission line design will be given.

In Part V, conclusions will be drawn.

PART I

ANALYSIS OF PRESENT EHV TRANSMISSION LINE DESIGN METHODS

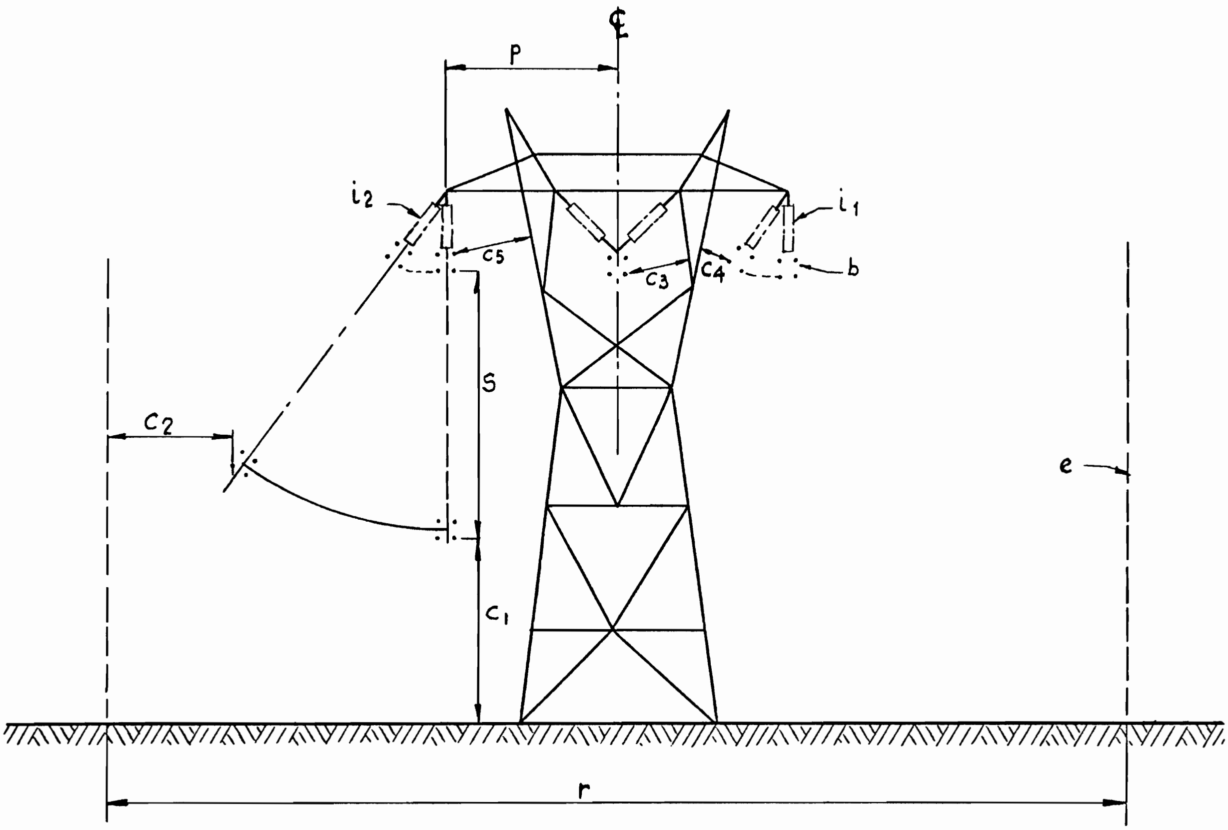
CHAPTER I

THE DESIGN PROBLEM

In the simplest of terms a transmission line is a set of conductors, which will transmit electrical power, and some supports--suitably insulated--which will carry these conductors (see Figure 1). Hence, the electrical design of this transmission line consists of two basic areas: 1) the insulation design and 2) the conductor design.

The insulation design will almost always be the designer's first task. This design will permit him to correctly estimate the transmission line tower costs which are of prime importance in selecting the most economical conductor size and subconductor bundle configuration.

The determination of the right-of-way width is dependant on both insulation and conductor design. Hence one might think that this determination is one of the last steps in the line design. This is usually not true since the right-of-way width will determine the amount of land to be acquired. This acquisition is a time-consuming process; hence the importance to know the right-of-way width as soon as possible.



Legend:

p = phase spacing
b = subconductor bundle
c_1 = clearance to ground
c_2 = clearance to right-of-way edge
c_3 = conductor clearance to steel (for V-string arrangement)
c_4 = conductor clearance to steel under extreme wind conditions (I-string)
c_5 = conductor clearance to steel (for I-string arrangement)
e = edge of right-of-way
i_1 = insulator string
i_2 = insulator string in deflected position
r = right-of-way width
s = maximum conductor sag

FIGURE 1

TYPICAL TRANSMISSION LINE STRUCTURE

In the next chapters, we will describe the different design items, associated with each basic area, and explain the relationship which exists between these items.

CHAPTER II

LINE INSULATION DESIGN

Insulation Requirements

This part of the design will determine the insulation dimensions necessary to obtain an adequate outage performance of the transmission line. "Insulation dimensions" is a very general term which includes mainly: insulator string length, insulator quantity per string, insulator creep and tower strike distances (see Figure 1). Although insulation design based on empirical criteria is still quite common, more and more designers are evaluating electrical performance of a transmission line by the aid of statistical methods.

There are three types of voltage stresses which can cause line flashovers:

1. Power frequency operating voltage
2. Switching surge voltage
3. Lightning voltage

The severity of the effect of a line flashover, on system operation, is dependant on which particular voltage stress triggered it. Hence it is logical to define an outage criterion for each type of stress. The line will then be designed in such a way, that the number of outages is less than that fixed by a predetermined outage criterion, and this will be applied for each type of stress.

Power Frequency Insulation

There are two cases where transmission line insulation has to be designed with regard to nominal 60 Hz (or 50 Hz) system voltage; these are respectively, insulator string strength, and air gap strength between conductor and structure, edge of right-of-way or another phase in the instance that the physical dimensions of this air gap are time-dependant and of short duration.

The insulator strings of a transmission line are subject to atmospheric contamination such as agricultural fertilizer, industrial pollution or sea spray. Under certain weather conditions--fog or morning dew--the deposit on the insulators will be wetted and leakage current will flow. Eventually this can result in a complete insulator string flashover (4) which will trip out the line. This is a very serious condition since it is almost impossible to reenergize this line as long as the strings remain wet. Hence, it is important to provide an adequate number of insulators in the string.

The action of the wind on a conductor will cause it to swing and this in turn will reduce the clearance between the conductor and the edge of the right-of-way; if attachment of the conductor to the tangent suspension tower is through means of an I-string arrangement, the insulator string will deflect also, and clearance to the structure will be reduced. Finally, under unfavorable wind conditions, the clearance between adjacent phases at mid-span can also be recuced. The occurrence of a switching or lightning surge, during the short time of minimum clearance, is most unlikely. Therefore, most designers will calculate conductor position under extreme wind conditions, and provide an air gap clearance with adequate power frequency strength.

This calculation implies however that the designer knows the span length between towers, in addition to the mechanical conductor loading, so that he can calculate the maximum conductor sag; it also implies that he knows the conductor size, so that he can evaluate the effect of the wind on this conductor in order to calculate the swing angle. The fact is, that conductor span optimization and selection are part of a later study, which starts once the insulation dimensions have been determined. In order to get out of this loop, the designer will usually choose a span, and a conductor configuration, which will yield him, in his own judgment, a conservative clearance.

Switching Surge Insulation

A switching surve travelling along a transmission line will stress the insulation of the successive supporting structures. The towers are to be designed in such a way, that the insulation strength of the line is not exceeded by the switching surge stress. Separate system studies will determine the maximum switching surge which can be expected on the system.

Until recently, transmission lines were designed--with respect to switching surge insulation--in such a way that tower withstand was adequate. Much research on full-scale towers has provided ample data in this regard. This was a deterministic design since it assumed that no switching surge flashovers would occur on the line. This manner of designing resulted in EHV transmission lines with extremely low flashover probabilities. In effect this means that the transmission line is over-insulated.

It has been shown (5) that much money can be saved by treating the whole insulation problem as a statistical problem. The withstand distribution of any structure, for a given clearance, can be determined as a function of voltage. The switching surge distribution is assumed to be normal (6). The convolution integral of the line flashover distribution and the switching surge density function, over the whole range of voltages, can be readily calculated with a computer. This convolution integral gives the line flashover expectancy, when a surge travels along the line. When, for example, a criteria of one flashover in a thousand surges is set, there will be a corresponding minimum clearance which can be calculated. Of course, the number of towers on the line should be known, which supposes again that span optimization has been performed. Again, the easiest solution is to assume a conservative number of towers--i.e., on the maximum side--which will produce a clearance bigger than necessary.

Lightning Insulation

Depending on the system voltage level, air gap clearances at the tower will be determined either by lightning surge or switching surge considerations (7). At 340 kV levels,lightning considerations will be important, and line flashover expectancy calculations will have to be made. At 700 kV levels, switching surge considerations will dominate the lightning requirements. The latter can be eliminated in low isokeraunic level regions. When flashover expectancies for lightning and switching surge are calculated, they should be combined to obtain a global line flashover expectancy (7).

CHAPTER III

CONDUCTOR SELECTION

Establishing Conductor Criteria

There is one basic criterion which has to be full-filled at all times. The line impedance should be low enough, in order not to endanger system operation from a stability point of view, at the time of maximum power transmission. This can be achieved by choosing conductors of adequate size, by splitting the phase conductor in a bundle of several subconductors, by incorporating series capacitors to reduce line reactance, or by suitable combination of the above means in order to obtain the most economical solution.

In addition to this basic criterion a number of criteria and/or arbitrary decisions might be dictated to the designer; this will affect the design process and its results. The fact that the design process is dependant on some--not always predictable--imposed criteria explains to a certain extent the difficulty encountered in implementing existing automated design programs.

Some additional criteria are:

1. Electrical criteria:

   An energized EHV conductor will produce some ionisation of the air (corona) around the conductor. This ionisation, caused by the intense electric field at the conductor surface, will have the following effects:

   (a) electromagnetic radiation from the transmission line--produced by burst pulses, streamers and/or corona glow--can cause along the right-of-way, a reduction of the signal-noise ratio of local radio and television stations. This situation could provoke complaints and possibly sueing by residents living near the line. Radio interference (RI) levels and television interference (TVI) levels are usually expressed in decibels (dB), and criteria could be formulated to limit the amount of RI and/or TVI generated by a transmission line.

   (b) the ionisation of the air discussed in (a) above is accompanied by audible noise. This audible noise is generated by the pressure waves produced by the continuing discharges taking place around the conductor. This noise can draw complaints from nearby residents and again a criterion can be developed to limit the audible noise, at the edge of the right-of-way, to an acceptable level.

(c) the power lost by the transmission line in ionising the air can be quite substantial and can be a big nuisance when this loss occurs during a peaking period. In the cases where this is important, the conductor can be penalized for the corona loss it produces. Usually the amount of the penalty will be derived by calculating the cost of providing for the lost power.

2. Mechanical criteria:

(a) For environmental reasons one might put a limit to the height of transmission line towers.

(b) Conductor manufacturers usually recommend that maximum conductor tension remains below 50% of the ultimate tensile strength (U.T.S.) of the conductor.

(c) In order to avoid wind-induced conductor vibration, most designers will limit the everyday tension of the conductor to 22% of the ultimate tensile strength.

Some Factors Influencing the Phase Spacing

The minimum phase spacing will be primarily dependant on the conductor-structure clearance (see Chapter II) and on the width of the tower legs located between the phases.

In some instances, phase spacing will be determined by 60 Hz insulation requirements at mid-span, under extreme wind conditions. Although this is usually not a problem on EHV lines, it should nevertheless be investigated, especially when long spans are considered.

The phase spacing will also be dependant on the insulator string arrangement. The conductor(s) can be isolated from the suspension tower by a vertical insulator string or by a V-string arrangement. There are three possible combinations: all phases have a vertical string arrangement (I-arrangement), the central phase has a V-string arrangement (M-arrangement), all phases have V-string arrangements (V-arrangement). In order to meet mechanical load requirements several insulator strings can be put in parallel.

A different phase spacing will be corresponding for each of the three possible insulator string combinations.
This is, of course, because the vertical insulator string is subject to wind-provoked swing, and the conductor has to have adequate insulation in all positions; therefore the conductor structure clearance, with a vertical string arrangement, will be greater than the clearance required with a V-string arrangement (see Figure 1).

Influence of Phase Spacing on Conductor Selection

The conductor electrical gradient is a function of the phase spacing. Hence the phase spacing will directly influence corona losses, audible, and radio noise levels; it will also influence line reactance calculations.

The designer has one of the two following choices:

1. He can choose the minimum phase spacing required, and then start with the conductor optimisation.
2. He wants to use some arbitrary conductor size(s) and bundle configuration, and wishes to know the phase spacing required to meet certain specific criteria.

Ideally choice number 1 should be taken. But several phase spacings should be considered, and conductor optimisation should be performed in each case in order to find the phase spacing that will provide the most economical solution. This means of course a tremendous amount of work which a designer could never try to perform without the use of a computer. The important consideration though, in transmission line design, is that the cost of doing an optimized design is very small when compared against the line savings involved.

The influence of phase spacing on conductor selection, which we just discussed, is a "direct" influence, i.e. phase spacing will directly influence corona losses, for example, and this affects the cost of the conductor under consideration. That phase spacing will also indirectly influence the conductor selection will be seen in the following section.

Some Factors Influencing the Tower Cost

The tower cost can be divided into three parts: (1) cost of the erected steel, (2) cost of the installed foundation, (3) cost of the insulators and associated hardware.

1. For a given type of structure--e.g. self-supporting, guyed-V-- the weight of the steel, hence its installed cost, will be mainly dependant on three independant factors:

   (a) The maximum unbalanced mechanical load exerted on the structure.

This load, applied on the crossarm, is the resultant load obtained from combining the lateral wind load and the longitudinal load; the latter can be either a broken subconductor unbalanced load, or an arbitrary load chosen to take stringing loads into consideration.

(b) The tower crossarm height.

The tower weight is obviously a direct function of the crossarm height.

(c) The phase spacing.

The crossarm length, hence its weight, is a function of the phase spacing.

Also influenced by the phase spacing, but to a lesser degree, is the amount of tower window steel in the case of a self-supporting structure.

2. The factors that influenced the steel cost will also influence the foundation cost, although in an entirely different way.

Steel and foundation cost will amount to approximately 90% of the total tower cost.

Hence we can conclude that factors such as span length, conductor tension and bundle configuration, which influence both the unbalanced tower load and the crossarm height, will affect the tower cost in a decisive manner.

3. Although the cost of the insulators and its associated hardware amounts to only 10% of the total tower cost, it is still worthwhile to analyse the influencing factors, considering the large amounts of money involved. Again there are three points to consider:

   (a) The insulator quantity per string will be determined by insulation requirements as discussed in Chapter II.

   (b) We have already seen previously that there are 3 possible insulator string arrangements (I, M, V). These arrangements affect the number of strings required per tower; hence the insulator cost. The insulator string arrangement also influences the phase spacing; hence steel and foundation costs.

   (c) The required insulator strength is dependent upon span length, conductor size and load conditions. Instead of using strings with strength x insulators, parallel strings with strength x/2 can be used.

Span Optimization

Let us consider a particular conductor which complies with the electrical criteria. The designer has now to determine the conductor loading conditions, the tower height and the span length. He can also, for a given span length, calculate the tower height in order that conductor stress complies with the mechanical criteria and that adequate conductor-to-clearance is maintained under maximum sag conditions. He will calculate the cost of the line (usually in $/mile). By repeating this calculation for different spans one can arrive at the optimum span length, i.e., that span length which produces the most economical design.

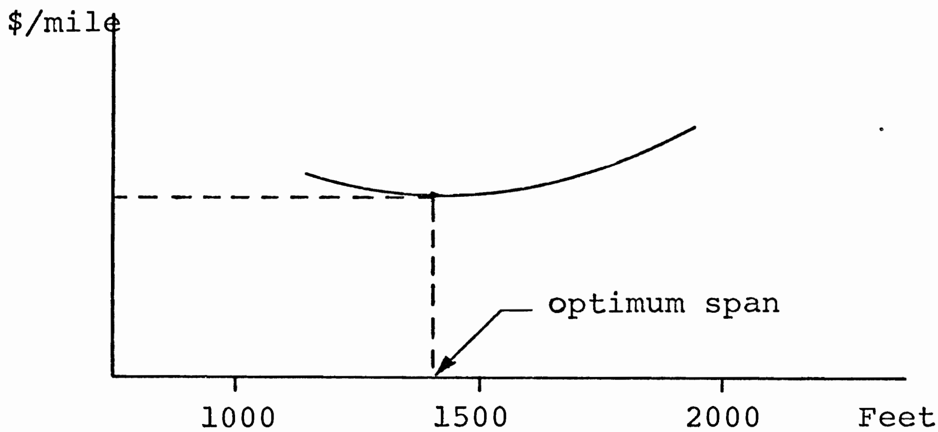


FIGURE 2

TOWER COST AS A FUNCTION OF SPAN LENGTH

Figure 2 shows how the cost of the line--for a particular conductor--is affected by the span length. Small spans require many towers; large spans require higher towers which have to withstand larger overturning moments. Somewhere in between is the optimum solution.

Since the electrical criteria will determine the minimum conductor size, for a given bundle configuration, choice of this conductor will give the lowest conductor cost. That it does not necessarily give the lowest line cost will be discussed in Chapter V. Furthermore, going to a different bundle arrangement will yield another minimum conductor size, another optimum span length and another line cost. It is evident that we are interested in the lowest total line cost.

PART II

IMPROVEMENTS ON PRESENT DESIGN METHODS

CHAPTER IV

COMPUTERIZING THE PROBLEM

In part I we have tried to give an understanding of the complexity of the EHV transmission line design problem. We have shown, that in order to reduce the large number of variables present, assumptions are made--some not always justified--and simplifications are eagerly adopted. Although rigor can never be claimed, nor error avoided, use of a computer can do much to reduce the number of simplifications, and the effect of different assumptions can be readily investigated. In fact, in order to solve the highly complex problem we are faced with, we are going to try to establish a working computer-oriented system, which will transform the design assumptions and criteria into a set of transmission line characteristics (8) (see figure 3).

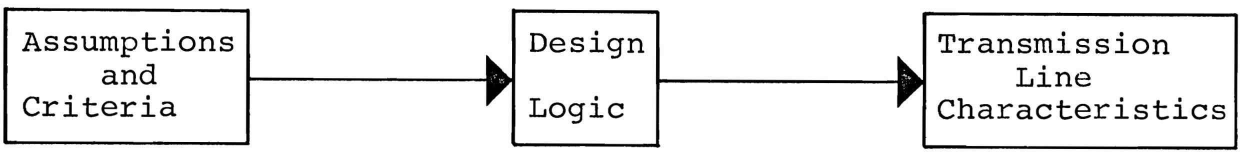


FIGURE 3

TRANSMISSION LINE DESIGN PROCESS

The design logic shown in figure 3 will be programmed and stored in the computer. This would be great if changes in assumptions and/or criteria did not change the design logic, i.e. if the design logic was independent of the input. Unfortunately this is not true; transmission line criteria vary to a great extent and are not always predictable. This has restrained many a designer from going to computerized design. If he uses the computer, it will be more as a big slide-rule than as a tool capable of making logic decisions. The few designers who have made elaborate efforts to put together a comprehensive program are not anxious to change the whole program just because a few criteria have changed. Hence, the danger arises that, in order to be able to run the program, approximations will be adopted which a designer would not consider during a manual design. Instead, of an invaluable aid, the computer will become the designer's enemy in that it can induce him to relax his critical judgment.

The qualities which the design logic structure should possess are:

- ease of following the logic
- ease of deletion, addition or change
- ease of programming

This is especially important if several people from different disciplines are collaborating on the design logic.

In Part III we will discuss the Decision Table technique which possesses the qualities mentioned above.

In the next chapter, a description of the design logic of a typical EHV transmission line will be given.

CHAPTER V

THE DESIGN LOGIC

What We Have and What We Want

Before starting the design logic synthesis, one should carefully divide the transmission line parameters in groups of input parameters, i.e. basic assumptions, and output parameters or required results. Most of these parameters will be part of every EHV transmission line design, but the separation in input and output groups is not necessarily the same. Phase spacing could be given as input in one design, and be a requested result in another. While in most cases conductor selection is one of the big problems in the design, it is conceivable that a conductor size might be dictated from the beginning; the designer would then have to play with the phase spacing and conductor bundle configuration to obtain the most economic design under the imposed conditions.

Figure 4 shows, as an example, how we can define the problem in terms of what we have and what we want. A change of one input parameter will most likely cascade into a bewildering array of effects on the final design.

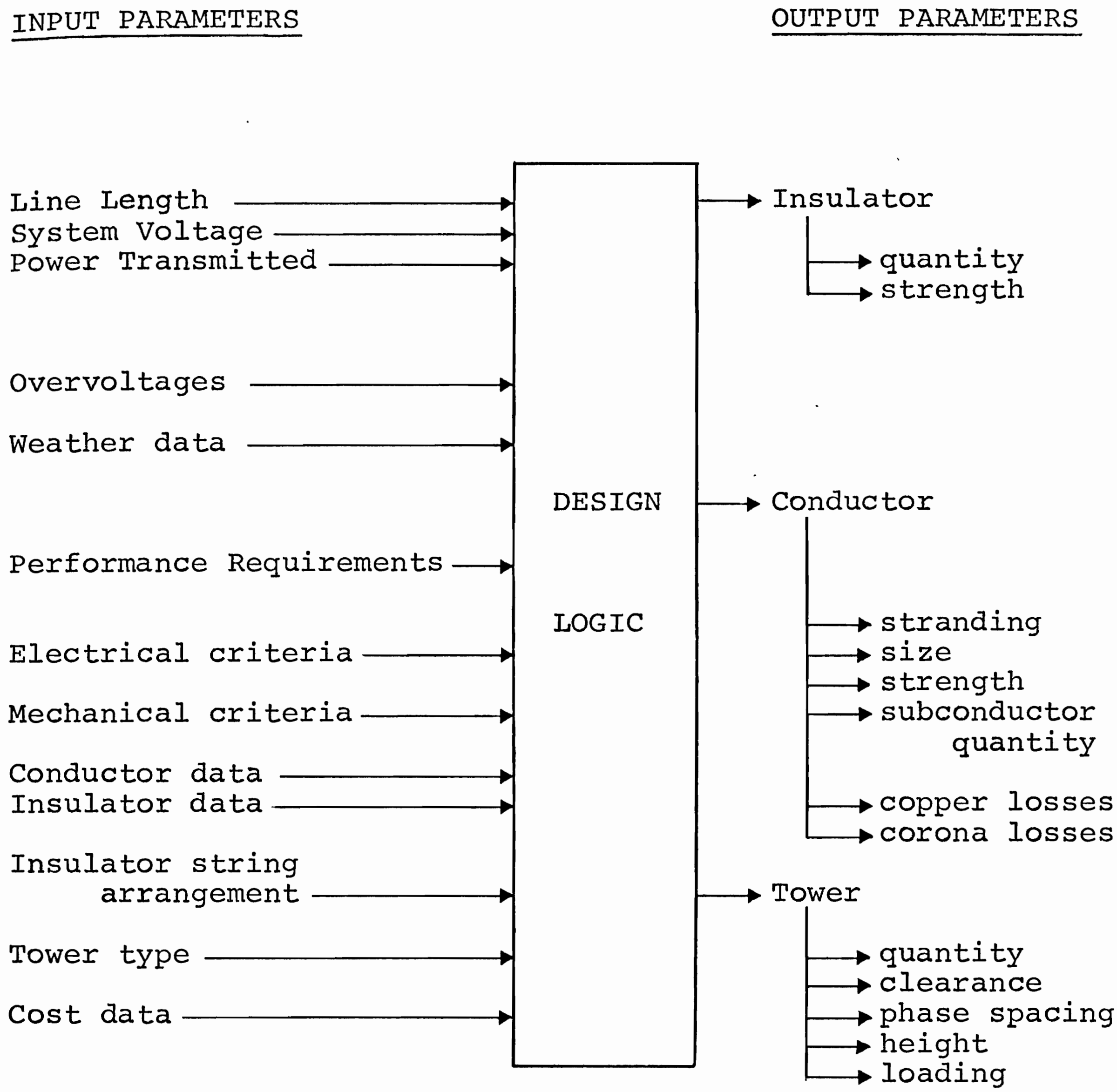


FIGURE 4

REPARTITION OF DESIGN PARAMETERS

That this can sharply affect the total cost was clearly illustrated in a recent article (9). Tables I, III, and V of the article are quoted below.

