" SERDIS SYSTEM " - A NEW APPROACH IN OPTIMIZED PLANNING OF DISTRIBUTION INVESTMENTS

A. Amendola & M. C. Rocha
Centrais Elétricas Brasileiras S.A. - ELETROBRÁS
Rua da Quitanda 196 – 11º – Rio de Janeiro – R.J. - BRAZIL
Tel : +55 21 5145091 – Fax : +55 21 2530398 – e-mail : alexaga@eletrobras.gov.br

ABSTRACT

*The worldwide trends show that, mainly, on account of, a lack of natural resources of the own planet, the electric energy conservation might be another alternative to be considered in power systems traditional expansion - also at the Distribution segment . So, the planning optics of Distribution systems has a new component to search the best way to plan the expansion in accordance with the least economic costs to the society as a whole . With the objective to determine these investments plans, it was created a system called "**SERDIS** - Software For Optimized Expansion Simulation Of Medium Tension - Version 2.0". At the end, an example shows the process described in the text .*

1 - INTRODUCTION

1.1 The Long Term Optics In Distribution Planning

In the range of the utilities, it was a natural process to define, in a deterministic way and based on specific plans, the Distribution investments programs only to the short term ; in the utilities with less development for one year and to the others till three years . This short term optics was caused by 2 reasons : the relative short time of works execution (till 6 months to medium an low tension networks and till 2 years to Distribution power substations) and the deterministic planning, linked to the topology, related to considerations of town planning and specific knowledge of street/avenues, making impossible to elaborate the planning with security in a longer term .

In other way, we must observe that, even if would be possible to determine the future topology in medium/long terms, the definition of investments, with a located approach for all the concession area of each enterprise would consider a set of infinite possibilities, making impossible the simulation and choice of technical solutions at a least cost .The impossibility of a detailed knowledge of the Distribution systems in a larger period of time imposes the appearance of geometric and statistical models which are not necessary linked with topological aspects of networks (field plans, charges and wires diagrams). We substitute the behavior analysis in field by a set of specific parameters which have stable values when studied in a set of networks belonging to actions zones with similar geometric forms. With these procedures, we can avoid to utilize some traditional actions used in detailed analysis of networks and with a hard use, like Distribution charge programs, which requires a great effort to update the data base to face the constants changes introduced by the Distribution works. In this way, we introduce some statistical concepts to achieve the Distribution planning systems. Moreover, we must consider that the decision to make na specific work and the subsequent execution influence the expansion system linked to it during all its useful life . So, it is reasonable to look at a greater period of time to elaborate the Distribution planning, with the objective to avoid the risk of considering anti-economic solutions and with a wrong work substitution time, adopting, in this way, not optimized solutions for systems expansion at the large term .

In this context, we verify a trend in developing the Global Plan Of Distribution System Expansion that, consists, mainly, in establish the system planning in a aggregate way in terms of concession area of the utility, looking for an integration of the several located plans with this global plan .

1.2 The Importance Of The Imperfections Costs To The Society as a Whole

The technological development makes the appearance of demanding energy consumers with quality and continuity of the product received from the utilities . In this way, as said before, one factor to be considered in the costs function to define an investment strategy is the supplying imperfections costs, where the emphasis is the one related to the not delivered energy - END, due to accidental interruptions. However, the estimation of the unitary cost to be used to calculate the END (cost by KWh interrupted) is not an easy task . This estimation involves the calculation of consumers damages which varies with the depth and the duration of the interruption .

2. THE CONSERVATION IMPORTANCE IN CURRENT SCENARIO

Conservation can be defines as a rational utilization of a same amount of energy sighting an increase in the capacity of supplying that can be obtained, basically, through the elimination of wastes, reduction of losses in the system, customs changes of consumption, utilization of equipments more efficient and/or increase of quality in productive processes. So, in this sense, conservation must be used as an efficient planning instrument, when it is time to define the strategic actions to be considered by utilities in next years

In face of a lack of resources and the important rates of growing predicted to supply the electric energy consumers market of the utilities, the investments demanded by the Distribution system must be placed in a degree of priorities, looking for an economy of resources and aiming at a gradual recuperation and losses reduction in period of study .It's important to emphasize that, a lot of these economy of resources can be obtained with the correct investments location with conservation programs use, at the system level and also under the optics of final users.