Table I shows the effects of a change in conductor size from 1.4 to 1.2 in. for a 735-kV single-circuit line with 4-conductor bundles on rigid towers:

Total transverse tower load	- 9%
Tower weight	- 3%
Conductor material and labor	- 24%
Tower material and labor	- 5%
Haul cost	- 9%
Total installed cost	- 9%

The design change of Table I saved $6-million on 375 miles of line. The smaller conductor, with ice and wind loads, reduced the sum transverse tower loads and, therefore, tower and foundation weights.

Table III shows the effects of a change from single to two-conductor bundled ACSR for a 315-kV double-circuit line:

MCM/phase	From 2,167 to 2,057	
Sum transverse load		+ 47%
Tower weight		+ 18%
Conductor material		- 3%
Conductor labor		+ 28%
Tower material and labor		+ 17%
Foundation material		+ 62%
Total installed cost		+ 19%

Table III indicates the economic penalty of bundle conductors for one particular design study.

Table V shows the effects of a change in the phase-spacing from 50 to 45 ft for a 735-kV line on rigid towers:

Tower and foundation weight	-13%
Tower and foundation material and labor	-13%
Haul cost	- 9%
Total installed cost	- 7%

Many 500- and 345kV lines have air gaps sufficiently large to provide a switching surge performance of no more than one trip-out each 10,000 years. Table V examines an experiment in reducing such air gaps for a more realistic figure.

A change of 5 to 10 percent of the total transmission line cost can run easily in the million dollar range. Hence the importance of accurately representing the interaction between the different parameters in the design process.

Transmission Line Parameter Interaction

One such representation is given in figure 5.

This flow chart, which at first view might seem quite complicated, does not represent all of the possible interactions. However, it is a big step in the right direction when compared to empirical transmission line design.

The flow chart fulfills a specific need; it is the tool which will yield us--with specific basic assumptions--certain desired results. If our basic assumptions or our desired results change, then another flow chart should be assembled.

FIGURE 5

FLOW CHART REPRESENTATION OF TRANSMISSION LINE DESIGN PROCESS

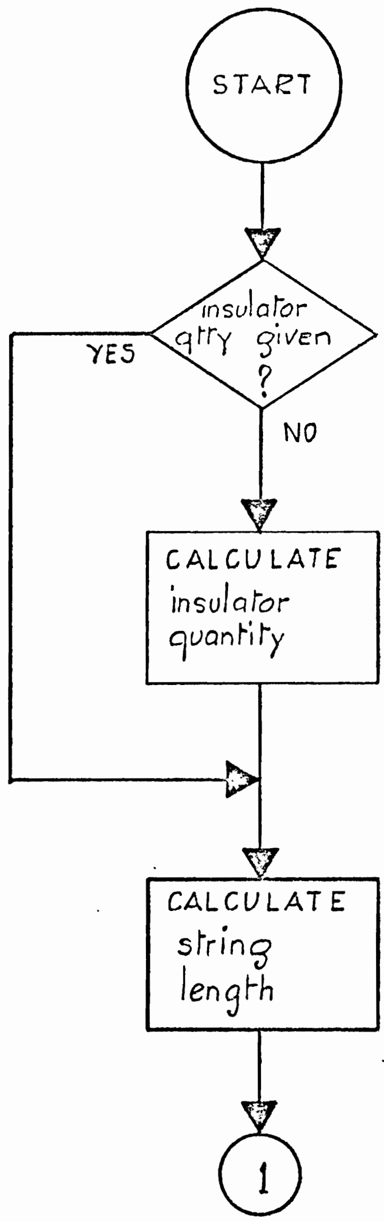


Fig. 5a

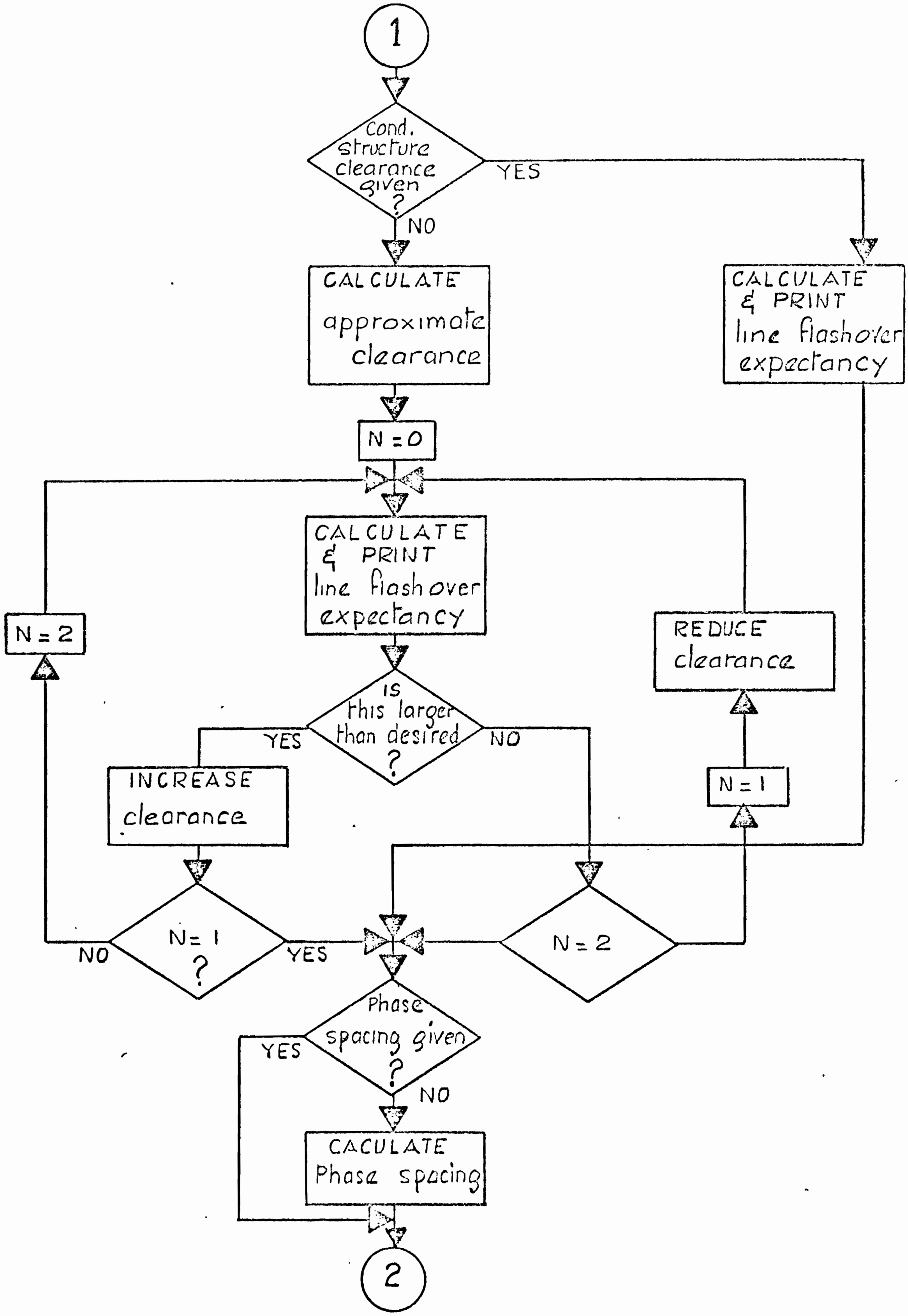
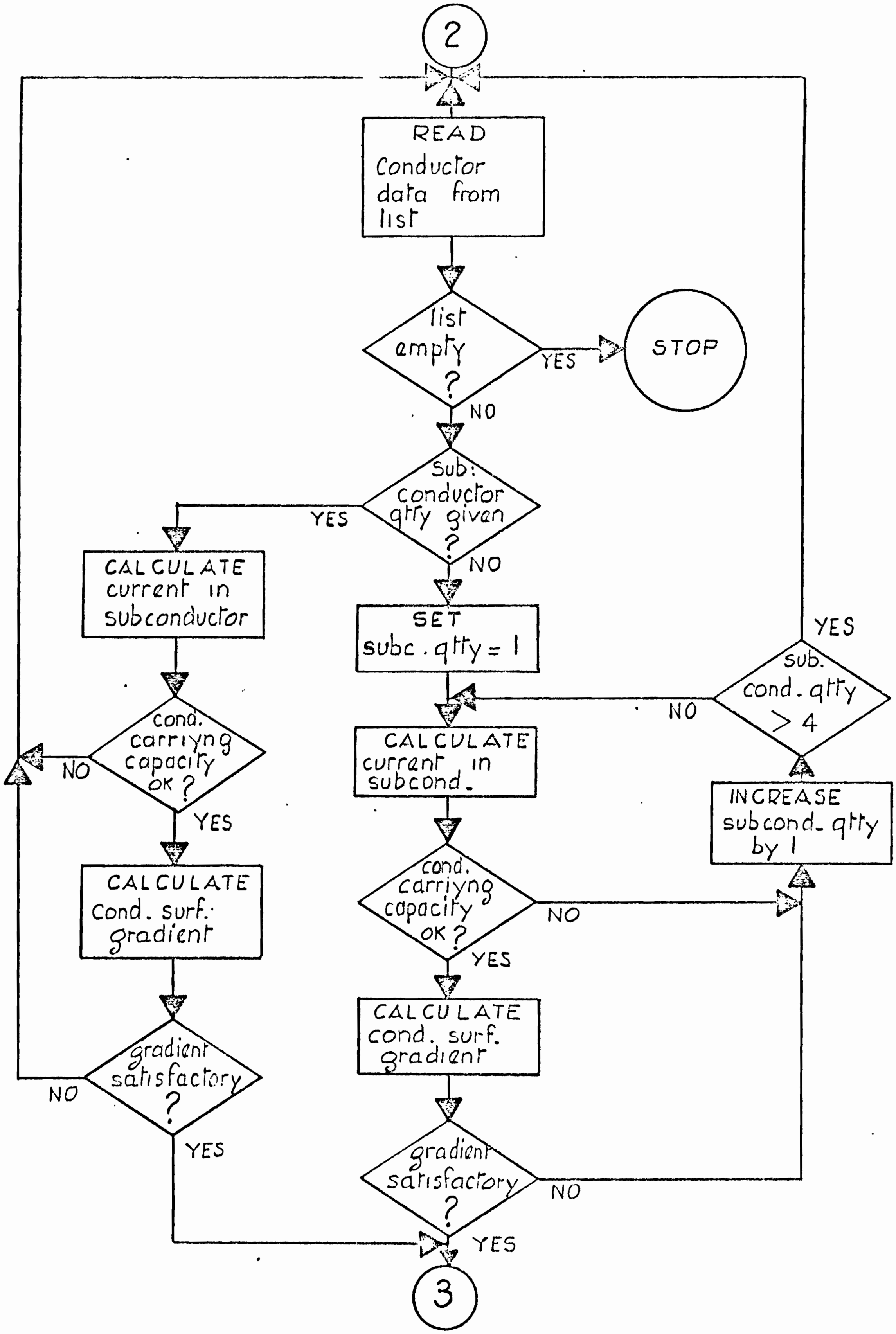

1
Cond. structure clearance given ?
YES
NO
CALCULATE approximate clearance
CALCULATE & PRINT line flashover expectancy
N = 0
CALCULATE & PRINT line flashover expectancy
N = 2
REDUCE clearance
is this larger than desired ?
YES
NO
INCREASE clearance
N = 1
N= 1 ?
NO
YES
N = 2
Phase spacing given ?
YES
NO
CACULATE Phase spacing
2

Fig. 5b


2
READ Conductor data from list
list empty ?
YES
STOP
NO
Sub: conductor qtty given ?
YES
NO
CALCULATE current in subconductor
SET subc. qtty = 1
YES
sub. cond. qtty > 4
NO
cond. carriyng capacity ok ?
NO
YES
CALCULATE current in subcond.
INCREASE subcond. qtty by 1
CALCULATE cond. surf. gradient
cond. carriyng capacity ok ?
NO
YES
CALCULATE cond. surf. gradient
gradient satisfactory ?
NO
YES
gradient satisfactory ?
NO
YES
3

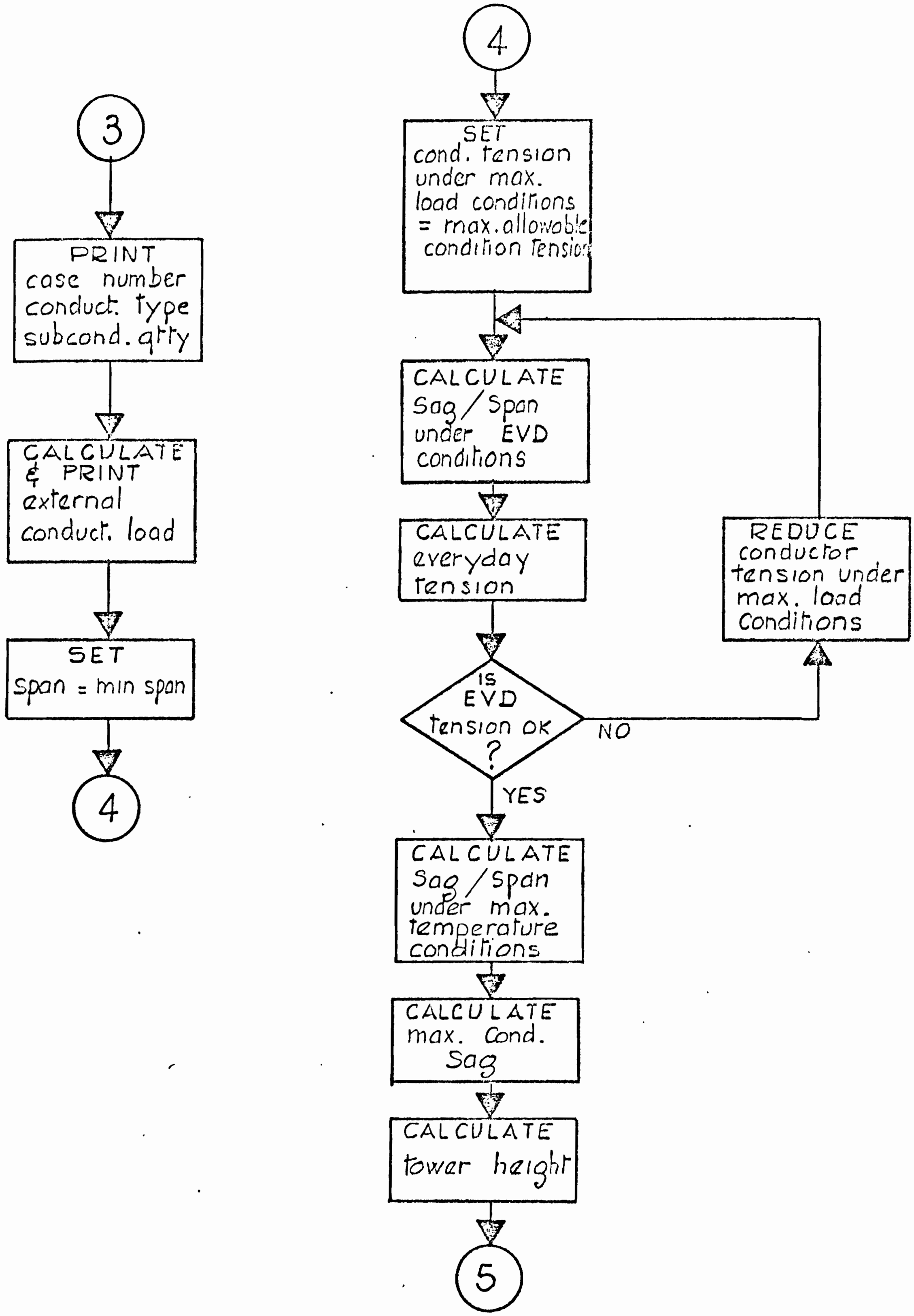

3
PRINT
case number
conduct. type
subcond. qtty
CALCULATE
& PRINT
external
conduct. load
SET
span = min span
4
4
SET
cond. tension
under max.
load conditions
= max. allowable
condition tension
CALCULATE
Sag / Span
under EVD
conditions
CALCULATE
everyday
tension
IS
EVD
tension OK
?
NO
REDUCE
conductor
tension under
max. load
conditions
YES
CALCULATE
Sag / Span
under max.
temperature
conditions
CALCULATE
max. cond.
Sag
CALCULATE
tower height
5

Fig. 5d

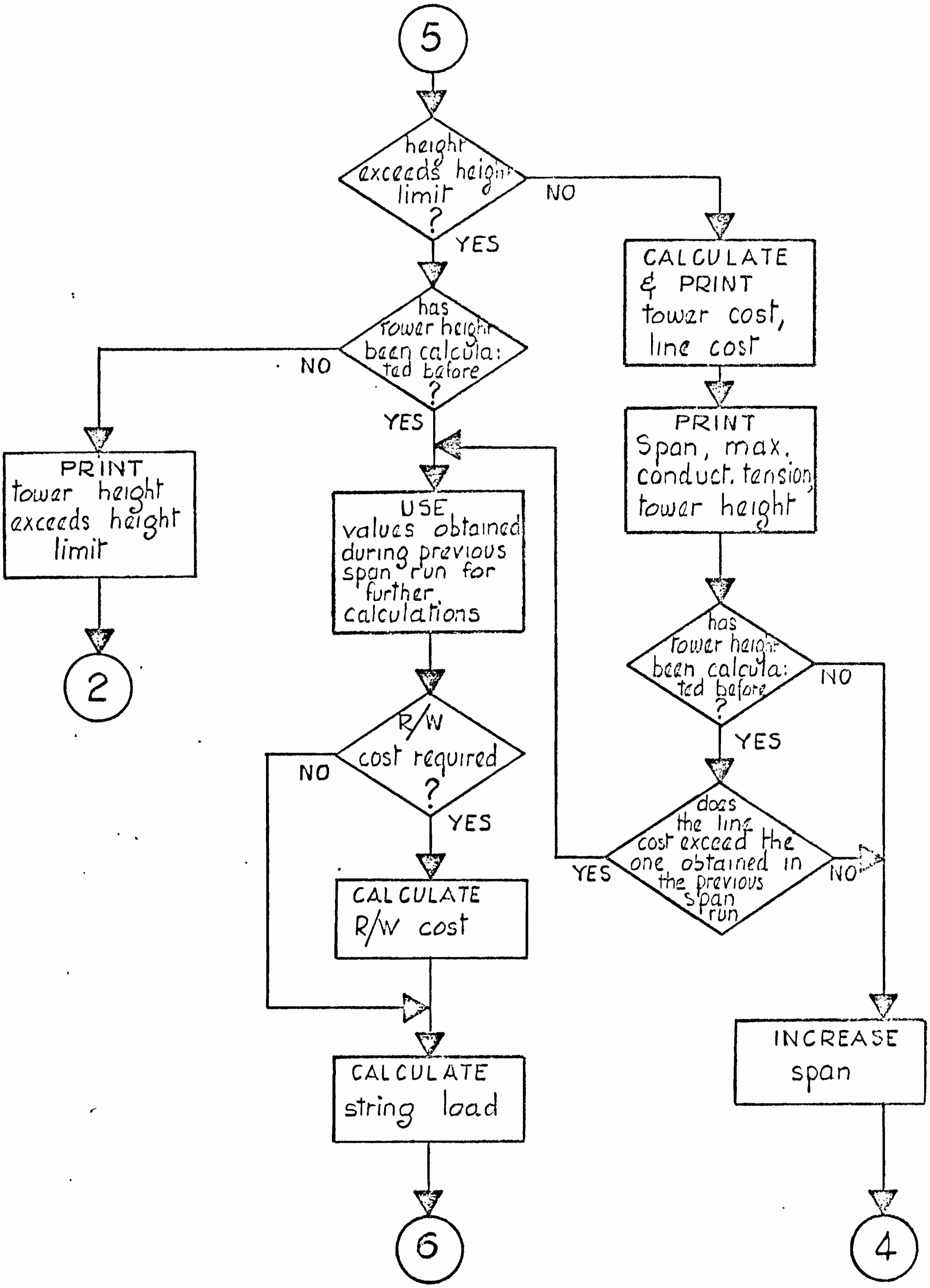

5
height exceeds height limit ?
NO
YES
has tower height been calcula: ted before ?
NO
YES
PRINT tower height exceeds height limit
2
USE values obtained during previous span run for further calculations
R/W cost required ?
NO
YES
CALCULATE R/W cost
CALCULATE string load
6
CALCULATE & PRINT tower cost, line cost
PRINT Span, max. conduct. tension, tower height
has tower height been calcula: ted before ?
NO
YES
does the line cost exceed the one obtained in the previous span run
YES
NO
INCREASE span
4

Fig. 5e

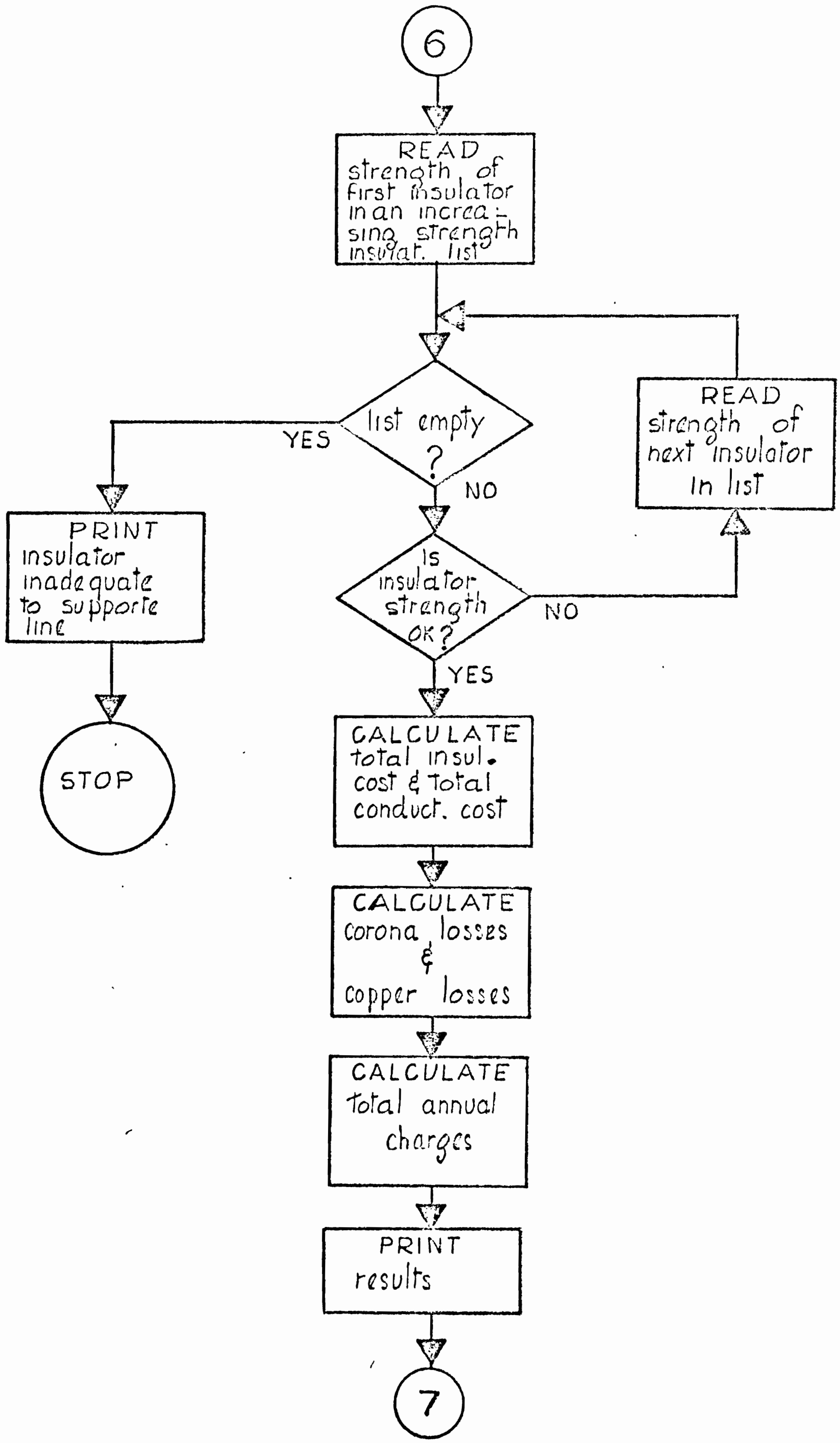

6
READ
strength of
first insulator
in an increa-
sing strength
insulat. list
list empty
?
YES
NO
READ
strength of
next insulator
in list
PRINT
insulator
inadequate
to supporte
line
Is
insulator
strength
OK?
NO
YES
STOP
CALCULATE
total insul.
cost & total
conduct. cost
CALCULATE
corona losses
&
copper losses
CALCULATE
total annual
charges
PRINT
results
7

Fig. 5f

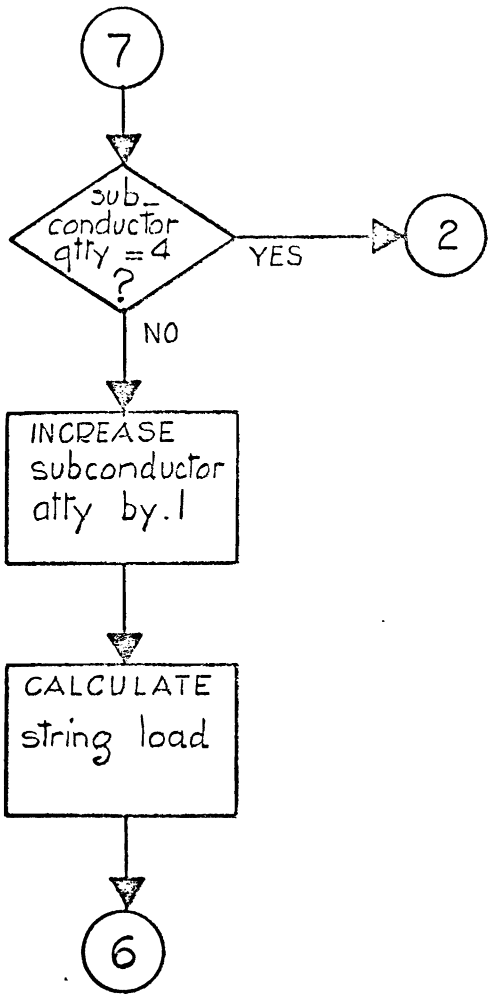

7
sub_ conductor qtty = 4 ?
YES
2
NO
INCREASE subconductor qtty by.1
CALCULATE string load
6

Fig. 5g

If we can separate the flow chart in individual parts or modules, we can hope that certain modules will not have to be modified. This will reduce the amount of reprogramming to be done.

On figure 5a, we can isolate one such module. It will calculate the number of insulators required in the tower suspension strings and the length of these strings. A second module appears in figure 5b. It calculates the conductor-to-structure clearance in order to satisfy a specific switching surge outage performance criterion.

Also on figure 5b, calculation of the phase spacing can still be regarded as a design module. In this case the phase spacing is either given or calculated empirically. The effect of a change in phase spacing on other design parameters can readily be investigated.

Once the phase spacing has been determined, we have taken the approach to investigate total transmission line cost as a function of the conductor choice. A list of suitable conductors--and their respective characteristics--is compiled. Conductor data is read in, one at a time, and the conductor is checked whether it complies with the required electrical criteria. Unless the subconductor quantity is given, one subconductor per phase is assumed at the start. If the electrical criteria are not met, the subconductor quantity is incremented, one at a time, to a maximum of four (figure 5c).

In the flow chart under discussion, two electrical criteria were assumed:

(1) current in a conductor should not exceed the current-carrying capacity of that conductor,

(2) the maximum surface electrical gradient on a subconductor bundle, should not exceed the corona inception gradient--under dry weather conditions--of that conductor.

A span optimization algorithm is introduced in figure 5d. For each span under consideration, the conductor will have to conform to the predetermined mechanical criteria. For the flow chart under consideration the mechanical criteria include:

(1) Maximum conductor tension (final) should remain at all times below the 50% value of the ultimate tensile strength of the conductor,

(2) Everyday tension of the conductor (final) should remain below an arbitrary chosen--usually 22%--percentage of the ultimate tensile strength,

(3) It is possible to specify a maximum permissible tower height.

Once the first two mechanical criteria are satisfied, the conductor sag under maximum temperature conditions can be determined in order to obtain the tower height. Criterion (3) can then also be checked.

Knowing the tower height, the phase spacing and the tower loading conditions, we can calculate the corresponding tower cost and hence the total tower cost for the line (figure 5e). This cost calculation is repeated for different spans; the minimum total cost will then indicate the optimum span. The most critical item in the preceding calculation is the determination of the tower cost. Empirical formulae (10) exist which will calculate the tower weight as a function of crossarm height, phase spacing, and applied loads (transverse, longitudinal and/or vertical). Existant tower designs of the same type will permit us to determine the coefficients in the above formulae. Other coefficients will transform the weights into costs. Foundation weights and costs can similarly be calculated. In the determination of the optimum span, the tower cost is only of interest from a comparative point of view. Small errors in tower cost are of little importance.

Once the optimum span and associated total tower cost have been calculated for a specific conductor bundle configuration, right-of-way costs--dependant on phase spacing --and insulator costs will be determined. Insulator cost is dependant on the insulator strength. In the flow chart under consideration, the insulator arrangement is given as input. Since we also know the conductor loads we can calculate the necessary insulator string load. Insulators with adequate strength--a 2.5 safety factor is normally used--are then selected.

Depending whether the transmission line is used primarily for power transmission or for system interconnection, power loss in the conductors can be charged accordingly. These charges will penalize the smaller conductors. Where these charges are substantial, they will have an important effect on the conductor selection.

Power loss in the conductors is due to: (1) RI^2 losses and (2) corona losses. The RI^2 losses and the mean yearly corona losses will produce a yearly energy loss which can be charged accordingly. The peak corona losses, when occurring in a period of maximum power delivery, can be charged for the loss of power they represent, i.e., cost of replacing this lost power by auxiliary power can be charged to the conductor.

The annual charges--due to losses--calculated above can be added to the yearly cost on installed capital to obtain the total annual charges associated with selecting a particular conductor bundle configuration.

The conductor configuration corresponding to the minimum total annual charges will then be our logical choice.

Other Possible Improvements

Many of the empirical formulae used in the flow chart of figure 5-- e.g. the tower cost formula--are apt to be improved either by better empirical formulae, or by small designs which can be treated as subroutines.

The flow chart under discussion was assembled primarily for use at the 700 kV voltage level. Conductor-structure clearance, for V-string arrangement, is determined solely from a switching surge point of view since lightning outages do not dictate the clearance at this voltage level. If lightning is expected to be a problem the design logic should be changed to take this into account.

Instead of considering standard conductors, gathered in a conductor list, it would be more logical to treat the conductor as a structural element just as the towers or the foundations. The conductor could then be specified as to the stranding and the ratio of steel to aluminum (if ACSR is indicated) in order to obtain the desired conductor strength. Of course, the conductor should be checked for conformance to the electrical criteria. This manner of proceeding would permit us to find a conductor tailored to our needs, rather than using the best conductor out of a given list.

Although we have tried to optimize every transmission line parameter in order to obtain the minimum line cost, it should be noted that the optimum values of these parameters are not necessarily the ones that ought to be chosen. For a slight increase in total cost, some safety factor--on the tower loading, for example--might be appreciably increased. This can be very desirable if the occurrence of failure of some element of the transmission line is of a statistical nature. How much we are willing to pay for a certain increase in realiability will require considerable judgment from the designer.

PART III

REPRESENTATION OF THE IMPROVED DESIGN PROCESS WITH THE USE OF THE DECISION TABLE TECHNIQUE

CHAPTER VI

DECISION TABLES

Introduction

In Part II, the design logic of an EHV transmission line was assembled in a flow chart form. Transforming this flow chart to an efficient program is a tricky job, and requires close communication between persons both within and outside the computer operating field. Decision tables will provide these persons with a tool that will ensure good communication. Decision tables will also be an extremely useful aid in converting the design logic into a program. This can be done either automatically or by hand-coding.

The use of decision tables provides a powerful means to convert complex, logical problems into an easily digestable form which will permit more effective analysis. Decision tables differ from flow charts in that they stress primarily the analytical rather than the documentary point of view as is the case with flow charts. Very complex problems can easily be partitioned in a set of interconnected decision tables.

Each decision table is problem-oriented, i.e. we can write down a set of actions to be executed for a particular problem which demands a decision. This contrasts with flow charting where we have a sequential order of operations.

Once all the individual problems and their solutions have been tabulated in the decision table format, the designer will be in a much better position--through his better understanding of the problem--to interconnect the different modules and come to a correct representation of the whole system.

Basic Concepts

A decision table is a representation of a situation which requires a decision. It is two-dimensional in nature, thus enabling us to express and consider both the sequential and parallel aspects of logic. The table is divided into four parts (see Table 1).

Table 1

DECISION TABLE ELEMENTS

	R1	R2	R3
I. Condition Statement	III Condition Entry		
II. Action Statement	IV Action Entry		

To the left of the double vertical line we will write:

(1) All possible actions that can be derived from the situation, once a decision has been reached. The order in which these actions are written is the order in which they have to be executed. The complete set of actions represents part II--the action statement--of the decision table.

(2) All conditions necessary to execute the actions; this is represented in part I--the condition statement--of the decision table.

To the right of the vertical double line are a set of columns each one of which represents a decision rule (R1, R2, R3,...). Each rule indicates a set of actions--below the double horizontal line--which has to be executed when the conditions for that rule--above the horizontal line--have been fulfilled.

Decision tables can appear in three different forms: (1) limited-entry table, (2) extended-entry table, (3) mixed-entry table.

1. In a limited-entry table, each condition row contains the condition to the left of the vertical line. Each rule, to the right of the

vertical line, will contain one of the following: "Y" (yes), "N" (no), "__" (irrevelant).

Each action row contains the action--left of the vertical line--and if the action has to be executed the rule contains an "X", otherwise it contains a "__" or a blank. An example of a limited entry table is given in Table 2.

Table 2

EXAMPLE OF LIMITED-ENTRY TABLE

	R1	R2	R3
Thesis completed	Y	Y	N
Thesis approved	Y	N	__
Continue work			X
Rework thesis		X	
Grant degree	X		

2. An extended-entry table consists of extended entries. An extended condition-entry is a row where the condition values for this variable and the rules contain values for this variable.

An extended action-entry is a row where the action stub does not completely define the action, i.e. part of the action is implied in the rule.

A simple example of an extended-entry table is given in Table 3.

Table 3

EXAMPLE OF EXTENDED-ENTRY TABLE

	R1	R2	R3
Money available to spend on new car	≤ $2,000	≥ $4,000	E
Buy	V.W.	Ferrari	Mustang

The "E" in R3 indicates an ELSE rule. All possible combinations which are irrelevant or impossible are grouped in <u>one</u> ELSE rule; i.e. all combinations not defined in the previous rules will fall in this ELSE rule and a common action will be executed.

3. A mixed-entry table consists of limited-entry and extended-entry rows. An example is given in Table 4.

Table 4

EXAMPLE OF MIXED-ENTRY TABLE

	R1	R2	R3	R4
Thesis completed	Y	Y	Y	E
Quality of thesis	Excellent	Good	Bad	—
Issue degree	X	X		
Mention	Honours	Satisfactory		
Work	Take Vacation	Take Vacation	Rework	Continue Work

Extended-entry tables can always be transformed to limited-entry tables. For example, Table 3 can easily be transformed into Table 5.

Table 5

TRANSFORMATION OF EXTENDED-ENTRY TABLE 3
INTO A LIMITED-ENTRY TABLE

	R1	R2	R3
Money available is less than $2,000	Y	N	N
Money available is less than $4,000	—	Y	N
Buy V.W.	X		
Buy Mustang		X	
Buy Ferrari			X

When considering limited-entry tables we can have either simple decision rules--which contain only "Y" or "N" --or compounded decision rules--which contain one or more "__". A compounded decision rule, containing x dashes is the equivalent of 2^x decision rules.

For example:

Y		Y	Y	Y	Y
N		N	N	N	N
-	=	Y	Y	N	N
N		N	N	N	N
-		Y	N	Y	N

A table is complete when it contains all the possible combinations of the condition statements. If there are x condition statements, there should be 2^x simple decision rules or it should be possible to reduce the rules to 2^x simple decision rules.

Advantages of the Decision Table Technique

Many articles have been written on decision tables and their advantages. Some of them have been listed in the "Bibliography". In the preceding sections, we mentioned some of the advantages attached in using the decision table technique. In this section, we will list a number of important advantages from a system analysis and programming point of view.

1. Since decision tables are problem-oriented, they will force a clear problem statement and show where information is missing.
   The problem will be described, in logic terms, and all possible decisions will be defined.

2. Experience has indicated that development, presentation and reading of complex logical systems is vastly improved when using the decision table technique; effective flow charting is very difficult for such systems. In addition it will provide for better communication between management, design engineers --or system analysts--and programmers.

3. When the decision tables have been prepared according to some well defined rules (11), it is possible to translate these tables automatically into a Fortran or some other high-level computer language program. In addition, algorithms exist (12,13) which will determine the optimum sequence for testing the conditions in a decision table. The optimum sequence will either benefit processing time or amount of memory space required by the program.

   Conversion of the system representation into a computer program is inexpensive when using decision tables. This is not so when one has to convert a flow chart representation.

4. Modifying a computer program is much easier when using decision tables. This is because of the more explicit documentation and modular form of the system representation. The effect of system changes on the decision logic can easily be determined.

5. The decision table technique is easy to learn.

CHAPTER VII

REPRESENTATION OF THE IMPROVED DESIGN PROCESS

Problem Definition

By asking the right questions about transmission line design, and by examining the different possible alternatives to each question, we can completely define the design problems.

We will partition the design process in distinct problem areas, and ask some questions in order to explore these areas on a preliminary basis.

1. Conductor-structure clearance.

   Do we want to calculate this clearance? Sometimes it is convenient to fix this clearance to see what the corresponding flashover performance of the line will be.

   If a clearance calculation is required, we can calculate an approximate clearance and see whether the line flashover expectancy corresponding to this clearance is adaquate? If no, we will increase the conductor-structure clearance, and ask the former question again.

2. Conductor conformance to electrical criteria. This problem area will also contain the subconductor quantity determination, if required. For a given subconductor quantity and conductor size we can see if the electrical criteria are met. If not, we can either increase the subconductor quantity or go to a larger conductor.

3. Conductor conformance to mechanical criteria. This problem area contains also span optimisation. A certain span length will be assumed, then conductor tensions will be adjusted so that the conductor conforms to the mechanical criteria. The span that corresponds to the minimum total cost will be the optimum span.

4. Phase spacing.
   Is it required to calculate the phase spacing? If yes, an empirical calculation, based on conductor-structure clearance, can be made.

5. Insulator quantity.
   Is it required to calculate the insulator quantity? If yes, calculate it.

6. Insulator strength.

Will a given insulator strength be adequate to support the conductor loads?

All these problem areas should be worked out in detail and put in decision table format. Once this has been done, it is relatively easy to interconnect decision tables of different problem areas.

Decision Table Generation

As an example of decision table generation we will detail problem area 5, i.e. insulator quantity determination.

In EHV systems, the insulator quantity is determined from a contamination point of view with regard to power-frequency flashovers. The creep distance of an insulator is the distance along the surface of the porcelain between both ends of the insulator. The specific creep is the creep distance per kV of maximum system voltage necessary to obtain an adequate flashover performance. Hence, the formula to calculate the insulator quantity is:

$$\text{IQTTY} = \frac{\text{VMAX}}{1.73} \times \frac{\text{SC}}{\text{CREEP}}$$

Where:

Where:	IQTTY	=	insulator quantity
	VMAX	=	maximum system voltage (kV, phase-phase)
	SC	=	specific creep (in./kV)
	CREEP	=	insulator creep distance (in.)

The insulator string length is then simply:

$$STRLG = IQTTY \times \frac{SLENT}{12}$$

Where: STRLG = insulator string length (ft.)
SLENT = insulator length (in.)

Contamination of the insulator string varies from one location to another. We will assume a specific creep of 0.9 in./kV for slightly polluted areas, and 1.0 in./kV for moderately polluted areas.

Figure 6 is a decision table--in mixed-entry form--which represents the whole problem. The table is written in such a form that it can automatically be converted in Fortran.

The first rule (operand 1) gives the actions which have to be taken when:

(a) IQTTY = 0, i.e. we want the insulator determination to be done.

(b) CREEP = 0, i.e. we do not know the insulator creep distance.

(c) IHCONT = 0, i.e. we have a slightly polluted environment.

The latter condition asks for a specific creep of 0.9 in./kV (row no. 5). Since we do not know what the insulator creep distance is, we will assume it to be a standard 12 in. (row no. 6). We will also assume that the insulator length is a standard 5.75 in. (row no. 7). Rows 8 and 9 perform the calculation of the insulator quantity and the string length. Row 10 states that the next problem to be handled can be found in Decision table 12.

There are 3 condition statements, hence we expect $2^3 = 8$ rules. We have eight rules, since the two "__" entries can each be reduced to two rules.

The 35 decision tables, which make up the main logic of the EHV transmission line design process, are exhibited in Appendix A.

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DECISION LOGIC CODING FORM

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SYSTEM ______________ ANALYST ______________

PAGE ________ OF ________ DATE ______________

TABLE NO.	ROW NO.	CARD	STUB		OP1 (01)	OPERAND 1 (02–04)	OP2 (05)	OPERAND 2 (06–08)	OP3 (09)	OPERAND 3 (10–12)	OP4 (13)	OPERAND 4 (14–16)	OP5 (17)	OPERAND 5 (18–20)	OP6 (21)	OPERAND 6 (22–24)
1.1	1	C	TABLE FOR DETERMINATION OF INSULATOR QUANTITY AND STRING LENGTH.													
1.1	2		IF IQTTY	=0	Y		Y		Y		Y		N		N	
1.1	3		IF CREEP	=0	Y		Y		N		N		Y		N	
1.1	4		IF IHCONT	=0	Y		N		Y		N		.		.	
1.1	5	A	SET SC	=		0.9		1.0		0.9		1.0				
1.1	6		SET CREEP	=12.0	X		X						X			
1.1	7		SET SLENT	=5.75	X		X						X			
1.1	8		DO FORMULA 1		X		X		X		X					
1.1	9		DO FORMULA 2		X		X		X		X		X		X	
1.1	10		GO TO TABLE 12		X		X		X		X		X		X	
1.1		F	FORMULA 1 IQTTY=VMAX*SC/CREEP/1.73+0.5													
1.1		F	FORMULA 2 STRLG=IQTTY*SLENT/12													

TABLE 6

EXAMPLE OF A DECISION TABLE

COMMENTS FIGURE 6

PART IV

CONVERSION TO PROGRAM FORM AND APPLICATION TO A SPECIFIC EHV TRANSMISSION LINE DESIGN

CHAPTER VIII

AUTOMATIC CONVERSION OF DECISION TABLES

Once the design logic has been expressed in decision tables, in a prespecified format, they can be punched into cards, and fed into the computer. The 35 decision tables of Appendix A conform to the specifications of a Fortran-oriented decision table language. This language is converted by a "Decision Logic Translator" (11) into Fortran statements written on disks or tape, or punched, and/or printed. The Decision Logic Translator is designed for use on an IBM System/360 Model 25 or 30 with 32 K bytes of main storage and two disk drives. The language used is System/360 Assembler, with the appropriate System/360 Disk Operating System (DOS) input/output macro instructions.

The main advantage of this system is that it accepts extended-entry decision tables. The main disadvantage of the translator is that on-line manipulation of the decision tables from a remote control terminal is not possible. Furthermore, the Model 25 or 30 compiler is already old, and for large problems, not economical when compared to the latest computer models available.

The printed output of both the decision tables (input) and the generated Fortran program (output) is exhibited in Appendix B.

A different "Decision Logic Translator" (24) is available which will convert PL-1 oriented decision table language into PL-1 statements. The IBM System/360 Model 85 has this translator program in its library and on-line remote terminal manipulation is possible. One disadvantage of this translator is that only limited-entry tables are accepted by the pre-compiler. However, the possibility of doing interactive computer aided design, more than compensates for this disadvantage.

CHAPTER IX

APPLICATION TO A SPECIFIC EHV TRANSMISSION LINE DESIGN

The Fortran program obtained from the "Decision Logic Translator" was used in order to determine the basic characteristics of a 765 kV transmission line, i.e. conductor-to-structure clearance, phase spacing, conductor size.

The significant part of the computer output is exhibited in Appendix C. A glossary to the variables and subprograms used in the main program is exhibited in Appendix D.

The first three computer sheets show how the clearance is increased until the line flashover expectancy is smaller than 0.0001; the 246 inch clearance corresponds to this condition. The chosen criteria of 0.0001 flashovers per switching surge--or 10,000 surges per flashover--is part of the input data (actually, this value is very conservative and will result in a heavily insulated transmission line).

A list of conductor sizes, in the input, will be read one at a time. When a particular conductor size conforms to the electrical criteria, it will receive a case number, and an analysis with regard to the minimum transmission line cost will be performed and the results printed. In Appendix C, we have included the first four cases of the computer output.

The printed output corresponding to each case consists of three computer sheets. The first sheet shows how the optimum span is determined in order to obtain minimum installed tower cost. The second sheet gives information with regard to conductor gradients and corona losses on the line. The third sheet summarizes design information, such as clearance and phase spacing, and prints transmission line cost data corresponding to the conductor under consideration. This data consists of total installed cost and total annual charges.

For this specific transmission line problem, case number 1 has the lowest total annual charges and hence the corresponding Cardinal type conductor is an obvious choice.

PART V

CONCLUSIONS

CHAPTER X

CONCLUSIONS

The following conclusions can be drawn with regard to the use of decision tables in EHV transmission line design.

1. The problem-oriented nature of decision tables is ideally suited to the representation of the highly complex and logical EHV transmission line design process.

2. Conversion of the decision tables to a high-level computer language can be done automatically.

3. Change of the transmission line design logic can easily be achieved by modifying the decision tables. The use of computer based design of EHV transmission lines is made attractive by this important advantage.

The possibility of using computer based design results in the following additional advantages:

1. An important gain in time is realised. The great quantity of possibilities that can be

investigated by the computer in a minimum of time would require months of engineering time in conventional design.

2. An important gain in design cost is realised. The cost of converting the decision tables in a computer language and running the problem is approximately fifty dollars[1]. Even when including the cost for modifying the decision logic to suit the particular design problem, would result in a total cost much lower than the cost of conventional based design with its fewer investigated possibilities.

3. A possible gain in transmission line cost. Since computer based design can investigate many more possibilities than conventional design it is quite possible that a more economical solution is found. As an example, the gain of one transmission line structure on a line corresponds to a $20,000 savings. This amount of money alone is about equal to the entire cost of the transmission line design.

---

[1]The reason for this relatively large cost is that the "Decision Logic Translator" was stored on a disk which had to be installed by an operator in order to run the program. Should the program be "on-line" the cost would be less than ten dollars.

The design logic for the transmission line design, used in this paper as an example, is apt to be considerably improved. The Author is presently working on these improvements. He is also investigating the use of interactive computer based design in order to implement these improvements.