3. DISTRIBUTION EXPANSION SYSTEMS CONSIDERING THE ENERGY CONSERVATION

The philosophy used in Distribution expansion systems of medium tension that glimpses greater periods of time and consider important aspects described before, can be applied with the utilization of a software like "SERDIS - Version 1.0", that achieves the systems expansion in a optimized way in medium/long terms . Figure 1 shows, briefly, the process used by SERDIS in medium tension planning systems .

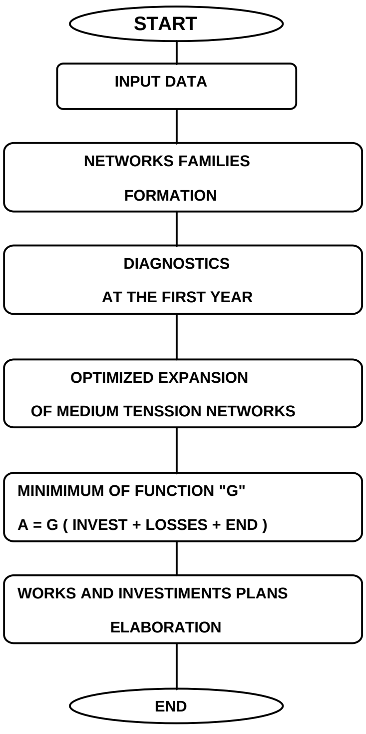


Figure 1 - Simplified Process Used By SERDIS - Version 1.0

As we'll see in next chapters, the methodology search to answer the following questions, considered essentials :

a) Which investments might be accomplished to guarantee the service with an specific quality ?

b) Which are the optimal levels to the annual electric energy conservation during the system expansion process ?

c) Which is the impact in service quality, if we change the amount of supposed investments ?

In current studies about this subject , we observe that, due to the energy conservation importance nowadays and future scenarios, it is essential its consideration during the system expansion for next years, in several segments of power system (Generation, Transmission and Distribution) .

Conservation must be included not as a right option to happen without any doubts, but as one more alternative to be compared with the traditional ones, used in the systems expansion .

However, in the elaboration of the expansion plans with conservation aspects in electric energy market, it is an usual practice among the utilities subtract from the energy market the part relative to the energy conservation amount predicted to next years . In this way, it is assumed that always will be possible to achieve the conservation, independent from the economical costs due to these programs. Another consequence of these practices is that the investments and works plans are merely a result of the new values of the estimated energy market for next years .

This procedure is completely wrong because, as said before, the correct way is to include conservation as one more alternative to be considered in the global costs that, together with projected investments, losses costs and the not delivered energy costs (END) will form a function to be a minimized under operational restrictions of tension fall and charge .

The function constructed as said before, constitutes an essential point in the optimized expansion process of Distribution networks of medium tension, which added to others considerations will constitute the "Integrated Investments Planning Methodology In Distribution And Energy Conservation" as described in the next sections of this document .

So, the proposed system is coherent with the worldwide literature about the theme, and can be a challenge to be followed by Distribution utilities .

Figure 2, shows , briefly, how electric energy conservation is considered in the planning process. If we compare

Figures 1 and 2, described before, we can easily verify that the calculation steps are quite the same .

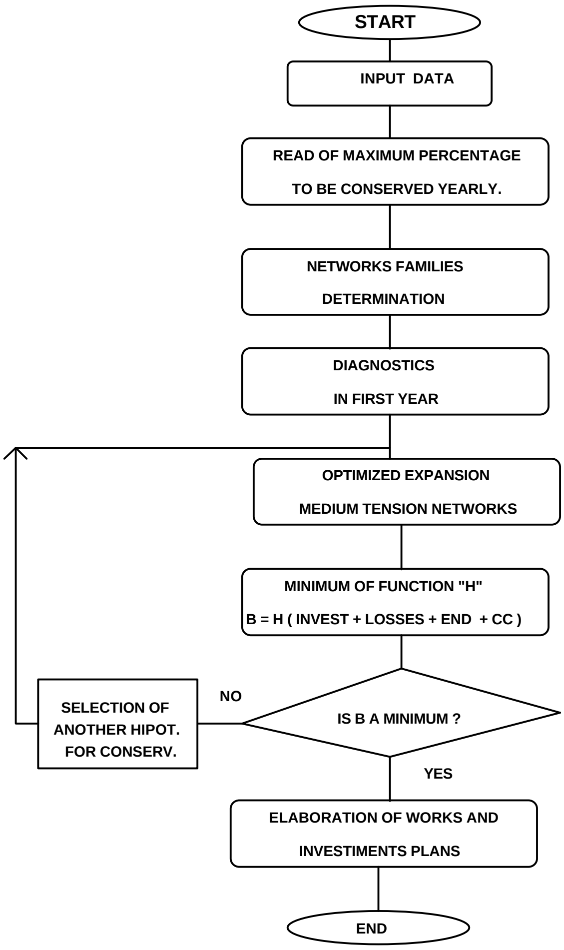


Figure 2 - Introduction of Conservation in Planning Process

The main difference remains in the consideration of the conservation costs at the function that will be minimized and also the creation of a new external loop with the objective of finding out which conservation values will correspond to an optimized expansion of medium tension Distribution networks .