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BIBLIOGRAPHY

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APPENDIXES

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SYSTEM TLDT
PAGE 1 OF 35

ANALYST GUY VAN UYTVEN
DATE 1 July 1970

TABLE NO.	ROW NO.	CARD	STUB / ENTRY
		I	TLDT PROGRAM
		C	TRANSMISSION LINE DESIGN USING DECISION TABLES BY GUY VAN UYTVEN
		S	COMMON CLEAR,STRLG,IQTTY,PFAC,WIDTS,WIDLG,RDENS,SURGFO,VNOM
		S	COMMON NTOWS,CSSFO,SSIGMA,DIST,FOPROB,NPRNT,NCRDR
		S	COMMON CDIA,GRDCL,FASP,NSC,CGRAD,CORGR,BUNSP,SURFC,SAG,LBC,OUTG,CT
		1	RG,CORL(6)
		S	DIMENSION INSSTR(4),COSTIN(4)
		S	DATA INSSTR/25000,36000,50000,0/
		S	DATA COSTIN/4.74,5.74,9.30,0/

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SYSTEM TLDT

PAGE 2 OF 35

ANALYST ____________

DATE ____________

TABLE NO.	ROW NO.	CARD	STUB / ENTRY
10	1	C	UNCONDITIONAL TABLE TO READ INPUT DATA
10	3	A	READ NCRDR F1 L1
10	5		READ NCRDR F2 L2
10	7		READ NCRDR F3 L3
10	9		READ NCRDR F4 L4
10	11		READ NCRDR F5 L5
10	13		GO TO TABLE 11
10		F	FORMAT 1 (12F6.2)
10		F	FORMAT 2 (7F6.1)
10		F	FORMAT 3 (2I1,2I5,I1,I4,I1)
10		F	FORMAT 4 (2F5.2,2F5.1,2E15.7,F5.1,F5.2,F5.3)
10		F	FORMAT 5 (3F5.2)
10		L	1 VNOM,VMAX,DIST,PFAC,CLEAR,FASP,CREEP,SLENT,WIDTS,WIDLG,RDENS,S
10		1	URFC
10		L	2 SSMAX,CSSFO,SSIGMA,GRDCL,BUNSP,ANGLE,RWSCOS
10		L	3 IHCONT,ISTRIN,IDFOPR,NTOWS,NSCG,MVA,LBC
10		L	4 XIICE,WINDL,AVTEMP,TOPTMP,ALFA,YOUNG,HTLIM,COEVDT,TCCOEF
10		L	5 ACOIC,ALOSC,DCOC

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TABLE NO.	ROW NO.	CARD	STUB		OP1	OPERAND 1	OP2	OPERAND 2	OP3	OPERAND 3	OP4	OPERAND 4	OP5	OPERAND 5	OP6	OPERAND 6
11	1	C	STRING LENGTH AND INSULATOR QUANTITY DETERMINATION													
11	3		IF IQTTY	=0	Y		Y		Y		Y		N		N	
11	5		IF CREEP	=0	Y		Y		N		N		Y		N	
11	7		IF IHCONT	=0	Y		N		Y		N		.		.	
11	9	A	SET SC	=		0.9		1.0		0.9		1.0				
11	11		SET CREEP	=12.0	X		X						X			
11	13		SET SLENT	=5.75	X		X						X			
11	15		DO FORMULA 1		X		X		X		X					
11	17		DO FORMULA 2		X		X		X		X		X		X	
11	19		GO TO TABLE 12		X		X		X		X		X		X	
11		F	FORMULA 1 IQTTY=VMAX*SC/CREEP/1.73+0.5													
11		F	FORMULA 2 STRLG=IQTTY*SLENT/12													

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TABLE NO.	ROW NO.	CARD	STUB		OP1 01	OPERAND 1 02	03	04
12	1	C	PRELIMINARY STRUCTURE CLEARANCE DETERMINATION AND CORRESPONDING LINE					
12	2	C	FLASHOVER EXPECTANCY CALCULATION.					
12	3	1	IF CLEAR	=0	N	Y	Y	
12	5		IF VNOM	LT 500	.	Y	N	
12	7	A	DO TABLE 13			X	X	
12	9		DO F 1			X		
12	11		DO F 2				X	
12	13		SET N=0			X	X	
12	15		DO TABLE 14		X	X	X	
12	17		GO TO TABLE 16			X	X	
12	19		GO TO TABLE 20		X			
12		F	1 CLEAR=2.5/155*(VNOM-345)+7.5					
12		F	2 CLEAR=8.0/235*(VNOM-500)+10					

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TABLE NO.	ROW NO.	CARD	STUB		OP1 01	OPERAND 1 02
13	1	C	THIS TABLE DETERMINES THE MEAN SWITCHING SURGE AND STANDARD DEVIATION			
13	3	I	IF SSMAX	=0	Y	N
13	5	A	DO BLOCK 1			X
13	7		RETURN		X	X
13		B	BLOCK 1	SSIGMA=(SSMAX-VNOM/1.73*1.41)/6		
13				CSSFO=SSMAX-3*SSIGMA		

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TABLE NO.	ROW NO.	CARD	STUB / ENTRY
14	1	C	FLASHOVER EXPECTANCY CALCULATION AND PRINTING OF RESULTS
14	3	A	SET ICLEAR=12*CLEAR
14	5		WRITE NPRNT F1 L1
14	7		CALL FOEXPL
14	9		WRITE NPRNT F2 L2
14	11		RETURN
14		F	FORMAT 1 (1H1/10X,'CONDUCTOR-STRUCTURE CLEARANCE DETERMINATION'//1
14			10X,I3,' INCH CLEARANCE',20X,'LINE FLASHOVER EXPECTANCY CALCULATION
14			2')
14		F	FORMAT 2 (////60X,'LINE FLASHOVER EXPECTANCY = ',F10.8///60X,'THIS
14			1 LINE FLASHOVER EXPECTANCY IS EQUIVALENT'/60X,'TO ',F10.0,'SWITCHI
14			2NG SURGES PER FLASHOVER.'/60X,'NOTE= THE DESIRED EXPECTANCY IS ',I
14			310,' SURGES'/60X,'PER FLASHOVER.')
14		L	LIST 1 ICLEAR
14		L	LIST 2 FOPROB,SURGFO,IDFOPR

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16	1	C	CONDUCTOR-STRUCTURE CLEARANCE DETERMINATION																									
16	3	I	IF SURGFO	GT IDFOPR	Y	N	Y																					
16	5	I	IF N	=2	N	.	Y																					
16	7	A	INCREMENT CLEAR BY 0.5			X																						
16	9		GO TO TABLE 17			X																						
16	11		WRITE NPRNT FI LI				X																					
16	13		GO TO TABLE 20				X																					
16	15		SET N=1		X																							
16	17		INCREMENT CLEAR BY -0.5		X																							
16	19		DO TABLE 14		X																							
16	21		GO TO TABLE 16		X																							
16		F	FORMAT 1 ('CONDUCTOR STRUCTURE CLEARANCE (FEET)=',F5.2)																									
16		L	LIST 1 CLEAR																									

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17	1	1	IF N	=1	Y	N																						
17	3	A	WRITE NPRNT F1 L1		X																							
17	5		GO TO TABLE 20		X																							
17	7		SET N=2			X																						
17	9		DO TABLE 14			X																						
17	11		GO TO TABLE 16			X																						
17		F	FORMAT 1 ('CONDUCTOR-STRUCTURE CLEARANCE (FEET)=',F5.2)																									
17		L	1 CLEAR																									

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20	1	C	PHASE SPACING DETERMINATION.													
20	3		FASP	=0	N		Y		Y		Y					
20	5		ISTRIN		.		LT	3	GT	4	E					
20	7	A	SET COF=					2.6		3.65		3.9				
20	9		SET FASP=COF*CLEAR				X		X		X					
20	11		DO B 1		X		X		X		X					
20	13		GO TO TABLE 21		X		X		X		X					
20		B	1 IFASP=FASP+0.6													
20			FASP=IFASP													
20			ICLEAR=12*CLEAR													
20			ICASE=0													

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TABLE NO.	ROW NO.	CARD	STUB / ENTRY
21	1	C	UNCONDITIONAL TABLE USED TO READ CONDUCTOR DATA
21	3	A	READ NCRDR F1 L1
21	5		SET CWGHT=AWGHT+SWGHT
21	7		GO TO TABLE 22
21		F	FORMAT 1 (2A8,3F5.3,I5,F8.1,F6.2,F6.4)
21		L	1 CO,TYP,CDIA,AWGHT,SWGHT,ICCCC,CUTS,BAZCOS,CONRES

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TABLE NO.	ROW NO.	CARD	STUB		OP1	OPERAND 1			OP2	OPERAND 2			OP3	OPERAND 3			OP4	OPERAND 4			OP5	OPERAND 5			OP6	OPERAND 6		
					01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
22	1	C	TABLE CALCULATING THE SUBCONDUCTOR CURRENT																									
22	3		CDIA	=0	Y	N	N																					
22	5		NSCG	=0	.	Y	N																					
22	7	A	CALL EXIT		X																							
22	9		SET NSC=1			X																						
22	11		SET NSC=NSCG				X																					
22	13		DO TABLE 25			X	X																					
22	15		GO TO TABLE 23			X	X																					

ENTRY

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TABLE NO.	ROW NO.	CARD	STUB		OP1 01	OPERAND 1 02	OPERAND 1 03	OPERAND 1 04
23	1	C	TABLE FOR CONDUCTOR SURFACE GRADIENT CALCULATION					
23	3	1	CURNT	LE ICCCC	Y	N	N	
23	5		NSCG	=0	.	Y	N	
23	7	A	CALL GRADNT		X			
23	9		INCREMENT NSC BY	1		X		
23	11		GO TO TABLE 21				X	
23	13		GO TO TABLE 26		X			
23	15		GO TO TABLE 27			X		

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TABLE NO.	ROW NO.	CARD	STUB	OP1 01	OPERAND 1 02 03 04	OP2 05	OPERAND 2 06 07 08	OP3 09	OPERAND 3 10 11 12	OP4 13	OPERAND 4 14 15 16	OP5 17	OPERAND 5 18 19 20	OP6 21	OPERAND 6 22 23 24
25	1	C	FORMULA USED FOR SUBCONDUCTOR CURRENT CALCULATION.												
25	3	A	DO F 1	X											
25	5		RETURN	X											
25		F	1 CURNT=MVA*1000.0/(1.73*VNOM*NSC)												

1 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80

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TABLE NO.	ROW NO.	CARD	STUB		OP1 01	OPERAND 1 02	03	04
26	1	C	TABLE TO CHECK IF GRADIENT IS SATISFACTORY					
26	3	1	CGRAD	LE CORGR	Y	N	N	
26	5		NSCG	=0	.	Y	N	
26	7	A	GO TO TABLE 29		X			
26	9		GO TO TABLE 21				X	
26	11		INCREMENT NSC BY	1		X		
26	13		GO TO TABLE 27			X		

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TABLE NO.	ROW NO.	CARD	STUB		OP1 01	OPERAND 1 02	03	04	OP2 05	OPERAND 2 06	07	08	OP3 09	OPERAND 3 10	11	12	OP4 13	OPERAND 4 14	15	16	OP5 17	OPERAND 5 18	19	20	OP6 21	OPERAND 6 22	23	24
27	1	C	TABLE TO CHECK IF SUBCONDUCTOR QUANTITY IS LARGER THAN 4.																									
27	3	I	NSC	GT 4	N	Y																						
27	5	A	DO TABLE 25		X																							
27	7		GO TO TABLE 23		X																							
27	9		GO TO TABLE 21			X																						

5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80

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TABLE NO.	ROW NO	CARD	STUB / ENTRY
29	1	C	TABLE FOR CONDUCTOR LOAD CALCULATION AND EDITING.
29	3	A	INCREMENT ICASE BY 1
29	5		WRITE NPRNT F1 L1
29	7		DO B 1
29	9		WRITE NPRNT F2 L2
29	11		WRITE NPRNT F3
29	13		SET SPAN1=1000.0
29	15		SET J=0
29	17		SET M=0
29	19		SET SPAN2=SPAN1
29	21		GO TO TABLE 30
29		B	1 VLOAD=(3.1416/4*((CDIA+2*X1ICE)**2))*0.39+CWGHT
29			HLOAD=(CDIA+2*X1ICE)/12*WINDL
29			RLOAD=SQRT(VLOAD**2+HLOAD**2)
29		F	FORMAT 1 (1H1//10X,'*** CASE NO ',I2,' ***',32X,'CONDUCTOR TYPE=',
29			12A8/60X,'SUBCONDUCTORS PER PHASE= ',I1)
29		F	FORMAT 2 (///35X,'LOADING CONDITIONS',22X,'CONDUCTOR LOADS (LBS/F
29			1T)'/35X,'********************',22X,'*************************'///29X,
29			2'ICE COATING (INCHES)=',F4.2,17X,'VERTICAL LOAD =',F6.3/29X,
29			3'WIND (LBS/SQ.FT.)=',F5.2,16X,'HORIZONTAL LOAD=',F6.3/29X,
29			4'CONDUCTOR WEIGHT (LBS/FT)=',F5.3,16X,'COMBINED LOAD =',F6.3///)
29		F	FORMAT 3 (/10X,'SPAN',11X,'CONDUCTOR MAX.',11X,'TOWER CROSSARM',12
29			1X,'INSTALLED TOWER COST'/10X,'(FT.)',10X,'TENSION (LBS.)',12X,'HEI

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TABLE NO.	ROW NO.	CARD	STUB / ENTRY
29		2	GHT (FT.)', 16X,'($)', 8X,'($/MILE)'//)
29		L	1 ICASE, CO, TYP, NSC
29		L	2 XIICE, VLOAD, WINDL, HLOAD, CWGHT, RLOAD

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TABLE NO.	ROW NO.	CARD	STUB	ENTRY: OP1, OPERAND 1, OP2, OPERAND 2, OP3, OPERAND 3, OP4, OPERAND 4, OP5, OPERAND 5, OP6, OPERAND 6 (01–24)
30	1	C	TABLE INTRODUCING SPAN OPTIMIZATION ALGORITHM.	
30	3	A	SET TENS1=0.5*CUTS	
30	5		MOVE TENS1 TO TENS2	
30	7		SET TEMP=AVTEMP	
30	9		GO TO TABLE 31	

1 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80

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TABLE NO.	ROW NO.	CARD	STUB	ENTRY
31	1	C	TABLE CALCULATING EVERYDAY TENSION	
31	3	A	DO F 1	
31	5		DO TABLE 33	
31	7		DO F 2	
31	9		GO TO TABLE 35	
31		F	1 TETA1=RLOAD*SPAN2/(8*TENS2)	
31		F	2 EVDT=CWGHT*SPAN2/(8*TETA2)*SQRT(1+16*TETA2**2)	

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TABLE NO.	ROW NO.	CARD	STUB / ENTRY
33	1	C	TABLE FOR SAG/SPAN RATIO DETERMINATION
33	3	A	DO B 1
33	5		CALL ORDER3(A,B,C,X)
33	7		SET TETA2=X
33	9		RETURN
33		B	1 A=-CWGHT*SPAN2/(3.1416*CDIA**2*YOUNG)
33			B=-3.0/8*((1+8*TETA1**2/3)*(1+ALFA*TEMP)-RLOAD*SPAN2*(1+16*TETA1**
33		1	2/3)/(2*TETA1*3.1416*CDIA**2*YOUNG))+3.0/8
33			C=3.0/16*A

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TABLE NO.	ROW NO.	CARD	STUB		OP1 01	OPERAND 1 02	03	04	OP2 05	OPERAND 2 06	07	08	OP3 09	OPERAND 3 10	11	12	OP4 13	OPERAND 4 14	15	16	OP5 17	OPERAND 5 18	19	20	OP6 21	OPERAND 6 22	23	24
35	1	C	TABLE FOR DETERMINATION OF EVERYDAY TENSION COEFFICIENT																									
35	3	I	IF COEVDT	=0	Y	N																						
35	5	A	SET COEVDT=0.22		X																							
35	7		GO TO TABLE 36		X	X																						

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TABLE NO.	ROW NO.	CARD	STUB	01	02	03	04
36	1	C	TABLE CHECKING IF EVD TENSION IS SATISFACTORY				
36	3		IF EVDT LT COEVDT*CUTS	N	Y	N	
36	5		IF M =0	Y	-	N	
36	7	A	INCREMENT TENS2 BY -500.0	X			
36	9		INCREMENT TENS2 BY -100.0			X	
36	11		GO TO TABLE 31	X		X	
36	13		SET TEMP=TOPTMP		X		
36	15		DO TABLE 33		X		
36	17		DO F 1		X		
36	19		GO TO TABLE 37		X		
36		F	1 SAG=SPAN2*TETA2				

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37	1	C	TABLE TO CALCULATE CROSSARM HEIGHT																									
37	3	I	IF ISTRIN	LT 3	Y	N																						
37	5	A	DO F 1		X																							
37	7		DO F 2			X																						
37	9		GO TO TABLE 38		X	X																						
37		F	1 TOHGT=GRDCL+SAG+CLEAR																									
37		F	2 TOHGT=GRDCL+SAG+STRLG																									

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TABLE NO.	ROW NO.	CARD	STUB		OP1 01	OPERAND 1 02	03	04
38	1	C	TABLE TO CALCULATE TOWER COST					
38	3	I	IF TOHGT	LT HTLIM	Y	N	N	Y
38	5	I	IF J	=0	Y	Y	N	N
38	7	A	DO B 1		X			X
38	9		WRITE NPRNT F1 L1		X			X
38	11		SET J=1		X			
38	13		GO TO TABLE 40		X			
38	15		GO TO TABLE 42					X
38	17		WRITE NPRNT F2			X		
38	19		GO TO TABLE 21			X		
38	21		GO TO TABLE 50				X	
38		B	1 TBWL=TENS2					
38			TLOAD=SQRT(TBWL**2+(3*NSC*HLOAD*SPAN2*1.1)**2)					
38			TCOST=TCCOEF*TOHGT*TLOAD**0.667					
38			NTOWS=5280*DIST/SPAN2+1					
38			TTCOS=NTOWS*TCOST/DIST					
38		F	FORMAT 1 (9X,F6.1,13X,F7.1,18X,F5.1,18X,F8.2,4X,F9.2)					
38		F	FORMAT 2 (20X,'** TOWER HEIGHT EXCEEDS TOWER HEIGHT LIMIT **')					
38		L	1 SPAN2,TENS2,TOHGT,TCOST,TTCOS					

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TABLE NO.	ROW NO.	CARD	STUB
40	1	C	TABLE TO STORE RESULTS OF SPAN RUN.
40	3	A	DO B 1
40	5		GO TO TABLE 30
40			B 1 SAG3=SAG
40			TCOST3=TCOST
40			TOHGT3=TOHGT
40			TENS3=TENS2
40			EVDT3=EVDT
40			TBWL3=TBWL
40			NTOWS3=NTOWS
40			TTCOS3=TTCOS
40			SPAN3=SPAN2
40			SPAN2=SPAN2+100

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TABLE NO.	ROW NO.	CARD	STUB		OP1 01	OPERAND 1 02	03	04
42	1	C	TABLE TO CHECK IF OPTIMUM COST IS OBTAINED					
42	3		IF TTCOS	LE TTCOS3	Y	N	N	
42	5		IF M	=0	-	Y	N	
42	7	A	GO TO TABLE 40		X			
42	9		INCREMENT J BY 1			X	X	
42	11		MOVE SPAN3 TO SPAN2			X		
42	13		SET M=1			X		
42	15		GO TO TABLE 43			X	X	

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TABLE NO.	ROW NO.	CARD	STUB	STUB (cont.)	OP1 01	OPERAND 1 02	03	04	OP2 05	OPERAND 2 06	07	08	OP3 09	OPERAND 3 10	11	12	OP4 13	OPERAND 4 14	15	16	OP5 17	OPERAND 5 18	19	20	OP6 21	OPERAND 6 22	23	24
43	1	C	AUXILIARY TABLE TO LOOK FOR OPTIMUM SPAN																									
43	3	I	IF J	LT 5	Y	N																						
43	5	A	GO TO TABLE 50			X																						
43	7		INCREMENT SPAN2 BY 100		X																							
43	9		GO TO TABLE 30		X																							

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TABLE NO.	ROW NO.	CARD	STUB		01	02	03	04
50	1	C	TABLE FOR RIGHT OF WAY WIDTH AND COST DETERMINATION (ONE CIRCUIT)					
50	3	I	IF ISTRIN	LT 3	Y	N	Y	N
50	5	I	IF RWSCOS	=0	Y	Y	N	N
50	7	A	DO F 1		X		X	
50	9		SET RWCOST=0		X	X		
50	11		DO F 2			X		X
50	13		DO F 3				X	X
50	15		GO TO TABLE 52		X	X	X	X
50		F	FORMULA 1 RWWID=FASP+1.41/2*SAG+GRDCL					
50		F	FORMULA 2 RWWID=FASP+1.41/2*(STRLG+SAG) +GRDCL					
50		F	FORMULA 3 RWCOST=RWWID*5280/43560*RWSCOS					

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TABLE NO.	ROW NO.	CARD	STUB		OPERAND 1	OPERAND 2	OPERAND 3	OPERAND 4	OPERAND 5	OPERAND 6
52	1	C	TABLE TO CALCULATE STRINGLOAD							
52	3		IF ISTRIN	=	1	2	3	4	5	6
52	5	A	DO F 1		X	X				
52	7		DO F 2		X	X				
52	9		DO B 1		X					
52	10		DO B 2			X				
52	11		DO B 3				X			
52	13		DO B 4					X		
52	15		DO B 5						X	
52	17		DO B 6							X
52	19		SET K=1		X	X	X	X	X	X
52	21		GO TO TABLE 55		X	X	X	X	X	X
52		F	FORMULA 1 ANGEL=3.1416/2*(1.0-ANGLE/90.0)-ATAN(HLOAD/VLOAD)							
52		F	FORMULA 2 STRLD=RLOAD*SPAN3*NSC*COS(ANGEL)							
52		B	1 STRINS=STRLD							
52			NUMST=6							
52		B	2 STRINS=STRLD/2							
52			NUMST=12							
52		B	3 STRINS=RLOAD*SPAN3*NSC							
52			NUMST=3							
52		B	4 STRINS=RLOAD*SPAN3*NSC/2							
52			NUMST=6							
52		B	5 STRINS=RLOAD*SPAN3*NSC							

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TABLE NO.	ROW NO	CARD	STUB	ENTRY
52			NUMST=4	
52		B	6 STRINS=RLOAD*SPAN3*NSC/2	
52			NUMST=8	

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TABLE NO.	ROW NO.	CARD	STUB	01	02	03	04
55	1	C	TABLE TO SELECT ADEQUATE INSULATOR STRENGTH				
55	3		STRINS LE 0.4*INSSTR(K)	Y	N	N	
55	5		INSSTR(K) =0	-	N	Y	
55	7	A	GO TO TABLE 60	X			
55	9		INCREMENT K BY 1		X	X	
55	11		WRITE NPRNT F1 L1			X	
55	13		CALL EXIT			X	
55	15		GO TO TABLE 55		X		
55		F	FORMAT 1 (//10X,I6,X,'LBS. INSULATOR INADEQUATE TO SUPPORT LINE')				
55		L	1 INSSTR(K-2)				

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TABLE NO.	ROW NO.	CARD	STUB / ENTRY
60	1	C	TABLE TO PRINT OUT RESULTS
60	3	A	DO B 1
60	5		CALL GRACOL
60	6		DO B 2
60	7		WRITE NPRNT F1
60	9		WRITE NPRNT F2 L2
60	11		WRITE NPRNT F3 L3
60	13		WRITE NPRNT F4 L4
60	15		WRITE NPRNT F5 L5
60	17		WRITE NPRNT F6
60	19		WRITE NPRNT F7 L7
60	21		GO TO TABLE 61
60		B	1 TOTINS=IQTTY*NUMST*NTOWS3*COSTIN(K)/DIST
60			TOTCON=NSC*3*5.28*0.975*BAZCOS
60			TINSTA=TTCOS3+RWCOST+TOTINS+TOTCON
60		B	2 RISQ=(MVA/VNOM)**2*CONRES/NSC*1000
60			ACA=TINSTA*ACOIC/100
60			ACB=(RISQ+CORL(1))*365*24*ALOSC/1000*0.65
60			ACC=CORL(5)*DCOC
60			TAC=ACA+ACB+ACC
60		F	FORMAT 1 (///10X,' 1. TRANSMISSION LINE DESIGN DATA.'/15X,'******
60		1	******************'/)

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TABLE NO.	ROW NO.	CARD	STUB / ENTRY
60		F	FORMAT 2 (//25X,'A) INSULATORS',21X,'INSULATOR RATED STRENGTH
60		1	=',I6,' LBS.'/29X,'**********',21X,'INSULATOR QUANTITY PER STRING
60		2	=',I3/)
60		F	FORMAT 3 (/25X,'B) CONDUCTOR',22X,'MAX. CONDUCTOR TENSION =',
60		1	F8.1,' LBS. (AT 0 DEG.F.,ICE+WIND)'/29X,'*********',22X,'CONDUCTOR
60		2	EVERY DAY TENSION=',F8.1,' LBS. (AT ',F5.1,' DEG.F.,NO ICE, NO WI
60		3	ND)'/60X,'MAX. CONDUCTOR SAG =',F8.1,' FT. (AT ',F5.1,' DE
60		4	G.F.)'/)
60		F	FORMAT 4 (/25X,'C) TOWER',26X,'CONDUCTOR TO STRUCTURE CLEARANCE='
60		1	,I4,' IN.'/29X,'*****',26X,'PHASE SPACING =',I4,
60		2	' FT.'/60X,'BROKEN WIRE LOAD =',F8.1,' LBS.'/60X,'C
60		3	ROSSARM HEIGHT =',F6.1,' FT.'/)
60		F	FORMAT 5 (/25X,'D) LINE',27X,'TOWER QUANTITY =',I4/29X,'****'
60		1	,27X,'RIGHT OF WAY WIDTH =',F6.1,' FT.'//60X,'LOSSES=',10X,'RESIST
60		2	IVE LOSSES =',F6.1,' KW/3-PHASE MILE'/77X,'AVERAGE ANNUAL
60		3	CORONA LOSS=',F6.1,8X,'ID.'/77X,' 15 PCT. ID. =',F6.
60		4	1,8X,'ID.'/77X,' 10 PCT. ID. =',F6.1,8X,'ID.'/77X,'
60		5	5 PCT. ID. =',F6.1,8X,'ID.'/77X,' 2 PCT. ID.
60		6	=',F6.1,8X,'ID.'/77X,' 0 PCT. ID. =',F6.1,8X,'
60		7	ID.'/)

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TABLE NO.	ROW NO.	CARD	STUB / ENTRY
60		F	FORMAT 6 (///10X,' 2. TRANSMISSION LINE COST DATA.'/15X,'********
60		1	**********************')
60		F	FORMAT 7 (//15X,' INSTALLED COST. ',50X,'ANNUAL CHARGES.'/16X,'($/
60		1	3-PHASE MILE)',46X,'($/3-PHASE MILE/YEAR)'//15X,'INSULATORS =',F
60		2	9.2,40X,F4.1,' PCT. CHARGE ON CAPITAL =',F9.2/15X,'TOWER
60		3	S =',F9.2,40X,F4.2,' MILLS/KWH ON LOSSES =',F9.
60		4	2/15X,'CONDUCTOR =',F9.2,40X,F4.1,' $/KW CORONA DEMAND CHARGE
60		5	=,F9.2/15X,'RIGHT OF WAY =',F9.2,40X,'(2 PCT. PROB.)'/29X,'-
60		6	---------',79X,'----------'//5X,'TOTAL INSTALLED COST =',F9.2,56X,
60		7	'TOTAL ANNUAL CHARGES =',F9.2)
60		L	2 INSSTR(K),IQTTY
60		L	3 TENS3,EVDT3,AVTEMP,SAG3,TOPTMP
60		L	4 ICLEAR,IFASP,TBWL3,TOHGT3
60		L	5 NTOWS3,RWWID,RISQ,CORL(1),CORL(2),CORL(3),CORL(4),CORL(5),CORL
60		1	(6)
60		L	7 TOTINS,ACOIC,ACA,TTCOS3,ALOSC,ACB,TOTCON,DCOC,ACC,RWCOST,TINST
60		1	A,TAC

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TABLE NO.	ROW NO.	CARD	STUB		OP1 01	OPERAND 1 02	03	04	OP2 05
61	1	C	TABLE TO CHECK IF	SUBCOND.	Q	T	T	Y =	4
61	3	I	NSC	LT 4	Y	N			
61	5	A	DO B 1		X				
61	7		INCREMENT NSC BY	1	X				
61	9		GO TO TABLE 55		X				
61	11		GO TO TABLE 21			X			
61		B	1 STRINS=STRINS	*(NSC+1)/NSC					
61			K=1						
		S	END						

COMMENTS

```
TLDT PROGRAM                                                              PAGE 001

      OPTION PUNCH
    CTRANSMISSION LINE DESIGN USING DECISION TABLES BY GUY VAN UYTVEN        TLDT0001
       COMMON CLEAR,STRLG,IQTTY,PFAC,WIDTS,WIDLG,RDENS,SURGFO,VNUM           TLDT0002
       COMMON NTOWS,CSSFO,SSIGMA,DIST,FOPROB,NPRNT,NCRDR                     TLDT0003
       COMMON TOWRS,CFUSTR,CFOTS,CFOLG,ISTRIN                                TLDT0004
       COMMON CDIA,GRDCL,FASP,NSC,CGRAD,CORGR,BUNSP,SURFC,SAG,LBC,OUTG,CTTLDT0005
      1RG,CORL(6)                                                            TLDT0006
       DIMENSION INSSTR(4),COSTIN(4)                                         TLDT0007
       DATA INSSTR/25000,36000,50000,0/                                      TLDT0008
       DATA COSTIN/4.74,5.74,9.30,0/                                         TLDT0009

TABLE 010  INPUT

    10 1UNCONDITIONAL TABLE TO READ INPUT DATA
    10 3 READ NCRDR  F1 L1
    10 5 READ NCRDR  F2 L2
    10 7 READ NCRDR  F3 L3
    10 9 READ NCRDR  F4 L4
    1011 READ NCRDR  F5 L5
    1013 GO TO TABLE 11
    10   FFORMAT 1 (12F6.2)
    10   FFORMAT 2 (7F6.1)
    10   FFORMAT 3 (2I1,2I5,I1,I4,I1)
    10   FFORMAT 4 (2F5.2,2F5.1,2E15.7,F5.1,F5.2,F5.3)
    10   FFORMAT 5 (3F5.2)
    10  L 1  VNUM,VMAX,DIST,PFAC,CLEAR,FASP,CREEP,SLENT,WIDTS,WIDLG,RDENS,S
    10   1URFC
    10  L 2  SSMAX,CSSFO,SSIGMA,GRDCL,BUNSP,ANGLE,RWSCOS
    10  L 3  IHCOUNT,ISTRIN,IDFOPR,NTOWS,NSCG,MVA,LBC
    10  L 4  XIICE,WINDL,AVTEMP,TOPTMP,ALFA,YOUNG,HTLIM,COEVDT,TCCOEF
    10  L 5  ACOIC,ALUSC,DCOC

TABLE 010 OUTPUT

    C                       TABLE 010                                        TLDT0010
    CUNCONDITIONAL TABLE TO READ INPUT DATA                                  TLDT0011
    C                       RULE 01                                          TLDT0012
    01000 READ(NCRDR,01003)VNUM,VMAX,DIST,PFAC,CLEAR,FASP,CREEP,SLENT,WIDTS,TLDT0013
         1WIDLG,RDENS,SURFC                                                  TLDT0014
    01003 FORMAT(12F6.2)                                                     TLDT0015
          READ(NCRDR,01004)SSMAX,CSSFO,SSIGMA,GRDCL,BUNSP,ANGLE,RWSCOS       TLDT0016
    01004 FORMAT(7F6.1)                                                      TLDT0017
          READ(NCRDR,01005)IHCOUNT,ISTRIN,IDFOPR,NTOWS,NSCG,MVA,LBC          TLDT0018
```

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TLDT PROGRAM                                                                  PAGE 002

      01005 FORMAT(2I1,2I5,I1,I4,I1)                                     TLDT0019
            READ(NCRDR,01006)XIICE,WINDL,AVTEMP,TOPTMP,ALFA,YOUNG,HTLIM,COEVDTTLDT0020
           1,TCCOEF                                                      TLDT0021
      01006 FORMAT(2F5.2,2F5.1,2E15.7,F5.1,F5.2,F5.3)                     TLDT0022
            READ(NCRDR,01007)ACOIC,ALOSC,DCOC                            TLDT0023
      01007 FORMAT(3F5.2)                                                TLDT0024
            GO TO 01100                                                  TLDT0025
```

```
TLDT PROGRAM                                                                 PAGE 003

TABLE 011   INPUT

     11 1CSTRING LENGTH AND INSULATOR QUANTITY DETERMINATION
     11 3 IF IQTTY          =0       Y       Y       Y       Y       N       N
     11 5 IF CREEP          =0       Y       Y       N       N       Y       N
     11 7 IF IHCONT         =0       Y       N       Y       N       .       .
     11 9ASET SC            =        0.9     1.0     0.9     1.0     0.9     0.9
     1111 SET CREEP         =12.0    X       X                       X
     1113 SET SLENT         =5.75    X       X                       X
     1115 DO FORMULA 1               X       X       X       X
     1117 DO FORMULA 2               X       X       X       X       X       X
     1119 GO TO TABLE 12             X       X       X       X       X       X
     11   FFORMULA 1    IQTTY=VMAX*SC/CREEP/1.73+0.5
     11   FFORMULA 2    STRLG=IQTTY*SLENT/12

TABLE 011 OUTPUT

    C                              TABLE 011                                TLDT0026
    CSTRING LENGTH AND INSULATOR QUANTITY DETERMINATION                     TLDT0027
    01100 IF(IQTTY                              )01103,01104,01103          TLDT0028
    01104 IF(CREEP                              )01105,01106,01105          TLDT0029
    01105 IF(IHCONT                             )01107,01108,01107          TLDT0030
    01103 IF(IHCONT                             )01109,01110,01109          TLDT0031
    01103 IF(CREEP                              )01111,01112,01111          TLDT0032
    C                              RULE 01                                  TLDT0033
    01108 SC=0.9                                                            TLDT0034
          CREEP=12.0                                                        TLDT0035
          SLENT=5.75                                                        TLDT0036
          IQTTY=VMAX*SC/CREEP/1.73+0.5                                      TLDT0037
          STRLG=IQTTY*SLENT/12                                              TLDT0038
          GO TO 01200                                                       TLDT0039
    C                              RULE 02                                  TLDT0040
    01107 SC=1.0                                                            TLDT0041
          CREEP=12.0                                                        TLDT0042
          SLENT=5.75                                                        TLDT0043
          IQTTY=VMAX*SC/CREEP/1.73+0.5                                      TLDT0044
          STRLG=IQTTY*SLENT/12                                              TLDT0045
          GO TO 01200                                                       TLDT0046
    C                              RULE 03                                  TLDT0047
    01110 SC=0.9                                                            TLDT0048
          IQTTY=VMAX*SC/CREEP/1.73+0.5                                      TLDT0049
          STRLG=IQTTY*SLENT/12                                              TLDT0050
```

```
TLDT PROGRAM                                                        PAGE 004

      GO TO 01200                                         TLDT0051
C                             RULE 04                     TLDT0052
01109 SC=1.0                                              TLDT0053
      IQTTY=VMAX*SC/CREEP/1.73+0.5                        TLDT0054
      STRLG=IQTTY*SLENT/12                                TLDT0055
      GO TO 01200                                         TLDT0056
C                             RULE 05                     TLDT0057
01112 SC=0.9                                              TLDT0058
      CREEP=12.0                                          TLDT0059
      SLENT=5.75                                          TLDT0060
      STRLG=IQTTY*SLENT/12                                TLDT0061
      GO TO 01200                                         TLDT0062
C                             RULE 06                     TLDT0063
01111 SC=0.9                                              TLDT0064
      STRLG=IQTTY*SLENT/12                                TLDT0065
      GO TO 01200                                         TLDT0066
```

TLDT PROGRAM PAGE 005

TABLE 012 INPUT

```
12 1CPRELIMINARY STRUCTURE CLEARANCE DETERMINATION AND CORRESPONDING LINE
12 2CFLASHOVER EXPECTANCY CALCULATION.
12 3IIF CLEAR           =0          N Y Y
12 5 IF VNUM            LT 500      . Y N
12 7ADD TABLE 13                      X X
12 9 DO FORMULA 1                     X
1211 DO FORMULA 2                       X
1213 SET N=C                          X X
1215 GO TABLE 14                    X X X
1217 GO TO TABLE 16                   X X
1219 GO TO TABLE 20                 X
12   FFORMULA 1    CLEAR=2.5/155*(VNUM-345)+7.5
12   FFORMULA 2    CLEAR=8.0/235*(VNUM-500)+10
```

TABLE 012 OUTPUT

```
C                               TABLE 012                               TLDT0067
CPRELIMINARY STRUCTURE CLEARANCE DETERMINATION AND CORRESPONDING LINE   TLDT0068
CFLASHOVER EXPECTANCY CALCULATION.                                      TLDT0069
01203 IF(CLEAR                             )01204,01203,01204           TLDT0070
01203 IF(VNUM              -(500           ))01206,01205,01205          TLDT0071
C                               RULE 01                                 TLDT0072
01204 JJJ014= 01                                                        TLDT0073
      GO TO 01400                                                       TLDT0074
01207 GO TO 02000                                                       TLDT0075
C                               RULE 02                                 TLDT0076
01206 JJJ013= 01                                                        TLDT0077
      GO TO 01300                                                       TLDT0078
01208 CLEAR=2.5/155*(VNUM-345)+7.5                                      TLDT0079
      N=0                                                               TLDT0080
      JJJ014= 02                                                        TLDT0081
      GO TO 01400                                                       TLDT0082
01209 GO TO 01600                                                       TLDT0083
C                               RULE 03                                 TLDT0084
01205 JJJ013= 02                                                        TLDT0085
      GO TO 01300                                                       TLDT0086
01210 CLEAR=8.0/235*(VNUM-500)+10                                       TLDT0087
      N=0                                                               TLDT0088
      JJJ014= 03                                                        TLDT0089
      GO TO 01400                                                       TLDT0090
```

```
TLDT PROGRAM                                                    PAGE 006

     01211 GO TO 01600                                     TLDT0091
```

TLDT PROGRAM   PAGE 007

TABLE 013 INPUT

```
13 1CTHIS TABLE DETERMINES THE MEAN SWITCHING SURGE AND STANDARD DEVIATION.
13 311F SSMAX         =0          Y N
13 5ACD BLOCK 1                     X
13 7 RETURN                       X X
13   8BLOCK 1     SSIGMA=(SSMAX-VNOM/1.73*1.41)/6
13                 CSSFO=SSMAX-3*SSIGMA
```

TABLE 013 OUTPUT

```
C                          TABLE 013                                TLDT0092
CTHIS TABLE DETERMINES THE MEAN SWITCHING SURGE AND STANDARD DEVIATION. TLDT0093
01300 IF(SSMAX                         )01303,01304,01303           TLDT0094
C                          RULE 01                                  TLDT0095
01304 GO TO 01302                                                   TLDT0096
C                          RULE 02                                  TLDT0097
01303 SSIGMA=(SSMAX-VNOM/1.73*1.41)/6                               TLDT0098
      CSSFO=SSMAX-3*SSIGMA                                          TLDT0099
      GO TO 01302                                                   TLDT0100
C                          OUT OF LINE                              TLDT0101
01302 GO TO(C1208,01210),JJJ013                                     TLDT0102
```

TLDT PROGRAM PAGE 008

TABLE 014 INPUT

```
14 1CFLASHOVER EXPECTANCY CALCULATION AND PRINTING OF RESULTS
14 3ASET ICLEAR=12*CLEAR
14 5 WRITE NPRNT F1 L1
14 7 CALL FOEXPL
14 9 WRITE NPRNT F2 L2
1411 RETURN
14   FFORMAT 1 (1H1/10X,'CONDUCTOR-STRUCTURE CLEARANCE DETERMINATION'//1
14   10X,I3,' INCH CLEARANCE',20X,'LINE FLASHOVER EXPECTANCY CALCULATION
14   2')
14   FFORMAT 2 (////60X,'LINE FLASHOVER EXPECTANCY = ',F10.8///60X,'THIS
14   1 LINE FLASHOVER EXPECTANCY IS EQUIVALENT'/60X,'TO ',F10.0,'SWITCHI
14   2NG SURGES PER FLASHOVER.'/60X,'NOTE= THE DESIRED EXPECTANCY IS ',I
14   310,' SURGES'/60X,'PER FLASHOVER.')
14   LLIST 1  ICLEAR
14   LLIST 2  FOPROB,SURGFO,IDFOPR
```

TABLE 014 OUTPUT

```
C                            TABLE 014                                  TLDT0103
CFLASHOVER EXPECTANCY CALCULATION AND PRINTING OF RESULTS                TLDT0104
C                            RULE 01                                    TLDT0105
01400 ICLEAR=12*CLEAR                                                   TLDT0106
      WRITE(NPRNT,01403)ICLEAR                                          TLDT0107
01403 FORMAT(1H1/10X,'CONDUCTOR-STRUCTURE CLEARANCE DETERMINATION'//1   TLDT0108
     10X,I3,' INCH CLEARANCE',20X,'LINE FLASHOVER EXPECTANCY CALCULATIONTLDT0109
     2')                                                                TLDT0110
      CALL FOEXPL                                                       TLDT0111
      WRITE(NPRNT,01404)FOPROB,SURGFO,IDFOPR                            TLDT0112
01404 FORMAT(////60X,'LINE FLASHOVER EXPECTANCY = ',F10.8///60X,'THIS   TLDT0113
     1LINE FLASHOVER EXPECTANCY IS EQUIVALENT'/60X,'TO ',F10.0,'SWITCHI TLDT0114
     2NG SURGES PER FLASHOVER.'/60X,'NOTE= THE DESIRED EXPECTANCY IS ',ITLDT0115
     310,' SURGES'/60X,'PER FLASHOVER.')                                TLDT0116
      GO TO(01207,01209,01211),JJJ014                                   TLDT0117
```

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```
TLDT PROGRAM                                                              PAGE 009


TABLE 016  INPUT

      16 1CONDUCTOR-STRUCTURE CLEARANCE DETERMINATION
      16 3IIF SURGED          GT IDFUPR Y N Y
      16 5 IF N                =2       N . Y
      16 7AINCREMENT CLEAR BY 0.5         X
      16 9 GO TO TABLE 17                 X
      1611 WRITE NPRNT F1 L1                X
      1613 GO TO TABLE 20                   X
      1615 SET N=1                        X
      1617 INCREMENT CLEAR BY -0.5        X
      1619 GO TABLE 14                    X
      1621 GO TO TABLE 16                 X
      16   FFORMAT 1 ('CONDUCTOR-STRUCTURE CLEARANCE (FEET)=',F5.2)
      16   LLIST 1  CLEAR


TABLE 016 OUTPUT

     C                          TABLE 016                                 TLDT0118
     CCONDUCTOR-STRUCTURE CLEARANCE DETERMINATION                         TLDT0119
     01600 IF(SURGED          -(IDFUPR          ))01603,01603,01604       TLDT0120
     01604 IF(N               -(2               ))01606,01605,01606       TLDT0121
     C                          RULE 01                                   TLDT0122
     01606 N=1                                                            TLDT0123
           CLEAR=CLEAR+(-0.5)                                             TLDT0124
           JJJJ14= 01                                                     TLDT0125
           GO TO C1400                                                    TLDT0126
     01607 GO TO 01600                                                    TLDT0127
     C                          RULE 02                                   TLDT0128
     01603 CLEAR=CLEAR+(0.5)                                              TLDT0129
           GO TO 01700                                                    TLDT0130
     C                          RULE 03                                   TLDT0131
     01605 WRITE(NPRNT,01608)CLEAR                                        TLDT0132
     01608 FORMAT('CONDUCTOR-STRUCTURE CLEARANCE (FEET)=',F5.2)           TLDT0133
           GO TO 02000                                                    TLDT0134
```

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```
TLDT PROGRAM                                                                PAGE 010

TABLE 017  INPUT

      17 111F N              =1         Y N
      17 3AWRITE NPRNT F1 L1            X
      17 5 GO TO TABLE 20               X
      17 7 SET N=2                        X
      17 9 GO TABLE 14                    X
      1711 GO TO TABLE 16                 X
      17  FFORMAT 1  ('CONDUCTOR-STRUCTURE CLEARANCE (FEET)=',F5.2)
      17  LLIST 1  CLEAR

TABLE 017 OUTPUT

     C                            TABLE 017                             TLDT0135
     01700 IF(N             -(1              ))01703,01704,01703        TLDT0136
     C                            RULE 01                               TLDT0137
     01704 WRITE(NPRNT,01705)CLEAR                                      TLDT0138
     01705 FORMAT('CONDUCTOR-STRUCTURE CLEARANCE (FEET)=',F5.2)         TLDT0139
           GO TO 02000                                                  TLDT0140
     C                            RULE 02                               TLDT0141
     01703 N=2                                                          TLDT0142
           JJJ014= 02                                                   TLDT0143
           GO TO 01400                                                  TLDT0144
     01706 GO TO C1600                                                  TLDT0145
```

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```
TLDT PROGRAM                                                                  PAGE 011

TABLE 020  INPUT

     20 1CPHASE SPACING DETERMINATION
     20 3 FASP             =0           N        Y         Y         Y
     20 5 ISTRIN                        .       LT 3      GT 4       E
     20 7ASET CUF=                                2.6       3.65      3.9
     20 9 SET FASP=COF*CLEAR                     X         X         X
     2011 GO B 1                        X        X         X         X
     2013 GO TO TABLE 21                X        X         X         X
     20  B 1     IFASP=FASP+0.6
     20          FASP=IFASP
     20          ICLEAR=12*CLEAR
     20          ICASE=0

TABLE 020 OUTPUT

    C                               TABLE 020                                 TLDT0146
    CPHASE SPACING DETERMINATION                                              TLDT0147
    02000 IF(FASP                                )02004,02003,02004           TLDT0148
    02003 IF(ISTRIN          -(3                 ))02006,02005,02005          TLDT0149
    02005 IF(ISTRIN          -(4                 ))02007,02007,02008          TLDT0150
    C                               RULE 01                                   TLDT0151
    02004 III020= 01                                                          TLDT0152
          GO TO 02009                                                         TLDT0153
    02010 GO TO 02100                                                         TLDT0154
    C                               RULE 02                                   TLDT0155
    02006 CUF=2.6                                                             TLDT0156
          FASP=CUF*CLEAR                                                      TLDT0157
          III020= 02                                                          TLDT0158
          GO TO 02009                                                         TLDT0159
    02011 GO TO 02100                                                         TLDT0160
    C                               RULE 03                                   TLDT0161
    02008 CUF=3.65                                                            TLDT0162
          FASP=CUF*CLEAR                                                      TLDT0163
          III020= 03                                                          TLDT0164
          GO TO 02009                                                         TLDT0165
    02012 GO TO 02100                                                         TLDT0166
    C                               RULE 04                                   TLDT0167
    02007 CUF=3.9                                                             TLDT0168
          FASP=CUF*CLEAR                                                      TLDT0169
          III020= 04                                                          TLDT0170
          GO TO 02009                                                         TLDT0171
```

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TLDT PROGRAM PAGE 012

```
02013 GO TO 02100                                      TLDT0172
C                        OUT OF LINE                   TLDT0173
02009 IFASP=FASP+0.6                                   TLDT0174
      FASP=IFASP                                       TLDT0175
      ICLEAR=12*CLEAR                                  TLDT0176
      ICASE=0                                          TLDT0177
      GO TO(02010,02011,02012,02013),III020            TLDT0178
```