So, the presented steps correspond to the SERDIS system - Version 2.0, which consider the energy conservation along the optimized expansion process of the networks in a medium / long term .

4. INTEGRATED INVESTMENTS PLANNING METHODDOLOGY IN DISTRIBUTION AND ENERGY CONSERVATION

4.1 Main Aspects Of The Proposed Methodology

Briefly, we present the main aspects used in the planning methodology .

4.1.1 Global Level Of Study . The study considers the input data in a aggregate way with respect to the concession area of the enterprise, giving results in global terms (“macro” level) relating to the investments / works plans of the utility .

4.1.2 Formation Of The "Networks Families" . The power substations and feeders are classified in homogeneous classes that present similar characteristics among them, forming “families”. In this way, when we make the analysis the behavior of a member belonging to a class, it is possible to study the behavior of several elements of the same “family” .

4.1.3 Geometric Model For Power Substations And Networks . Once constituted, the class or family is represented by a geometric figure called ellipse, with the SE located at the on of the focus of the figure. An example of a substation with 8 feeders is shown in Figure 3, below..

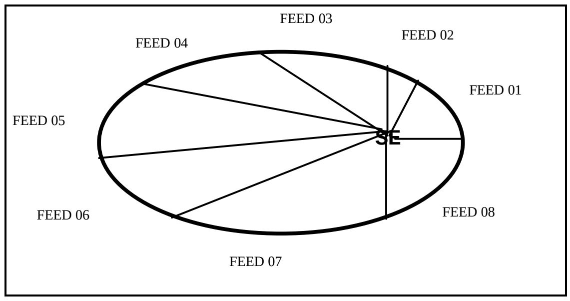


Figure 3 - Geometric Model Of Substations And Feeders

4.1.4 Validity of Statistical Laws. It is established a set of statistical laws involving the main variables which represents the real situation and the future behavior of the networks . If the class is located in an area where the town planning is not entirely developed (charge density not saturated), we use an algorithm called “Chronological Tree of Minimum Length”, where the points of charge appears in a random way in a specific kind of action zone . The figure formed like this procedure will represent the least network that supplies the points of charge in the geometric figure considered . Figure 4 shows an example of use of the “Tree” algorithm with 30 points of charge in the range of a circular sector.

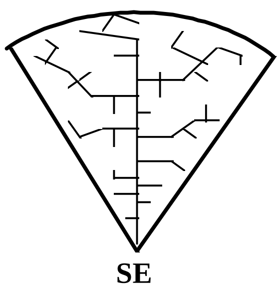


Figure - Algorithm Chronological Tree Of Minimum Lenght

If the class is located in a dense urban area (high charge density) we adopt a model that considers an uniform charge distribution along the feeder, as shown in Figure 5, below .

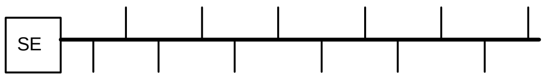


Figure 5 - Model For Dense Urban Areas

4.1.5 Determination of Technical Choices. As na income of the process, it is given to the system the main options which will define the networks expansion process, like planning and project criteria, materials, important conditions, and so on .

4.1.6. Determination of Conservation Parameters. In simulations we consider the value "% $C_{máx}$" which corresponds to the maximum percentage of annual conserved energy .

The methodology also uses a function called “conservation cost” that varies in a linear way in accordance with the energy to be conserved - C . Its form is :

$$CC(C) = a + b.C \tag{1}$$

where a and b are positive constants to be defined outside the process .