TLDT PROGRAM PAGE 013

TABLE 021 INPUT

```
21 1CONCONDITIONAL TABLE USED TO READ CONDUCTOR DATA
21 3AREAD NCRDR F1 L1
21 5 SET CWGHT=AWGHT+SWGHT
21 7 GO TO TABLE 22
21  FFORMAT 1 (2A8,3F5.3,I5,F8.1,F6.2,F6.4)
21  L 1  CO,TYP,CDIA,AWGHT,SWGHT,ICCCC,CUTS,BAZCOS,CONRES
```

TABLE 021 OUTPUT

```
C                              TABLE 021                                 TLDT0179
CONCONDITIONAL TABLE USED TO READ CONDUCTOR DATA                         TLDT0180
C                              RULE 01                                   TLDT0181
02100 READ(NCRDR,02103)CO,TYP,CDIA,AWGHT,SWGHT,ICCCC,CUTS,BAZCOS,CONRES  TLDT0182
02103 FORMAT(2A8,3F5.3,I5,F8.1,F6.2,F6.4)                                TLDT0183
      CWGHT=AWGHT+SWGHT                                                  TLDT0184
      GO TO 02200                                                        TLDT0185
```

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```
TLDT PROGRAM                                                                  PAGE 014

TABLE 022  INPUT

      22 1CTABLE CALCULATING THE SUBCONDUCTOR CURRENT
      22 31CDIA              =0         Y N N
      22 5 NSCG              =0         . Y N
      22 7ACALL EXIT                    X
      22 9 SET NSC=1                      X
      2211 SET NSC=NSCG                     X
      2213 GO TABLE 25                    X X
      2215 GO TO TABLE 23                 X X

TABLE 022 OUTPUT

     C                          TABLE 022                                 TLDT0186
     CTABLE CALCULATING THE SUBCONDUCTOR CURRENT                          TLDT0187
     02200 IF(CDIA                         )02203,02204,02203             TLDT0188
     02203 IF(NSCG                         )02205,02206,02205             TLDT0189
     C                          RULE 01                                   TLDT0190
     02204 CALL EXIT                                                      TLDT0191
     C                          RULE 02                                   TLDT0192
     02206 NSC=1                                                          TLDT0193
           JJJ025= 01                                                     TLDT0194
           GO TO 02500                                                    TLDT0195
     02207 GO TO 02300                                                    TLDT0196
     C                          RULE 03                                   TLDT0197
     02205 NSC=NSCG                                                       TLDT0198
           JJJ025= 02                                                     TLDT0199
           GO TO 02500                                                    TLDT0200
     02208 GO TO 02300                                                    TLDT0201
```

```
TLDT PROGRAM                                                            PAGE 015

TABLE 023  INPUT

     23 1CTABLE FOR CONDUCTOR SURFACE GRADIENT CALCULATION
     23 3ICURNT          LE ICCCC   Y N N
     23 5 NSCG           =0         . Y N
     23 7ACALL GRADNT               X
     23 9 INCREMENT NSC BY 1          X
     2311 GO TO TABLE 21                X
     2313 GO TO TABLE 26            X
     2315 GO TO TABLE 27              X

TABLE 023 OUTPUT

    C                          TABLE 023                          TLDT0202
    CTABLE FOR CONDUCTOR SURFACE GRADIENT CALCULATION             TLDT0203
    02300 IF(CURNT          -(ICCCC          ))02304,02304,02303  TLDT0204
    02303 IF(NSCG                             )02305,02306,02305  TLDT0205
    C                          RULE 01                            TLDT0206
    02304 CALL GRADNT                                             TLDT0207
          GO TO 02600                                             TLDT0208
    C                          RULE 02                            TLDT0209
    02306 NSC=NSC+(1)                                             TLDT0210
          GO TO 02700                                             TLDT0211
    C                          RULE 03                            TLDT0212
    02305 GO TO 02100                                             TLDT0213
```

```
TLDT PROGRAM                                                          PAGE 016

TABLE 025  INPUT

    25 1CFORMULA USED FOR SUBCONDUCTOR CURRENT CALCULATION
    25 3ADD FORMULA 1                     X
    25 5 RETURN                           X
    25  FFORMULA 1  CURNT=MVA*1000.0/(1.73*VNGM*NSC)

TABLE 025 OUTPUT

   C                           TABLE 025                           TLDT0214
   CFORMULA USED FOR SUBCONDUCTOR CURRENT CALCULATION              TLDT0215
   C                           RULE 01                             TLDT0216
   02500 CURNT=MVA*1000.0/(1.73*VNUM*NSC)                          TLDT0217
         GO TO(02207,02208),JJJ025                                 TLDT0218
```

```
TLDT PROGRAM                                                                                PAGE 017

TABLE 026  INPUT

      26 1CTABLE TO CHECK IF GRADIENT IS SATISFACTORY
      26 31CGRAD           LE CORGR  Y N N
      26 5 NSCG            =0        . Y N
      26 7AGO TO TABLE 29           X
      26 9 GO TO TABLE 21              X
      2611 INCREMENT NSC BY 1         X
      2613 GO TO TABLE 27             X

TABLE 026 OUTPUT

     C                         TABLE 026                                  TLDT0219
     CTABLE TO CHECK IF GRADIENT IS SATISFACTORY                          TLDT0220
     02600 IF(CGRAD          -(CORGR          ))02604,02604,02603         TLDT0221
     02603 IF(NSCG                             )02605,02606,02605         TLDT0222
     C                         RULE 01                                    TLDT0223
     02604 GO TO 02900                                                    TLDT0224
     C                         RULE 02                                    TLDT0225
     02606 NSC=NSC+(1)                                                    TLDT0226
           GO TO 02700                                                    TLDT0227
     C                         RULE 03                                    TLDT0228
     02605 GO TO 02100                                                    TLDT0229
```

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```
TLDT PROGRAM                                                              PAGE 018

TABLE 027  INPUT

     27 1CTABLE TO CHECK IF SUBCONDUCTOR QTTY IS LARGER THAN 4
     27 31NSC              GT 4        N Y
     27 5ADD TABLE 25                   X
     27 7 GO TO TABLE 23                X
     27 9 GO TO TABLE 21                  X

TABLE 027 OUTPUT

    C                               TABLE 027                                  TLDT0230
    CTABLE TO CHECK IF SUBCONDUCTOR QTTY IS LARGER THAN 4                      TLDT0231
    02700 IF(NSC              -(4                ))02704,02704,02703           TLDT0232
    C                               RULE 01                                    TLDT0233
    02704 JJJ025= 01                                                           TLDT0234
          GO TO 02500                                                          TLDT0235
    02705 GO TO 02300                                                          TLDT0236
    C                               RULE 02                                    TLDT0237
    02703 GO TO 02100                                                          TLDT0238
```

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TLDT PROGRAM PAGE 019

TABLE 029 INPUT

```
29 1CTABLE FOR CONDUCTOR LOAD CALCULATION AND EDITING
29 3AINCREMENT ICASE BY 1
29 5 WRITE NPRNT F1 L1
29 7 DO 8 1
29 9 WRITE NPRNT F2 L2
2911 WRITE NPRNT F3
2913 SET SPAN1=1000.0
2915 SET J=0
2917 SET M=0
2919 SET SPAN2=SPAN1
2921 GO TO TABLE 30
29 8 1   VLOAD=(3.1416/4*((CDIA+2*XIICE)**2))*0.39+CWGHT
29       HLOAD=(CDIA+2*XIICE)/12*WINDL
29       RLOAD=SQRT(VLOAD**2+HLOAD**2)
29  FFORMAT 1 (1H1//10X,'*** CASE NO ',I2,' ***',32X,'CONDUCTOR TYPE=',
29  12A8/80X,'SUBCONDUCTORS PER PHASE= ',I1)
29  FFORMAT 2  (///35X,'LOADING CONDITIONS',22X,'CONDUCTOR LOADS (LBS/F
29  1T)'/35X,'******************',22X,'*************************'///29X,
29  2'ICE COATING       (INCHES)=',F4.2,17X,'VERTICAL LOAD  =',F6.3/29X,
29  3'WIND          (LBS/SQ.FT.)=',F5.2,16X,'HORIZONTAL LOAD=',F6.3/29X,
29  4'CONDUCTOR WEIGHT (LBS/FT)=',F5.3,16X,'COMBINED LOAD  =',F6.3///)
29  FFORMAT 3 (/10X,'SPAN',11X,'CONDUCTOR MAX.',11X,'TOWER CROSSARM',12
29  1X,'INSTALLED TOWER COST'/10X,'(FT.)',10X,'TENSION (LBS.)',12X,'HEI
29  2GHT (FT.)',16X,'($)',8X,'($/MILE)'//)
29  L 1  ICASE,CO,TYP,NSC
29  L 2  XIICE,VLOAD,WINDL,HLOAD,CWGHT,RLOAD
```

TABLE 029 OUTPUT

```
C                      TABLE 029                                   TLDT0239
CTABLE FOR CONDUCTOR LOAD CALCULATION AND EDITING                   TLDT0240
C                      RULE 01                                     TLDT0241
02900 ICASE=ICASE+(1)                                              TLDT0242
      WRITE(NPRNT,02903)ICASE,CO,TYP,NSC                           TLDT0243
02903 FORMAT(1H1//10X,'*** CASE NO ',I2,' ***',32X,'CONDUCTOR TYPE=',  TLDT0244
     12A8/80X,'SUBCONDUCTORS PER PHASE= ',I1)                      TLDT0245
      VLOAD=(3.1416/4*((CDIA+2*XIICE)**2))*0.39+CWGHT              TLDT0246
      HLOAD=(CDIA+2*XIICE)/12*WINDL                                TLDT0247
      RLOAD=SQRT(VLOAD**2+HLOAD**2)                                TLDT0248
      WRITE(NPRNT,02904)XIICE,VLOAD,WINDL,HLOAD,CWGHT,RLOAD        TLDT0249
```

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```
TLDT PROGRAM                                                                          PAGE 020

      02904 FORMAT(///35X,'LOADING CONDITIONS',22X,'CONDUCTOR LOADS (LBS/F     TLDT0250
           1T)'/35X,'******************',22X,'*************************'///29X,TLDT0251
           2'ICE COATING       (INCHES)=',F4.2,17X,'VERTICAL LOAD   =',F6.3/29X,TLDT0252
           3'WIND          (LBS/SQ.FT.)=',F5.2,16X,'HORIZONTAL LOAD=',F6.3/29X,TLDT0253
           4'CONDUCTOR WEIGHT (LBS/FT)=',F5.3,16X,'COMBINED LOAD   =',F6.3///) TLDT0254
            WRITE(NPRNT,02905)                                                 TLDT0255
      02905 FCRMAT(/10X,'SPAN',11X,'CONDUCTOR MAX.',11X,'TOWER CROSSARM',12    TLDT0256
           1X,'INSTALLED TOWER COST'/10X,'(FT.)',10X,'TENSION (LBS.)',12X,'HEITLDT0257
           2GHT (FT.)',16X,'($)',8X,'($/MILE)'//)                              TLDT0258
            SPAN1=1000.0                                                       TLDT0259
            J=0                                                                TLDT0260
            M=0                                                                TLDT0261
            SPAN2=SPAN1                                                        TLDT0262
            GO TO 03000                                                        TLDT0263
```

TLDT PROGRAM PAGE 021

TABLE 030 INPUT

```
30 1CTABLE INTRODUCING SPAN OPTIMIZATION ALGORITHM
30 3ASET TENS1=0.5*CUTS
30 5 MOVE TENS1 TO TENS2
30 7 SET TEMP=AVTEMP
30 9 GO TO TABLE 31
```

TABLE 030 OUTPUT

```
C                                  TABLE 030                             TLDT0264
CTABLE INTRODUCING SPAN OPTIMIZATION ALGORITHM                           TLDT0265
C                                  RULE 01                               TLDT0266
03000 TENS1=0.5*CUTS                                                     TLDT0267
      TENS2=TENS1                                                        TLDT0268
      TEMP=AVTEMP                                                        TLDT0269
      GO TO 03100                                                        TLDT0270
```

```
TLDT PROGRAM                                                        PAGE 022

TABLE 031  INPUT

     31 1CTABLE CALCULATING EVERYDAY TENSION
     31 3ACC F 1
     31 5 GO TABLE 33
     31 7 GO F 2
     31 9 GO TO TABLE 35
     31   F 1    TETA1=RLOAD*SPAN2/(8*TENS2)
     31   F 2    EVDT=(WGHT*SPAN2/(8*TETA2)*SQRT(1+16*TETA2**2)

TABLE 031 OUTPUT

    C                            TABLE 031                TLDT0271
    CTABLE CALCULATING EVERYDAY TENSION                   TLDT0272
    C                            RULE 01                  TLDT0273
    03100 TETA1=RLOAD*SPAN2/(8*TENS2)                     TLDT0274
          JJJ033= 01                                      TLDT0275
          GO TO 03300                                     TLDT0276
    03103 EVDT=(WGHT*SPAN2/(8*TETA2)*SQRT(1+16*TETA2**2)  TLDT0277
          GO TO 03500                                     TLDT0278
```

```
TLDT PROGRAM                                                             PAGE 023

TABLE 033  INPUT

     33 1CTABLE FOR SAG/SPAN RATIO DETERMINATION
     33 3ADD B 1
     33 5 CALL ORDER3(A,B,C,X)
     33 7 SET TETA2=X
     33 9 RETURN
     33  B 1  A=-CWGHT*SPAN2/(3.1416*CDIA**2*YOUNG)
     33    B=-3.0/8*((1+8*TETA1**2/3)*(1+ALFA*TEMP)-RLOAD*SPAN2*(1+16*TETA1**
     33  12/3)/(2*TETA1*3.1416*CDIA**2*YOUNG))+3.0/8
     33    C=3.0/16*A

TABLE 033 OUTPUT

    C                             TABLE 033                         TLDT0279
    CTABLE FOR SAG/SPAN RATIO DETERMINATION                         TLDT0280
    C                             RULE 01                           TLDT0281
    03300 A=-CWGHT*SPAN2/(3.1416*CDIA**2*YOUNG)                      TLDT0282
          B=-3.0/8*((1+8*TETA1**2/3)*(1+ALFA*TEMP)-RLOAD*SPAN2*(1+16*TETA1**TLDT0283
         12/3)/(2*TETA1*3.1416*CDIA**2*YOUNG))+3.0/8                 TLDT0284
          C=3.0/16*A                                                 TLDT0285
          CALL ORDER3(A,B,C,X)                                       TLDT0286
          TETA2=X                                                    TLDT0287
          GO TO(03103),JJJ033                                        TLDT0288
```

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```
TLDT PROGRAM                                                              PAGE 024

TABLE 035  INPUT

     35 1CTABLE FOR DETERMINATION OF EVERYDAY TENSION COEFFICIENT
     35 31IF COEVDT       =0        Y N
     35 5ASET COEVDT=0.22           X
     35 7 GO TO TABLE 36            X X

TABLE 035 OUTPUT

    C                           TABLE 035                          TLDT0289
    CTABLE FOR DETERMINATION OF EVERYDAY TENSION COEFFICIENT       TLDT0290
    03500 IF(COEVDT                     )03503,03504,03503         TLDT0291
    C                           RULE 01                            TLDT0292
    03504 COEVDT=0.22                                              TLDT0293
          GO TO 03600                                              TLDT0294
    C                           RULE 02                            TLDT0295
    03503 GO TO C3600                                              TLDT0296
```

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```
TLDT PROGRAM                                                              PAGE 025

TABLE 036  INPUT

      36 1CTABLE CHECKING IF EVD TENSION IS SATISFACTORY
      36 311F EVDT LT COEVDT*CUTS       N Y N
      36 5 IF M             =0          Y . N
      36 7AINCREMENT TENS2 BY -500.0    X
      36 9 INCREMENT TENS2 BY -100.0        X
      3611 GO TO TABLE 31               X   X
      3613 SET TEMP=TOPTMP                X
      3615 DO TABLE 33                    X
      3617 GO F1                          X
      3619 GO TO TABLE 37                 X
      36  F 1    SAG=SPAN2*TETA2

TABLE 036 OUTPUT

     C                              TABLE 036                           TLDT0297
     CTABLE CHECKING IF EVD TENSION IS SATISFACTORY                     TLDT0298
     03600 IF(EVDT             -(COEVDT*CUTS      ))03603,03604,03604   TLDT0299
     03604 IF(M                                   )03605,03606,03605    TLDT0300
     C                              RULE 01                             TLDT0301
     03606 TENS2=TENS2+(-500.0)                                         TLDT0302
           GO TO 03100                                                  TLDT0303
     C                              RULE 02                             TLDT0304
     03603 TEMP=TOPTMP                                                  TLDT0305
           JJJ033= 01                                                   TLDT0306
           GO TO 03300                                                  TLDT0307
     03607 SAG=SPAN2*TETA2                                              TLDT0308
           GO TO 03700                                                  TLDT0309
     C                              RULE 03                             TLDT0310
     03605 TENS2=TENS2+(-100.0)                                         TLDT0311
           GO TO 03100                                                  TLDT0312
```

```
TLDT PROGRAM                                                         PAGE 026

TABLE 037   INPUT

      37 1CTABLE TO CALCULATE CROSSARM HEIGHT
      37 311F ISTRIN          LT 3        Y N
      37 5ADD F 1                         X
      37 7 DO F 2                           X
      37 9 GO TO TABLE 38                 X X
      37   F 1    TOHGT=GRDCL+SAG+CLEAR
      37   F 2    TOHGT=GRDCL+SAG+STRLG

TABLE 037 OUTPUT

     C                            TABLE 037                            TLDT0313
     CTABLE TO CALCULATE CROSSARM HEIGHT                               TLDT0314
     03700 IF(ISTRIN          -(3              ))03704,03703,03703     TLDT0315
     C                            RULE 01                              TLDT0316
     03704 TOHGT=GRDCL+SAG+CLEAR                                       TLDT0317
           GO TO 03800                                                 TLDT0318
     C                            RULE 02                              TLDT0319
     03703 TOHGT=GRDCL+SAG+STRLG                                       TLDT0320
           GO TO C3800                                                 TLDT0321
```

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TLDT PROGRAM PAGE 027

TABLE 038 INPUT

```
38 1CTABLE TO CALCULATE TOWER COST
38 311F TOHGT           LT HTLIM   Y N N Y
38 5 IF J               =0         Y Y N N
38 7ADD 8 1                        X     X
38 9 WRITE NPRNT F1 L1             X     X
3811 SET J=1                       X
3813 GO TO TABLE 40                X
3815 GO TO TABLE 42                      X
3817 WRITE NPRNT F2                  X
3819 GO TO TABLE 21                  X
3821 GO TO TABLE 50                    X
38 B 1      TBWL=TENS2
38          TLOAD=SQRT(TBWL**2+(3*NSC*HLOAD*SPAN2*1.1)**2)
38          TCOST=TCOEF*TOHGT*TLOAD**0.667
38          NTOWS=5280*DIST/SPAN2+1
38          TTCOS=NTOWS*TCOST/DIST
38   FFORMAT 1 (9X,F6.1,13X,F7.1,18X,F5.1,18X,F8.2,4X,F9.2)
38   FFORMAT 2 (20X,'** TOWER HEIGHT EXCEEDS TOWER HEIGHT LIMIT **')
38   L 1   SPAN2,TENS2,TOGHT,TCOST,TTCOS
```

TABLE 038 OUTPUT

```
C                            TABLE 038                                TLDT0322
CTABLE TO CALCULATE TOWER COST                                        TLDT0323
03800 IF(TOHGT          -(HTLIM          ))03804,03803,03803          TLDT0324
03804 IF(J                               )03805,03806,03805           TLDT0325
03803 IF(J                               )03807,03808,03807           TLDT0326
C                            RULE 01                                  TLDT0327
03806 III038= 01                                                      TLDT0328
      GO TO 03809                                                     TLDT0329
03810 WRITE(NPRNT,03812)SPAN2,TENS2,TOGHT,TCOST,TTCOS                 TLDT0330
03812 FORMAT(9X,F6.1,13X,F7.1,18X,F5.1,18X,F8.2,4X,F9.2)              TLDT0331
      J=1                                                             TLDT0332
      GO TO 04000                                                     TLDT0333
C                            RULE 02                                  TLDT0334
03808 WRITE(NPRNT,03813)                                              TLDT0335
03813 FORMAT(20X,'** TOWER HEIGHT EXCEEDS TOWER HEIGHT LIMIT **')     TLDT0336
      GO TO 02100                                                     TLDT0337
C                            RULE 03                                  TLDT0338
03807 GO TO 05000                                                     TLDT0339
```

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TLDT PROGRAM PAGE 028

```
C                          RULE 04                              TLDT0340
03805 III038= 02                                                TLDT0341
      GO TO 03809                                               TLDT0342
03811 WRITE(NPRNT,03812)SPAN2,TENS2,TOGHT,TCOST,TTCOS           TLDT0343
      GO TO 04200                                               TLDT0344
C                          OUT OF LINE                          TLDT0345
03809 TBWL=TENS2                                                TLDT0346
      TLOAD=SQRT(TBWL**2+(3*NSC*HLOAD*SPAN2*1.1)**2)            TLDT0347
      TCOST=TCCOEF*TOHGT*TLOAD**0.667                           TLDT0348
      NTOWS=5280*DIST/SPAN2+1                                   TLDT0349
      TTCOS=NTOWS*TCOST/DIST                                    TLDT0350
      GO TO(03810,03811),III038                                 TLDT0351
```

```
TLDT PROGRAM                                                    PAGE 029

TABLE 040   INPUT

      40 1CTABLE TO STORE RESULTS OF SPAN RUN
      40 3ADD B 1
      40 5 GO TO TABLE 30
      40  B 1    SAG3=SAG
      40         TCOST3=TCOST
      40         TOHGT3=TOHGT
      40         TENS3=TENS2
      40         EVDT3=EVDT
      40         TOWL3=TOWL
      40         NTOWS3=NTOWS
      40         TTCOS3=TTCOS
      40         SPAN3=SPAN2
      40         SPAN2=SPAN2+100

TABLE 040 OUTPUT

     C                             TABLE 040                   TLDT0352
     CTABLE TO STORE RESULTS OF SPAN RUN                       TLDT0353
     C                             RULE 01                     TLDT0354
     04000 SAG3=SAG                                            TLDT0355
           TCOST3=TCOST                                        TLDT0356
           TOHGT3=TOHGT                                        TLDT0357
           TENS3=TENS2                                         TLDT0358
           EVDT3=EVDT                                          TLDT0359
           TOWL3=TOWL                                          TLDT0360
           NTOWS3=NTOWS                                        TLDT0361
           TTCOS3=TTCOS                                        TLDT0362
           SPAN3=SPAN2                                         TLDT0363
           SPAN2=SPAN2+100                                     TLDT0364
           GO TO 03000                                         TLDT0365
```

```
TLDT PROGRAM                                                        PAGE 030

TABLE 042  INPUT

     42 1CTABLE TO CHECK IF OPTIMUM COST IS OBTAINED
     42 311F ITCOS           LE ITCOS3 Y N N
     42 5 IF M               =0        . Y N
     42 7ACO TO TABLE 40             X
     42 9 INCREMENT J BY 1             X X
     4211 MOVE SPAN3 TO SPAN2          X
     4213 SET M=1                      X
     4215 GO TO TABLE 43               X X

TABLE 042 OUTPUT

    C                       TABLE 042                              TLDT0366
    CTABLE TO CHECK IF OPTIMUM COST IS OBTAINED                    TLDT0367
    04200 IF(ITCOS         -(TTCOS3          ))04204,04204,04203   TLDT0368
    04203 IF(M                                )04205,04206,04205   TLDT0369
    C                       RULE 01                                TLDT0370
    04204 GO TO 04000                                              TLDT0371
    C                       RULE 02                                TLDT0372
    04206 J=J+(1)                                                  TLDT0373
          SPAN2=SPAN3                                              TLDT0374
          M=1                                                      TLDT0375
          GO TO 04300                                              TLDT0376
    C                       RULE 03                                TLDT0377
    04205 J=J+(1)                                                  TLDT0378
          GO TO 04300                                              TLDT0379
```

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TLDT PROGRAM                                                                PAGE 031


TABLE 043  INPUT

       43 1CAUXILIARY TABLE TO LOOK FOR OPTIMUM SPAN
       43 311F J                  LT 5       Y N
       43 5AGO TO TABLE 50                     X
       43 7 INCREMENT SPAN2 BY 100           X
       43 9 GO TO TABLE 30                   X


TABLE 043 OUTPUT

      C                              TABLE 043                               TLDT0380
      CAUXILIARY TABLE TO LOOK FOR OPTIMUM SPAN                              TLDT0381
      04300 IF(J               -15               ))04304,04303,04303        TLDT0382
      C                              RULE 01                                 TLDT0383
      04304 SPAN2=SPAN2+(100)                                                TLDT0384
            GO TO 03000                                                      TLDT0385
      C                              RULE 02                                 TLDT0386
      04303 GO TO 05000                                                      TLDT0387
```

011041

TLDT PROGRAM PAGE 032

TABLE 050 INPUT

```
50 1CTABLE FOR RIGHT OF WAY WIDTH AND COST DETERMINATION (ONE CIRCUIT)
50 311F ISTRIN          LT 3        Y N Y N
50 5 IF RWSCOS          =0          Y Y N N
50 7ACO F 1                         X   X
50 9 SET RWCOST=0                   X X
5011 DO F 2                           X   X
5013 DO F 3                             X X
5015 GO TO TABLE 52                 X X X X
50   FFORMULA 1    RWWID=FASP+1.41/2*SAG+GRDCL
50   FFORMULA 2    RWWID=FASP+1.41/2*(STRLG+SAG)+GRDCL
50   FFORMULA 3    RWCOST=RWWID*5280/43560*RWSCOS
```

TABLE 050 OUTPUT

```
C                               TABLE 050                                TLDT0388
CTABLE FOR RIGHT OF WAY WIDTH AND COST DETERMINATION (ONE CIRCUIT)       TLDT0389
05000 IF(ISTRIN           -(3               ))05004,05003,05003          TLDT0390
05004 IF(RWSCOS                              )05005,05006,05005          TLDT0391
05003 IF(RWSCOS                              )05007,05008,05007          TLDT0392
C                               RULE 01                                  TLDT0393
05006 RWWID=FASP+1.41/2*SAG+GRDCL                                        TLDT0394
      RWCOST=0                                                           TLDT0395
      GO TO C5200                                                        TLDT0396
C                               RULE 02                                  TLDT0397
05008 RWCOST=0                                                           TLDT0398
      RWWID=FASP+1.41/2*(STRLG+SAG)+GRDCL                                TLDT0399
      GO TO 05200                                                        TLDT0400
C                               RULE 03                                  TLDT0401
05005 RWWID=FASP+1.41/2*SAG+GRDCL                                        TLDT0402
      RWCOST=RWWID*5280/43560*RWSCUS                                     TLDT0403
      GO TO 05200                                                        TLDT0404
C                               RULE 04                                  TLDT0405
05007 RWWID=FASP+1.41/2*(STRLG+SAG)+GRDCL                                TLDT0406
      RWCOST=RWWID*5280/43560*RWSCUS                                     TLDT0407
      GO TO C5200                                                        TLDT0408
```

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```
TLDT PROGRAM                                                          PAGE 033

TABLE 052  INPUT

     52 1CTABLE TO CALCULATE STRINGLOAD
     52 3 IF ISTRIN           =              1    2    3    4    5    6
     52 5ADD F 1                             X    X
     52 7 DO F 2                             X    X
     52 9 DO B 1                             X
     5210 DO B 2                                  X
     5211 DO B 3                                       X
     5213 DO B 4                                            X
     5215 DO B 5                                                 X
     5217 DO B 6                                                      X
     5219 SET K=1                            X    X    X    X    X    X
     5221 GO TO TABLE 55                     X    X    X    X    X    X
     52  FFORMULA 1  ANGEL=3.1416/2*(1.0-ANGLE/90.0)-ATAN(HLOAD/VLOAD)
     52  FFORMULA 2  STRLD=RLOAD*SPAN3*NSC*COS(ANGEL)
     52  B 1  STRINS=STRLD
     52       NUMST=6
     52  B 2  STRINS=STRLD/2
     52       NUMST=12
     52  B 3  STRINS=RLOAD*SPAN3*NSC
     52       NUMST=3
     52  B 4  STRINS=RLOAD*SPAN3*NSC/2
     52       NUMST=6
     52  B 5  STRINS=RLOAD*SPAN3*NSC
     52       NUMST=4
     52  B 6  STRINS=RLOAD*SPAN3*NSC/2
     52       NUMST=8

TABLE 052 OUTPUT

    C                        TABLE 052                            TLDT0409
    CTABLE TO CALCULATE STRINGLOAD                                TLDT0410
    05200 IF(ISTRIN          -(1        ))05203,05204,05203       TLDT0411
    05203 IF(ISTRIN          -(2        ))05205,05206,05205       TLDT0412
    05205 IF(ISTRIN          -(3        ))05207,05208,05207       TLDT0413
    05207 IF(ISTRIN          -(4        ))05209,05210,05209       TLDT0414
    05209 IF(ISTRIN          -(5        ))05211,05212,05211       TLDT0415
    05211 IF(ISTRIN          -(6        ))05201,05213,05201       TLDT0416
    C                        RULE 01                              TLDT0417
    05204 ANGEL=3.1416/2*(1.0-ANGLE/90.0)-ATAN(HLOAD/VLOAD)       TLDT0418
          STRLD=RLOAD*SPAN3*NSC*COS(ANGEL)                        TLDT0419
```

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TLDT PROGRAM PAGE 034

```
      STRINS=STRLD                                            TLDT0420
      NUMST=6                                                 TLDT0421
      K=1                                                     TLDT0422
      GO TO 05500                                             TLDT0423
C                          RULE 02                            TLDT0424
05206 ANGEL=3.1416/2*(1.0-ANGLE/90.0)-ATAN(HLOAD/VLOAD)       TLDT0425
      STRLD=RLOAD*SPAN3*NSC*COS(ANGEL)                        TLDT0426
      STRINS=STRLD/2                                          TLDT0427
      NUMST=12                                                TLDT0428
      K=1                                                     TLDT0429
      GO TO 05500                                             TLDT0430
C                          RULE 03                            TLDT0431
05208 STRINS=RLOAD*SPAN3*NSC                                  TLDT0432
      NUMST=3                                                 TLDT0433
      K=1                                                     TLDT0434
      GO TO 05500                                             TLDT0435
C                          RULE 04                            TLDT0436
05210 STRINS=RLOAD*SPAN3*NSC/2                                TLDT0437
      NUMST=6                                                 TLDT0438
      K=1                                                     TLDT0439
      GO TO 05500                                             TLDT0440
C                          RULE 05                            TLDT0441
05212 STRINS=RLOAD*SPAN3*NSC                                  TLDT0442
      NUMST=4                                                 TLDT0443
      K=1                                                     TLDT0444
      GO TO 05500                                             TLDT0445
C                          RULE 06                            TLDT0446
05213 STRINS=RLOAD*SPAN3*NSC/2                                TLDT0447
      NUMST=8                                                 TLDT0448
      K=1                                                     TLDT0449
      GO TO 05500                                             TLDT0450
C                          FALL-OUT-OF-TABLE                  TLDT0451
05201 CONTINUE                                                TLDT0452
```

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TABLE 055 INPUT

```
55 1CTABLE TO SELECT ADEQUATE INSULATOR STRENGTH
55 31STRINS LE 0.4*INSSTR(K)      Y N N
55 5 INSSTR(K)          =0        . N Y
55 7AGO TO TABLE 60              X
55 9 INCREMENT K BY 1               X X
5511 WRITE NPRNT F1 L1                X
5513 CALL EXIT                        X
5515 GO TO TABLE 55                 X
55  FFORMAT 1 (//10X,I6,X,'LBS. INSULATOR INADEQUATE TC SUPPORT LINE')
55  L 1   INSSTR(K-2)
```

TABLE 055 OUTPUT

```
C                              TABLE 055                                TLDT0453
CTABLE TO SELECT ADEQUATE INSULATOR STRENGTH                            TLDT0454
05500 IF(STRINS         -(0.4*INSSTR(K)    ))05504,05504,05503          TLDT0455
05503 IF(INSSTR(K)                         )05506,05505,05506          TLDT0456
C                              RULE 01                                  TLDT0457
05504 GO TO 06000                                                       TLDT0458
C                              RULE 02                                  TLDT0459
05506 K=K+(1)                                                           TLDT0460
      GO TO 05500                                                       TLDT0461
C                              RULE 03                                  TLDT0462
05505 K=K+(1)                                                           TLDT0463
      WRITE(NPRNT,05507)INSSTR(K-2)                                     TLDT0464
05507 FORMAT(//10X,I6,X,'LBS. INSULATOR INADEQUATE TO SUPPORT LINE')    TLDT0465
      CALL EXIT                                                         TLDT0466
```

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TABLE 660 INPUT

```
60 1CTABLE TO PRINT OUT RESULTS
60 3ADD B 1
60 5 CALL GRACOL
60 6 GO B 2
60 7 WRITE NPRNT F1
60 9 WRITE NPRNT F2 L2
6011 WRITE NPRNT F3 L3
6013 WRITE NPRNT F4 L4
6015 WRITE NPRNT F5 L5
6017 WRITE NPRNT F6
6019 WRITE NPRNT F7 L7
6021 GO TO TABLE 61
60  B 1   TOTINS=IQTTY*NUMST*NTOWS3*COSTIN(K)/DIST
60        TOTCON=NSC*3*5.28*0.975*BAZCOS
60        TINSTA=TTCOS3+RWCOST+TOTINS+TOTCON
60  B 2   RISQ=(MVA/VNOM)**2*CONRES/NSC*1000
60        ACA=TINSTA*ACOIC/100
60        ACB=(RISQ+CORL(1))*365*24*ALDSC/1000*0.65
60        ACC=CORL(5)*DCUC
60        TAC=ACA+ACB+ACC
60  FFORMAT 1 (///10X,' 1.  TRANSMISSION LINE DESIGN DATA.'/15X,'******
60  1***************************'/)
60  FFORMAT 2 (//25X,'A)  INSULATORS',21X,'INSULATOR RATED STRENGTH
60  1 =',I6,' LBS.'/29X,'***********',21X,'INSULATOR QUANTITY PER STRING
60  2=',I3/)
60  FFORMAT 3 (/25X,'B)  CONDUCTOR',22X,'MAX. CONDUCTOR TENSION     =',
60  1F8.1,' LBS. (AT 0 DEG.F.,ICE+WIND)'/29X,'*********',22X,'CONDUCTOR
60  2 EVERY DAY TENSION=',F8.1,' LBS. (AT ',F5.1,' DEG.F.,NO ICE, NO WI
60  3ND)'/60X,'MAX. CONDUCTOR SAG          =',F8.1,' FT. (AT ',F5.1,' DE
60  4G.F.)'/)
60  FFORMAT 4 (/25X,'C)  TOWER',26X,'CONDUCTOR TO STRUCTURE CLEARANCE='
60  1,I4,' IN.'/29X,'******',26X,'PHASE SPACING                  =',I4,
60  2' FT.'/60X,'BROKEN WIRE LOAD               =',F8.1,' LBS.'/60X,'C
60  3ROSSARM HEIGHT          =',F6.1,' FT.'/)
60  FFORMAT 5 (/25X,'D)  LINE',27X,'TOWER QUANTITY      =',I4/29X,'*****'
60  1,27X,'RIGHT OF WAY WIDTH =',F6.1,' FT.'//60X,'LOSSES=',10X,'RESIST
60  2IVE LOSSES           =',F6.1,' KW/3-PHASE MILE'/77X,'AVERAGE ANNUAL
60  3 CORONA LOSS=',F6.1,8X,'ID.'/77X,' 15 PCT.         ID.      =',F6.
60  41,8X,'ID.'/77X,' 10 PCT.          ID.      =',F6.1,8X,'ID.'/77X,'
60  55 PCT.        ID.      =',F6.1,8X,'ID.'/77X,'  2 PCT.         ID.
60  6      =',F6.1,8X,'ID.'/77X,'  0 PCT           ID       =',F6.1,8X,'
60  7ID.'/)
```

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```
    60   FFORMAT 6 (///10X,' 2.  TRANSMISSION LINE COST DATA.'/15X,'********
    60   1*********************')
    60   FFORMAT 7 (//15X,' INSTALLED  COST.',50X,'ANNUAL CHARGES.'/16X,'($/
    60   13-PHASE MILE)',46X,'($/3-PHASE MILE/YEAR)'//15X,'INSULATORS    =',F
    60   29.2,40X,F4.1,' PCT. CHARGE ON CAPITAL          =',F9.2/15X,'TOWER
    60   3S       =',F9.2,40X,F4.2,' MILLS/KWH ON LOSSES            = ',F9.
    60   42/15X,'CONDUCTOR     =',F9.2,40X,F4.1,' $/KW CORONA DEMAND CHARGE
    60   5     = ,F9.2/15X,'RIGHT OF WAY =',F9.2,40X,'(2 PCT. PROB.)'/29X,'-
    60   6--------',79X,'---------'//5X,' TOTAL  INSTALLED  COST =',F9.2,56X,
    60   7'TOTAL ANNUAL CHARGES = ',F9.2)
    60   L 2  INSSTR(K),IQTTY
    60   L 3  TENS3,EVDT3,AVTEMP, SAG3,TOPTMP
    60   L4   ICLEAR,IFASPY03=  000660
    60   L 5  NTOWS3,RWWID,RISQ,CORL(1),CORL(2),CORL(3),CORL(4),CORL(5),CORL
    60   1(6)
    60   L 7  TOTINS,AC01C,ACA,ITCOS3,ALOSC,ACB,TOTCON,DCOC,ACC,RWCOST,TINST
    60   1A,TAC
```

TABLE 060 OUTPUT

```
      C                             TABLE 060                         TLDT0467
      CTABLE TO PRINT OUT RESULTS                                     TLDT0468
      C                              RULE 01                          TLDT0469
      06000 TOTINS=IQTTY*NUMST*NTOWS3*COSTIN(K)/DIST                  TLDT0470
            TOTCON=NSC*3*5.28*0.975*BAZCOS                            TLDT0471
            TINSTA=ITCOS3+RWCOST+TOTINS+TOTCON                        TLDT0472
            CALL GRACOL                                               TLDT0473
            RISQ=(MVA/VNUM)**2*CONRES/NSC*1000                        TLDT0474
            ACA=TINSTA*AC01C/100                                      TLDT0475
            ACB=(RISQ+CORL(1))*365*24*ALOSC/1000*0.65                 TLDT0476
            ACC=CORL(5)*DCOC                                          TLDT0477
            TAC=ACA+ACB+ACC                                           TLDT0478
            WRITE(NPRNT,06003)                                        TLDT0479
      06003 FORMAT(///10X,' 1.  TRANSMISSION LINE DESIGN DATA.'/15X,'******  TLDT0480
           1***************************'/)                            TLDT0481
            WRITE(NPRNT,06004)INSSTR(K),IQTTY                         TLDT0482
      06004 FORMAT(//25X,'A)  INSULATORS',21X,'INSULATOR RATED STRENGTH   TLDT0483
           1=',I6,' LBS.'/25X,'***********',21X,'INSULATOR QUANTITY PER STRING TLDT0484
           2=',I3/)                                                   TLDT0485
            WRITE(NPRNT,06005)TENS3,EVDT3,AVTEMP,SAG3,TOPTMP          TLDT0486
      06005 FORMAT(/25X,'B)  CONDUCTOR',22X,'MAX. CONDUCTOR TENSION      =',  TLDT0487
           1F8.1,' LBS. (AT 0 DEG.F.,ICE+WIND)'/29X,'**********',22X,'CONDUCTORTLDT0488
           2EVERY DAY TENSION=',F8.1,' LBS. (AT ',F5.1,' DEG.F.,NO ICE, NO WI TLDT0489
           3ND)'/60X,'MAX. CONDUCTOR SAG           =',F8.1,' FT. (AT ',F5.1,' DETLDT0490
           4G.F.)'/)                                                  TLDT0491
```

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```
      WRITE(NPRNT,06006)ICLEAR,IFASPYOBW-000&&0                         TLDT0492
06006 FORMAT(/25X,'C)  TOWER',26X,'CONDUCTOR TO STRUCTURE CLEARANCE='   TLDT0493
     1,I4,' IN.'/29X,'*****',26X,'PHASE SPACING                  =',I4,TLDT0494
     2' FT.'/60X,'BROKEN WIRE LOAD                =',F8.1,' LBS.'/60X,'CTLDT0495
     3ROSSARM HEIGHT              =',F6.1,' FT.'/)                      TLDT0496
      WRITE(NPRNT,06007)NTOWS3,RWWID,RISQ,CORL(1),CORL(2),CORL(3),CORL(4TLDT0497
     1),CORL(5),CORL(6)                                                 TLDT0498
06007 FORMAT(/25X,'D)  LINE',27X,'TOWER QUANTITY     =',I4/29X,'****'   TLDT0499
     1,27X,'RIGHT OF WAY WIDTH =',F6.1,' FT.'//60X,'LOSSES=',10X,'RESISTTLDT0500
     2IVE LOSSES          =',F6.1,' KW/3-PHASE MILE'/77X,'AVERAGE ANNUALTLDT0501
     3CORONA LOSS=',F6.1,8X,'ID.'/77X,' 15 PCT.        ID.     =',F6.  TLDT0502
     41,8X,'ID.'/77X,' 10 PCT.        ID.      =',F6.1,8X,'ID.'/77X,'  TLDT0503
     55 PCT.        ID.      =',F6.1,8X,'ID.'/77X,'  2 PCT.        ID.TLDT0504
     6=',F6.1,8X,'ID.'/77X,'  0 PCT          ID       =',F6.1,8X,'     TLDT0505
     7ID.'/)                                                            TLDT0506
      WRITE(NPRNT,06008)                                                TLDT0507
06008 FORMAT(///10X,' 2.  TRANSMISSION LINE COST DATA.'/15X,'********   TLDT0508
     1*********************')                                           TLDT0509
      WRITE(NPRNT,06009)TOTINS,ACOIC,ACA,TTCOS3,ALOSC,ACB,TOTCON,OCOC,ACTLDT0510
     1C,KWCOST,TINSTA,TAC                                               TLDT0511
06009 FORMAT(//15X,' INSTALLED  COST.',50X,'ANNUAL CHARGES.'/16X,'($/   TLDT0512
     13-PHASE MILE)',46X,'($/3-PHASE MILE/YEAR)'//15X,'INSULATORS    =',FTLDT0513
     29.2,40X,F4.1,' PCT. CHARGE ON CAPITAL              =',F9.2/15X,'TOWER TLDT0514
     3S        =',F9.2,40X,F4.2,' MILLS/KWH ON LOSSES              = ',F9.TLDT0515
     42/15X,'CONDUCTOR     =',F9.2,40X,F4.1,' $/KW CORONA DEMAND CHARGE  TLDT0516
     5= ',F9.2/15X,'RIGHT OF WAY =',F9.2,40X,'(2 PCT. PROB.)'/29X,'-     TLDT0517
     6--------',79X,'---------'//5X,'TOTAL  INSTALLED  COST =',F9.2,56X,TLDT0518
     7'TOTAL ANNUAL CHARGES = ',F9.2)                                   TLDT0519
      GO TO 06100                                                       TLDT0520
```

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```
TLDT PROGRAM                                                          PAGE 039


TABLE 061  INPUT

      61 1CTABLE TO CHECK IF SUBCOND. QTTY = 4
      61 3INSC                  LT 4         Y N
      61 5ACO B 1                            X
      61 7 INCREMENT NSC BY 1                X
      61 9 GO TO TABLE 55                    X
      6111 GO TO TABLE 21                      X
      61  6 1     STRINS=STRINS*(NSC+1)/NSC
      61          K=1


TABLE 061 OUTPUT

     C                              TABLE 061                              TLDT0521
     CTABLE TO CHECK IF SUBCOND. QTTY = 4                                  TLDT0522
     06100 IF(NSC              -(4              ))06104,06103,06103        TLDT0523
     C                              RULE 01                                TLDT0524
     06104 STRINS=STRINS*(NSC+1)/NSC                                       TLDT0525
           K=1                                                             TLDT0526
           NSC=NSC+(1)                                                     TLDT0527
           GO TO C5500                                                     TLDT0528
     C                              RULE 02                                TLDT0529
     06103 GO TO C2100                                                     TLDT0530
```

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CONDUCTOR-STRUCTURE CLEARANCE DETERMINATION.

240 INCH CLEARANCE. LINE FLASHOVER EXPECTANCY CALCULATION.

STRING CFO (KV,CREST)=1618.1
LEG CFO (KV,CREST)=1580.2
TRUSS CFO (KV,CREST)=1682.7

SURGE VOLTAGE (KV,CREST)	TOWER WITHSTAND PROB.	SURGE*WITHSTAND CONVOLUTION
955.4	1.00000000	0
992.7	1.00000000	0
1030.0	1.00000000	0
1067.3	1.00000000	.00000000
1104.6	1.00000000	.00000000
1141.9	.99999997	.00000001
1179.2	.99999955	.00000003
1216.5	.99999515	.00000015
1253.8	.99995714	.00000049
1291.1	.99969307	.00000106
1328.4	.99821295	.00000140
1365.7	.99152387	.00000076
1402.9	.96725678	.00000018
1440.2	.89758641	.00000003
1477.5	.74435667	.00000001
1514.8	.50045101	.00000000
1552.1	.24093194	.00000000
ERROR IN Q1QEXRI CALLED FROM 67611 , EXP. OVERFLOW		
1589.4	.07265117	.00000000
ERROR IN Q1QEXRI CALLED FROM 67611 EXP. OVERFLOW		
1626.7	.01209161	.00000000
ERROR IN Q1QEXRI CALLED FROM 67611 EXP. OVERFLOW		
1664.0	.00099685	.00000000

LINE FLASHOVER EXPECTANCY = .00015393

THIS LINE FLASHOVER EXPECTANCY IS EQUIVALENT
TO 6496 SWITCHING SURGES PER FLASHOVER.
NOTE= THE DESIRED EXPECTANCY IS 10000 SURGES
PER FLASHOVER.

```
CONDUCTOR-STRUCTURE CLEARANCE DETERMINATION.

243 INCH CLEARANCE.                LINE FLASHOVER EXPECTANCY CALCULATION.

                    STRING CFO (KV,CREST)=1624.3
                       LEG CFO (KV,CREST)=1592.7
                     TRUSS CFO (KV,CREST)=1695.7

                  SURGE VOLTAGE (KV,CREST)   TOWER WITHSTAND PROB.   SURGE*WITHSTAND CONVOLUTION

                                 955.7          1.00000000                     0
                                 993.7          1.00000000                     0
                                1031.6          1.00000000                     0
                                1069.6          1.00000000             .00000000
                                1107.5          1.00000000             .00000000
                                1145.4           .99999998             .00000000
                                1183.4           .99999967             .00000002
                                1221.3           .99999617             .00000011
                                1259.3           .99996453             .00000034
                                1297.2           .99973486             .00000075
                                1335.2           .99839603             .00000101
                                1373.1           .99213244             .00000056
                                1411.1           .96872447             .00000013
                                1449.0           .89987538             .00000002
                                1487.0           .74579375             .00000000
                                1524.9           .49845867             .00000000
                                1562.8           .23615945             .00000000
ERROR IN Q1QEXRI  CALLED FROM 67611  EXP. OVERFLOW
                                1600.8           .06905493             .00000000
ERROR IN Q1QEXRI  CALLED FROM 67611  EXP. OVERFLOW
                                1638.7           .01094210             .00000000

                           LINE FLASHOVER EXPECTANCY =  .00011192

                 THIS LINE FLASHOVER EXPECTANCY IS EQUIVALENT
                  TO       8935 SWITCHING SURGES PER FLASHOVER.
                 NOTE= THE DESIRED EXPECTANCY IS  10000 SURGES
                 PER FLASHOVER.
```

CONDUCTOR-STRUCTURE CLEARANCE DETERMINATION.