4.1.7. Global Costs Function . The main characteristic of this methodology is the minimization of a global function that considers the investment costs necessary to expansion, added to losses costs , energy interruption costs ("END" - not delivered energy) to the society as a whole and the conservation programs costs . This function is studied along the process, considering restrictions of tension fall and charge . The model is presented in Figure 6, below .

min F (I + P + END + CC)

restr. tension fall and charge

Figure 6 - Proposed Model For Global Costs Function

4.1.8. Optimized Networks Expansion . The network expansion is made for all possible situations involving the creation of new feeders , new substations and/or reinforcement of the current substations. The laws are introduced in the system and, after a representative model defined by an ellipse, we achieve to each year of study :

- Growth of model charge
- Diagnostics of the networks technical conditions
- Simulation involving its development, which objectives:

 * To supply new consumers
 * To remove technical restrictions
 * To improve the losses levels and/or service quality
 * To supply the optimal levels of conservation

and, finally, choose the sequence of optimal development.

Before the beginning of the expansion process, the methodology also predicts current situation analysis (diagnosis), trying to verify the amount of investments that would be necessary to recover the electric system, bringing it to the minimal conditions established before by the planning criteria and/or project .

4.1.9 General Plans of Works and Investments. The system generates the plans of works, describing global physics challenges, giving, to each year of study, the number of power substations, number and respective lengths and number of Distribution transformers As a consequence, we also obtain the amount of investments predicted to each year and to an specific service quality .

Under situation of financial restrictions, where the amount of resources is fewer than the investments obtained, the system is “flexible” with the technical restrictions and/or a changes in the unitary cost of not delivered energy - END which causes a degeneration of the final service quality to the consumers .

4.1.10 Annual Conservation . The system also gives the conservation annual values to be achieved, in terms of MWh and % .

4.11 Cost x Quality Study . The methodology presupposes the execution of the called “cost x quality study”, that, mainly, makes an sensibility analysis of some parameters, describing :

* Current Investments x unitary cost of END
* Gain over losses x unitary cost of END
* Gain over reliability x unitary cost of END
* Works programs to several values of END
* Investment Plans to several values of END
* Energy Conservation (MWh) x unitary cost of END

4.1.12 Impacts in Operational Parameters . At the end, as a consequence of the works/investments plans, the system verifies the impacts in following parameters :

* Tension fall
* DEC
* Losses rate

5. IMPACTS OF FINANCIAL RESTRICTIONS OVER DISTRIBUTION INVESTMENTS ANNUAL PLANS

The practice in adopting investments numeric extrapolation after the third or fourth year in order to obtain a period of 10 years to the Distribution planning is inadmissible because does not answer, in a objective way, which would be the service quality resulting from the applying of the projected resources, and which would be the optimal percentages to the energy conservation . In this way, the obtained plan is vulnerable under the financial restrictions in face of its incapacity to evaluate the restrictions (and eventual “cuts ”) in the expected service quality .

Meanwhile, the others segments of the power system (Generation and Transmission) with expansion simulation models, in a great level of development, succeed to answer to these questions and justify itself in a effective way in face of the financial restrictions ; there is an objective evaluation of its effects over the quality service. Moreover, these segments have bigger works with a great time of execution (hydro or thermal electric power plants, transmission lines and substations), there is a natural and correct worrie to guarantee financial resources in advance .

This previous definition of financial resources, which are scarse to the great works of Generation and Transmission, may generate repercussions on the own Distribution expansion system investments, considering the lack of technical/economical justifications to the projected investments in this segment of the electric sector .

Because of the considerations mentioned before, and also, in face of the conservation importance in current scenarios of poor resources, it become essential that Distribution segment has a methodology which permits the execution of expansion systems in a coherent way in a medium/long terms, making possible to answer, in terms of service quality degeneration, in face of eventual financial restrictions that couuld be considered .It is also desirable that the software gives support to the methodology application, and also to permit the execution of simulations, tests, specific studies, sensibility analysis and so on . In this direction it was developed the software of calculation called "**SERDIS -** Software For Optimized Expansion simulation Of Medium Tension - Version 2.0 ", which includes, in this version, an integration of the Investments Plans with the respective energy conservation optimal levels .

6. SOFTWARE "SERDIS – VERSION 2.0"

The software used in this methodology is an update version of SERDIS system, now in version 2.0, which considers conservation in the optimized expansion of the Distribution medium tension system .

6.1 Set of Menus Used By SERDIS

Figure 7 shows the main menu used by SERDIS

PRESENTATION
INPUT DATA
CHOICES
EXECUTION
PRINTER
DATABASE
CONSOLIDATION
QUIT

Figure 7 - Main Menu of SERDIS System

Each option originates another set of menus .

7. MAIN INPUT DATA

The main input data to use SERDIS is briefly described below .