246 INCH CLEARANCE.   LINE FLASHOVER EXPECTANCY CALCULATION.

STRING CFO (KV,CREST)=1630.9
LEG CFO (KV,CREST)=1605.1
TRUSS CFO (KV,CREST)=1708.6

SURGE VOLTAGE (KV,CREST)	TOWER WITHSTAND PROB.	SURGE*WITHSTAND CONVOLUTION
956.0	1.00000000	0
994.6	1.00000000	0
1033.2	1.00000000	0
1071.8	1.00000000	.00000000
1110.4	1.00000000	.00000000
1149.0	.99999998	.00000000
1187.6	.99999975	.00000002
1226.2	.99999694	.00000008
1264.8	.99997037	.00000024
1303.4	.99976906	.00000054
1342.0	.99855025	.00000072
1380.6	.99265627	.00000041
1419.2	.97000130	.00000009
1457.8	.90184008	.00000001
1496.4	.74683261	.00000000
1535.0	.49617100	.00000000
1573.6	.23137587	.00000000

ERROR IN Q1QEXRI CALLED FROM 67611 , EXP. OVERFLOW

1612.2	.06563990	.00000000

ERROR IN Q1QEXRI CALLED FROM 67611 EXP. OVERFLOW

1650.8	.00991152	.00000000

LINE FLASHOVER EXPECTANCY = .00008140

THIS LINE FLASHOVER EXPECTANCY IS EQUIVALENT
TO 12284 SWITCHING SURGES PER FLASHOVER.
NOTE= THE DESIRED EXPECTANCY IS 10000 SURGES
PER FLASHOVER.

*** CASE NO 1 ***

CONDUCTOR TYPE= ACSR CARDINAL
SUBCONDUCTORS PER PHASE= 4

LOADING CONDITIONS		CONDUCTOR LOADS (LBS/FT)	
ICE COATING (INCHES)=	.50	VERTICAL LOAD =	2.266
WIND (LBS/SQ.FT.)=	8.00	HORIZONTAL LOAD=	1.464
CONDUCTOR WEIGHT (LBS/FT)=	1.227	COMBINED LOAD =	2.698

SPAN (FT.)	CONDUCTOR MAX. TENSION (LBS.)	TOWER CROSSARM HEIGHT (FT.)	INSTALLED TOWER COST ($)	INSTALLED TOWER COST ($/MILE)
1000.0	15125.0	85.7	11712.98	61932.39
1100.0	15125.0	90.4	12366.69	59514.68
1200.0	15125.0	95.7	13079.12	57711.60
1300.0	15625.0	100.0	13969.48	56751.41
1400.0	15625.0	105.9	14792.16	55840.41
1500.0	15625.0	112.2	15673.80	55250.16
1600.0	15625.0	118.9	16614.73	55036.28
1700.0	15625.0	126.1	17615.10	54827.01
1800.0	15625.0	133.6	18675.07	54658.03
1800.0	15825.0	132.7	18702.88	54939.71
1900.0	15825.0	140.6	19817.92	55242.45
2000.0	15825.0	149.0	20992.50	55630.12

TRANSMISSION LINE GRADIENT AND CORONA LOSS CALCULATION

NOMINAL VOLTAGE (KV,L-L) 765.0

PHASE SPACING (FEET) 53.00

SUBCONDUCTOR QTTY 4

BUNDLE SPACING (INCHES) 18.0

CONDUCTOR DIA. (INCHES) 1.196

GROUND CLEARANCE (FEET) 40.0

MAXIMUM VERTICAL GRADIENT (KV/CM,RMS) 18.77

AVERAGE INSIDE GRADIENT (KV/CM,RMS) 17.07

AVERAGE OUTSIDE GRADIENT (KV/CM,RMS) 16.07

CORONA INITIATION GRADIENT(KV/CM,RMS) 18.52

PROBABILITY OF EXCEEDING THE COMPUTED CORONA LOSSES (IN PERCENT)	CORONA LOSS (KW/3 PHASE MILE)
50.0	18.5
15.0	35.2
10.0	53.3
5.0	80.2
2.0	111.0
0	362.9

```
1.  TRANSMISSION LINE DESIGN DATA.
    ******************************

        A)  INSULATORS            INSULATOR RATED STRENGHT     = 25000 LBS.
            **********            INSULATOR QUANTITY PER STRING= 35

        B)  CONDUCTOR             MAX. CONDUCTOR TENSION      = 15625.0 LBS. (AT 0 DEG.F.,ICE+WIND)
            *********             CONDUCTOR EVERY DAY TENSION=  7413.1 LBS. (AT  50.0 DEG.F.,NO ICE, NO WIND)
                                  MAX. CONDUCTOR SAG          =    65.5 FT. (AT 110.0 DEG.F.)

        C)  TOWER                 CONDUCTOR TO STRUCTURE CLEARANCE= 246 IN.
            *****                 PHASE SPACING                   =  53 FT.
                                  BROKEN WIRE LOAD                = 11718.8 LBS.
                                  CROSSARM HEIGHT                 = 126.1 FT.

        D)  LINE                  TOWER QUANTITY      = 249
            ****                  RIGHT OF WAY WIDTH = 155.3 FT.

                                  LOSSES=     RESISTIVE LOSSES             = 156.1 KW/3-PHASE MILE
                                              AVERAGE ANNUAL CORONA LOSS=   18.5       **
                                               15 PCT.          **       =  35.2       **
                                               10 PCT.          **       =  53.3       **
                                                5 PCT.          **       =  80.2       **
                                                2 PCT.          **       = 111.0       **
                                                0 PCT.          **       = 362.9       **

2.  TRANSMISSION LINE COST DATA.
    ****************************

     INSTALLED  COST.                              ANNUAL CHARGES.
     ($/3-PHASE MILE)                            ($/3-PHASE MILE/YEAR)

    INSULATORS    =   6196.36                 12.0 PCT. CHARGE ON CAPITAL        =  11214.03
    TOWERS        =  54827.01                 3.50 MILLS/KWH ON LOSSES           =   3480.22
    CONDUCTOR     =  32426.84                 10.0 $/KW CORONA DEMAND CHARGE     =   1110.39
    RIGHT OF WAY  =         0                 (2 PCT. PROB.)
                    ---------                                                       ---------
TOTAL  INSTALLED  COST = 93450.21                          TOTAL ANNUAL CHARGES =  15804.63
```

*** CASE NO 2 ***

CONDUCTOR TYPE= ACSR CURLEW
SUBCONDUCTORS PER PHASE= 4

LOADING CONDITIONS
****

ICE COATING (INCHES)= .50
WIND (LBS/SQ.FT.)= 8.00
CONDUCTOR WEIGHT (LBS/FT)=1.330

CONDUCTOR LOADS (LBS/FT)
****

VERTICAL LOAD = 2.400
HORIZONTAL LOAD= 1.497
COMBINED LOAD = 2.828

SPAN (FT.)	CONDUCTOR MAX. TENSION (LBS.)	TOWER CROSSARM HEIGHT (FT.)	INSTALLED TOWER COST ($)	INSTALLED TOWER COST ($/MILE)
1000.0	16175.0	85.5	12220.16	64614.10
1100.0	16375.0	89.8	12946.12	62303.20
1200.0	16375.0	94.9	13675.66	60343.83
1300.0	16475.0	100.1	14489.22	58662.47
1400.0	16575.0	105.7	15360.03	57984.12
1500.0	16575.0	111.9	16267.56	57343.15
1600.0	16675.0	118.2	17254.50	57155.52
1700.0	16675.0	125.3	18281.85	56902.24
1800.0	16675.0	132.7	19370.23	56900.04
1900.0	16675.0	140.6	20519.77	57198.86
2000.0	16775.0	148.4	21740.62	57612.37

TRANSMISSION LINE GRADIENT AND CORONA LOSS CALCULATION

NOMINAL VOLTAGE (KV,L-L) 765.0

PHASE SPACING (FEET) 53.00

SUBCONDUCTOR QTTY 4

BUNDLE SPACING (INCHES) 18.0

CONDUCTOR DIA. (INCHES) 1.246

GROUND CLEARANCE (FEET) 40.0

MAXIMUM VERTICAL GRADIENT (KV/CM,RMS) 18.11

AVERAGE INSIDE GRADIENT (KV/CM,RMS) 16.41

AVERAGE OUTSIDE GRADIENT (KV/CM,RMS) 15.43

CORONA INITIATION GRADIENT (KV/CM,RMS) 18.45

PROBABILITY OF EXCEEDING THE COMPUTED CORONA LOSSES (IN PERCENT)	CORONA LOSS (KW/3 PHASE MILE)
50.0	16.5
15.0	31.5
10.0	47.7
5.0	71.7
2.0	99.3
0	324.5

```
1.  TRANSMISSION LINE DESIGN DATA.
    ******************************

    A)  INSULATORS        INSULATOR RATED STRENGHT      = 25000 LBS.
        **********        INSULATOR QUANTITY PER STRING= 35

    B)  CONDUCTOR         MAX. CONDUCTOR TENSION       = 16675.0 LBS. (AT 0 DEG.F.,ICE+WIND)
        *********         CONDUCTOR EVERY DAY TENSION=  8132.5 LBS. (AT  30.0 DEG.F.,NO ICE, NO WIND)
                          MAX. CONDUCTOR SAG           =    72.2 FT. (AT 110.0 DEG.F.)

    C)  TOWER             CONDUCTOR TO STRUCTURE CLEARANCE= 246 IN.
        *****             PHASE SPACING                   =  53 FT.
                          BROKEN WIRE LOAD                = 12506.3 LBS.
                          CROSSARM HEIGHT                 = 132.7 FT.

    D)  LINE              TOWER QUANTITY      = 235
        ****              RIGHT OF WAY WIDTH = 161.1 FT.

                          LOSSES=      RESISTIVE LOSSES              = 143.3 KW/3-PHASE MILE
                                       AVERAGE ANNUAL CORONA LOSS=  16.5        **
                                        15 PCT.        **         =  31.5        **
                                        10 PCT.        **         =  47.7        **
                                         5 PCT.        **         =  71.7        **
                                         2 PCT.        **         =  99.3        **
                                         0 PCT.        **         = 324.5        **

2.  TRANSMISSION LINE COST DATA.
    ****************************

     INSTALLED  COST.                               ANNUAL CHARGES.
     ($/3-PHASE MILE)                             ($/3-PHASE MILE/YEAR)

    INSULATORS    =  5847.98                      12.0 PCT. CHARGE ON CAPITAL          =  11741.75
    TOWERS        = 56900.04                      3.50 MILLS/KWH ON LOSSES             =   3184.69
    CONDUCTOR     = 35099.89                      10.0 $/KW CORONA DEMAND CHARGE       =    992.96
    RIGHT OF WAY  =        0                      (2 PCT. PROB.)
                   ---------                                                             ---------
TOTAL  INSTALLED  COST = 97847.90                           TOTAL ANNUAL CHARGES =  15919.40
```

*** CASE NO 3 ***

CONDUCTOR TYPE= ACSR FINCH
SUBCONDUCTORS PER PHASE= 4

LOADING CONDITIONS
****

ICE COATING (INCHES)= .50
WIND (LBS/SQ.FT.)= 8.00
CONDUCTOR WEIGHT (LBS/FT)=1.425

CONDUCTOR LOADS (LBS/FT)
****

VERTICAL LOAD = 2.523
HORIZONTAL LOAD= 1.529
COMBINED LOAD = 2.950

SPAN (FT.)	CONDUCTOR MAX. TENSION (LBS.)	TOWER CROSSARM HEIGHT (FT.)	INSTALLED TOWER COST ($)	INSTALLED TOWER COST ($/MILE)
1000.0	17200.0	85.2	12698.95	67145.68
1100.0	17300.0	89.7	13414.79	64558.70
1200.0	17400.0	94.5	14189.01	62609.02
1300.0	17500.0	99.7	15021.74	61025.82
1400.0	17500.0	105.4	15890.65	59987.21
1500.0	17600.0	111.3	16842.16	59368.62
1600.0	17600.0	117.9	17833.32	59072.87
1700.0	17600.0	124.8	19886.72	58784.91
1800.0	17700.0	131.8	20017.55	58801.55
1900.0	17700.0	139.6	21193.81	59077.75
2000.0	17700.0	147.7	25432.65	59446.53

TRANSMISSION LINE GRADIENT AND CORONA LOSS CALCULATION

NOMINAL VOLTAGE (KV,L-L) 765.0

PHASE SPACING (FEET) 53.00

SUBCONDUCTOR QTTY .4

BUNDLE SPACING (INCHES) 18.0

CONDUCTOR DIA. (INCHES) 1.293

GROUND CLEARANCE (FEET) 40.0

MAXIMUM VERTICAL GRADIENT (KV/CM,RMS) 17.56

AVERAGE INSIDE GRADIENT (KV/CM,RMS) 15.85

AVERAGE OUTSIDE GRADIENT (KV/CM,RMS) 14.90

CORONA INITIATION GRADIENT (KV/CM,RMS) 18.38

PROBABILITY OF EXCEEDING THE COMPUTED CORONA LOSSES (IN PERCENT)	CORONA LOSS (KW/3 PHASE MILE)
50.0	15.1
15.0	28.7
10.0	43.5
5.0	65.4
2.0	90.5
0	295.9

```
1.  TRANSMISSION LINE DESIGN DATA.
    ******************************

      A)  INSULATORS                   INSULATOR RATED STRENGHT       = 25000 LBS.
          **********                   INSULATOR QUANTITY PER STRING= 35

      B)  CONDUCTOR                    MAX. CONDUCTOR TENSION       = 17600.0 LBS. (AT 0 DEG.F.,ICE+WIND)
          *********                    CONDUCTOR EVERY DAY TENSION=  8794.4 LBS. (AT  50.0 DEG.F.,NO ICE, NO WIND)
                                       MAX. CONDUCTOR SAG           =    64.3 FT. (AT 110.0 DEG.F.)

      C)  TOWER                        CONDUCTOR TO STRUCTURE CLEARANCE= 246 IN.
          *****                        PHASE SPACING                   =  53 FT.
                                       BROKEN WIRE LOAD                = 13200.0 LBS.
                                       CROSSARM HEIGHT                 = 124.8 FT.

      D)  LINE                         TOWER QUANTITY      = 249
          ****                         RIGHT OF WAY WIDTH = 160.5 FT.

                                       LOSSES=        RESISTIVE LOSSES          = 134.1 KW/3-PHASE MILE
                                                      AVERAGE ANNUAL CORONA LOSS=  15.1        **
                                                       15 PCT.       **        =  24.7        **
                                                       10 PCT.       **        =  43.5        **
                                                        5 PCT.       **        =  65.4        **
                                                        2 PCT.       **        =  90.5        **
                                                        0 PCT.       **        = 295.9        **

2.  TRANSMISSION LINE COST DATA.
    ****************************

     INSTALLED  COST.                                   ANNUAL CHARGES.
     ($/3-PHASE MILE)                               ($/3-PHASE MILE/YEAR)

    INSULATORS    =  6196.36                        12.0 PCT. CHARGE ON CAPITAL          =  12370.76
    TOWERS        = 58784.91                        3.50 MILLS/KWH ON LOSSES             =   2973.56
    CONDUCTOR     = 38108.38                        10.0 $/KW CORONA DEMAND CHARGE       =    905.40
    RIGHT OF WAY  =        0                        (2 PCT. PROB.)
                   ---------                                                              ---------
TOTAL  INSTALLED  COST =103089.66                               TOTAL ANNUAL CHARGES =  16249.72
```

*** CASE NO 4 ***

CONDUCTOR TYPE= ACSR GRACKLE
SUBCONDUCTORS PER PHASE= 4

LOADING CONDITIONS		CONDUCTOR LOADS (LBS/FT)	
ICE COATING (INCHES)=	.50	VERTICAL LOAD =	2.652
WIND (LBS/SQ.FT.)=	8.00	HORIZONTAL LOAD=	1.559
CONDUCTOR WEIGHT (LBS/FT)=	1.526	COMBINED LOAD =	3.076

SPAN (FT.)	CONDUCTOR MAX. TENSION (LBS.)	TOWER CROSSARM HEIGHT (FT.)	INSTALLED TOWER COST ($)	INSTALLED TOWER COST ($/MILE)
1000.0	18150.0	85.2	13153.26	69447.86
1100.0	18250.0	89.6	13887.51	66833.64
1200.0	18350.0	94.4	14681.50	64782.13
1300.0	18350.0	99.7	15511.40	63015.06
1400.0	18450.0	105.2	16426.84	62011.33
1500.0	18450.0	111.3	17381.50	61269.79
1600.0	18450.0	117.9	18399.70	60948.99
1700.0	18450.0	124.8	19481.68	60636.74
1800.0	18550.0	131.8	20643.05	60638.97
1900.0	18550.0	139.5	21851.09	60909.92
2000.0	18550.0	147.6	23123.31	61276.76

TRANSMISSION LINE GRADIENT AND CORONA LOSS CALCULATION

NOMINAL VOLTAGE (KV,L-L)765.0

PHASE SPACING (FEET)	53.00
SUBCONDUCTOR QTTY	4
BUNDLE SPACING (INCHES)	18.0
CONDUCTOR DIA. (INCHES)	1.338
GROUND CLEARANCE (FEET)	40.0

MAXIMUM VERTICAL GRADIENT (KV/CM,RMS)	17.06
AVERAGE INSIDE GRADIENT (KV/CM,RMS)	15.35
AVERAGE OUTSIDE GRADIENT (KV/CM,RMS)	14.43
CORONA INITIATION GRADIENT(KV/CM,RMS)	18.32

PROBABILITY OF EXCEEDING THE COMPUTED CORONA LOSSES (IN PERCENT)	CORONA LOSS (KW/3 PHASE MILE)
50.0	13.9
15.0	26.4
10.0	39.9
5.0	60.0
2.0	83.1
0	271.7

```
1.  TRANSMISSION LINE DESIGN DATA.
    ******************************

        A)  INSULATORS          INSULATOR RATED STRENGHT     = 36000 LBS.
            **********          INSULATOR QUANTITY PER STRING= 35

        B)  CONDUCTOR           MAX. CONDUCTOR TENSION      = 18450.0 LBS. (AT 0 DEG.F..ICE+WIND)
            *********           CONDUCTOR EVERY DAY TENSION=  9426.9 LBS. (AT  50.0 DEG.F..NO ICE, NO WIND)
                                MAX. CONDUCTOR SAG          =    64.3 FT. (AT 110.0 DEG.F.)

        C)  TOWER               CONDUCTOR TO STRUCTURE CLEARANCE= 246 IN.
            *****               PHASE SPACING                   =  53 FT.
                                BROKEN WIRE LOAD                = 13837.5 LBS.
                                CROSSARM HEIGHT                 = 124.8 FT.

        D)  LINE                TOWER QUANTITY     = 249
            ****                RIGHT OF WAY WIDTH = 160.4 FT.

                                LOSSES=         RESISTIVE LOSSES              = 125.4 KW/3-PHASE MILE
                                                AVERAGE ANNUAL CORONA LOSS=  13.9          **
                                                 15 PCT.        **           =  20.4          **
                                                 10 PCT.        **           =  37.9          **
                                                  5 PCT.        **           =  60.0          **
                                                  2 PCT.        **           =  83.1          **
                                                  0 PCT.        **           = 271.7          **

2.  TRANSMISSION LINE COST DATA.
    ****************************

     INSTALLED  COST.                                  ANNUAL CHARGES.
     ($/3-PHASE MILE)                              ($/3-PHASE MILE/YEAR)

    INSULATORS   =   7503.61                       12.0 PCT. CHARGE ON CAPITAL        =  13070.61
    TOWERS       =  60636.74                       3.50 MILLS/KWH ON LOSSES           =   2775.19
    CONDUCTOR    =  40781.43                       10.0 $/KW CORONA DEMAND CHARGE     =    831.37
    RIGHT OF WAY =         0                       (2 PCT. PROB.)
                   ---------                                                            ---------
TOTAL  INSTALLED  COST =108921.78                           TOTAL ANNUAL CHARGES =  15677.17
```

APPENDIX "D"

GLOSSARY OF IDENTIFIER AND SUBROUTINE NAMES

(listed in order of occurrence in the program)

CLEAR	Conductor-structure clearance (ft.)
IQTTY	Number of insulators on one string
PFAC	Precipitation frequency
WIDTS	Tower truss width (ft.)
WIDLG	Tower leg width (ft.)
RDENS	Relative air density
STRLG	Insulator string length (ft.)
SURGFO	Expected quantity of switching surges per flashover
VNOM	Nominal system voltage (kV, L-L)
NTOWS	Number of towers on the line
CSSFO	Critical switching surge flashover voltage (kV)
SSIGMA	Standard deviation of the switching surge distribution (kV)
DIST	Length of transmission line (miles)
FOPROB	Line flashover probability
NPRNT	Printer location identification
NCRDR	Cardreader location identification
TOWWS	Tower withstand probability
CFOSTR	Insulator string critical flashover (kV)
CFOTS	Tower truss critical flashover (kV)
CFOLG	Tower leg critical flashover (kV)
ISTRIN	Insulator string arrangement 1 = single V 2 = double V 3 = single I 4 = double I 5 = single M 6 = double M

CDIA	Conductor diameter (in.)
GRDCL	Minimum ground clearance (ft.)
FASP	Phase spacing (ft.)
NSC	Number of subconductors per phase
CGRAD	Center average conductor bundle gradient (kV/cm)
CORGR	Corona inception gradient (kV/cm)
BUNSP	Subconductor bundle spacing (in.)
SURFC	Conductor surface coefficient
SAG	Maximum conductor sag (ft.)
LBC	Equivalent U.S. climatic area: 1 = Northeastern U.S. 2 = Southeastern U.S. 3 = Western Steppe 4 = Western Mountains 5 = Western Desert 6 = Coastal Pacific Southwest 7 = Coastal Pacific Northwest
OUTG	Outside average conductor bundle gradient (kV/cm)
CTRG	Center average conductor bundle gradient (kV/cm)
CORL (I)	Corona losses (kW/3 phase mile). The probability that these losses will be exceeded is: I = 1 Prob. = 50% 2 15% 3 10% 4 5% 5 2% 6 0%
INSSTR	Insulator strength (lbs.)
COSTIN	Insulator cost ($)
VMAX	Maximum system voltage (kV, L-L)
CREEP	Insulator creep distance (in.)
SLENT	Insulator length (in.)
SSMAX	Maximum switching surge (kV)
ANGLE	Angle between truss and insulator string (deg.)
RWSCOS	Right-of-way cost ($/acre)
IHCONT	Insulator contamination level 0 = slight 1 = moderate
IDFOPR	Desired line flashover probability
NSCG	Number of subconductors (given)
MVA	transmitted power (MVA)
XIICE	Radial ice thickness on conductor (in.)

WINDL	Wind load (lbs./sq.ft.)
AVTEMP	Average temperature (Deg.F.)
TOPTMP	Max. conductor temperature (Deg.F.)
ALFA	Coeff. of linear expansion (1/Deg.F.)
YOUNG	Final modulus of elasticity (psi)
HTLIM	Crossarm height limitation (ft.)
COEVDT	Coeff. of everyday tension (% of U.T.S.)
TCCOEF	Tower cost coefficient
ACOIC	Annual charges on installed cost (%)
ALOSC	Annual loss charges (mills/kWh)
DCOC	Demand charge on corona ($/kW)
CWGHT	Conductor weight (lbs./ft.)
AWGHT	Aluminium weight of conductor (lbs./ft.)
SWGHT	Steel weight of conductor (lbs./ft.)
CO, TYP	Conductor trade name
ICCCC	Conductor current carrying capacity (A)
CUTS	Conductor ultimate tensile strength (lbs.)
BAZCOS	Conductor basic cost ($/1,000 ft.)
CONRES	Conductor resistivity (Ohms/mile)

SUBROUTINES

GRADNT	Calculates the average gradient on the center phase and the corona initiation gradient.
ORDER3	Calculates the real root of a third order equation.
GRACOL	Calculates gradients and corona losses.
GCFO	Calculates critical flashover of a gap.
FOEXPL	Calculates the line flashover expectancy.
TOWITS (V)	Calculates tower withstand probability at voltage V.
NDTR (X,P,D)	Calculates normal probability and density.