7.1 Technical Choices

These are the planner options, project and planning criteria and others .

7.2 “Family” Data

Here, we have the characteristic data of each “family” of networks (high tension lines, number of feeders by power substations, wires section, growing rates and others) .

7.3 General Cost Data Of Substations And Lines

The unitary line costs, power transformers and equipments for substations are considered here .

7.4 General Costs Of Feeders, Distribution Transformers And Marginal Costs

We consider the main feeders, ramification, and Distribution transformers costs. We also introduce the marginal costs .

8. OUTPUT DATA

The system gives, mainly, the Works Plan in terms of global physics challenges, where we can list :

* Number of New Distribution Power Substations
* High Tension Network Length
* Numbers of Reinforcements
* Number of New Feeders
* Medium Tension Network Length
* Number of Distribution Transformers

The Investments Plan is given in global terms :

* Investments in new power substations (Ses)
* Investments in new lines of high tension
* Investments in reinforcements
* Investments in new feeders
* Investments in Distribution Transformers

The system also gives :

* Annual conservation in MWh and % of the consumption
* Conservation aggregated values to the considered period of time (MWh and %)

With respect of the "cost x quality", study , **SERDIS** can give all the comparisons described in 4.1.11.

10. EXAMPLE

An example of calculation is given below, in a very brief way, showing the diagnosis and some results using **SERDIS** for an specific “family” with 5 power substations (or members) .

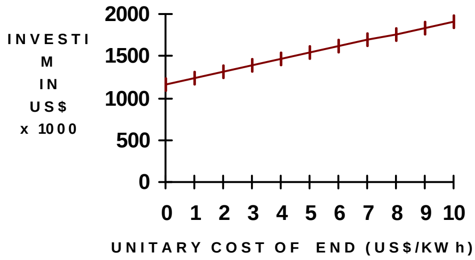
DIAGNOSTICS AT FIRST YEAR

VARIABLE	VALUES
TRANSFORMERS (CARREEG) (%)	100
CHARGE DENSITY (KW/KM)	320.99
TENSION FALL (%)	1.40
LOSSES (KW)	81.26
FEEDERR (CARREG) (%)	68
ENERGY NOT DISTRIBUTED (MWh)	0.12
LOSSES (% OF MAXIMUM DEM)	2.4
LENGHT(KM)	19.0
TRANSF. BY FEEDER	80
POWER CAPACITY(MVA)	15.43
NÚMB OF FEEDER BY SE	4
TOTAL NUMBER OF TRANSF	320
MEDIUM POWER OF TRANSF(KVA)	46.2
MÁX DEMAND BY FEEDER(MW)	3.45
POWER BY SE(MVA)	12.3
CURRENT BY FEEDER(A)	161.4

FORECAST FOR NEXT 10 YEARS

1- PHISICS CHALLENGES	
NÚMBER OF SEs REINFORC	15
NÚMBER OF SUBSTATIONS HT/MT	5.0
NÚMBER OF FEEDERS - MT	25
NÚMBER OF DISTRIBUTION TRANSF.	850
NETWORK LENGHT OF MT (KM)	100
NETWORK LENGHT OF HT(KM)	25
2- INVESTMENTS FORECAST	US$ x 1000
INVESTIM. IN SEs	578.0
INVESTIM. IN REINF.OF TRANSF	144.5
INVESTIM. IN DISTRIBUTIO TRANSF.	216.7
INVESTIM. IN FEEDERS MT	317.9
INVESTIM. IN LINES HT	187.8
3- ENERGY CONSERVATION	
AGREGGATED VALUES TO 20 YEARS (Mwh)	130
AGREGGATED VALUES TO 20 YEARS (%)	3

COST x QUALITY



REFERENCES

[1] P. Messager, *Modelisation des Reseaux MT Aériens*, EDF, Paris (1980), pp 1-11 .

[2] EDF International Consultant, *Planification des Investissemnets de Reseaux de Distribution - Rapport R2*, Eletrobrás, R.J.(1989) .

[3] A.G. Amendola, & M.C. Rocha, *Determination of Algorithm Chronological Tree Of Minimum Length*, Elerobrás, R.J. (1991) .

[4] A.G. Amendola, "*Determination of Statistical Laws Laws Involving Equivalent Constant of Losses and Tension Fall*, Eletrobrás, R.J. (1993) .

[5] A.G. Amendola, "*Determination of Criteria For Optmal Expansion in Distribution Networks* Eletrobrás, R.J. (1996) .