Interactive Intuitive Graphical Simulation Package for the Analysis of Electric Distribution System

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ABSTRACT

An interactive intuitive graphical simulation package for the analysis of electric distribution systems is presented. It incorporates interactive graphical design of the electric network with a relational data base. The interaction is facilitated with the use of GUI (Graphical User Interface). Two analysis algorithms are integrated allowing the study of load flow conditions as well as the optimization of reactive power allocation and sizing. The package provides an easy to use, state of the art tool for the analysis, design and planning of electrical distribution systems.

KEYWORDS: Load flow distribution system, interactive computation.

1. Introduction

The analysis of electric distribution systems is of great interest for utilities which want to increase their efficiency and improve energy management. The study of electric distribution system (EDS) should be focused on independent way because the used models in medium voltage necessarily do not incorporate the valid suppositions and simplifications for high voltage. This paper contributes with the integration of specialized algorithms in EDS, by means of an **Interactive Intuitive Graphical Simulation Package.**

The new generation of PC software in EDS[1,2] takes advantage of interactive graphic environment, which tries to develop friendly interfaces between the man and the machine and also increases the engineer productivity. From interfaces through batch processes, it has been developed interactive processes in which an user interacts with the computer, using macros, pull-down menu and dialog boxes[4,13,11]. Most of local utilities make use of traditional procedures of interaction and calculus. This paper seeks to demonstrate alternatives which would permit to perform their studies in a rapid, effective, and accurate way.

2. The Electrical Distribution Systems

The distribution systems include all the elements of electrical energy transport comprised between the primary substations, where the power transmission is reduced to distribution levels, and the home connections to the consumers [1,6,7]. The distribution networks present very particular characteristics, which make them different from the transmission ones. Among them it is distinguished: radial topologies, high R/X ratio, multiphase natures, complex side structure, distinct nature loads, lines without transpositions, distributed loads, etc. [12]. Due to the growing complexity of the distribution systems, the electric companies have been incorporating increasingly automation and control schemes and remote measure of the networks.

It is understood by distribution automation and control (DAC), the application of the necessary techniques and resources so that the distribution system on the whole may be operated and controlled remotely, coordinating the use of its different elements in real-time. The proper functions of the DAC are classified according to the elements on which they act, grouping them in three levels: substation, feeder, consumer [9].

This division has been criticized for not corresponding to a classification of automation functions, but related to the necessary equipment to control. Taking into account the operation and planning of the electrical distribution systems (EDS), it has been proposed a classification by objectives: information management, efficiency management, security an quality management[6,7], which incorporate help functions as the ones shown in figure 2.1. In this latter aspect, computational tools as the one reported in this work are inserted.
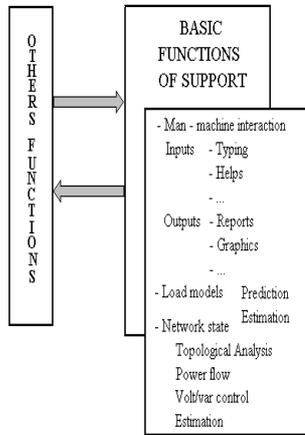
Fig. 2.1. Basic Functions of Support
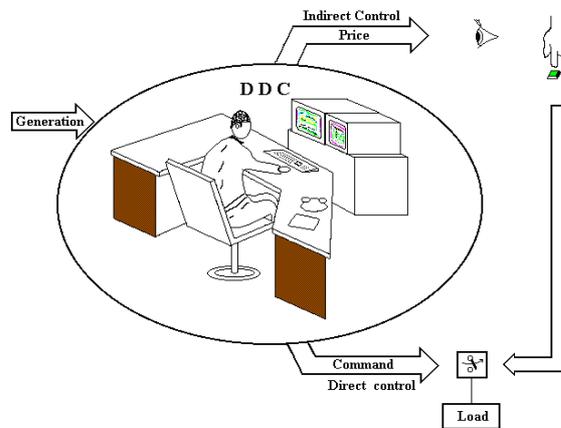
Fig. 2.2 Actions in the Distribution Dispatch Center (DDC)

As illustration of the automation trends of distribution systems, it is wise to point up the called distribution dispatch centers (figure 2.2). The data-collect system of the center is in charge of collecting and storing the information. A state estimating program takes the necessary data, calculates the system state, and shows the answers. The state calculus is based in a specialized software. Beginning with the state, the power flow, possible contingencies, voltage regulation, loss calculus, etc. are evaluated, using computational tools as the ones reported here. Based on the evaluations, decisions are made; they are executed as control signals though the SCADA system.

2.1. Power Flow in Distribution Systems

For the power flow analysis of electrical distribution systems, it can be used any of the conventional methods of power flow analysis such as node or meshing type - However, the EDS normally operate in radial configurations, and it has been demonstrated the convenience of using special methods of power flow, with better concurrence characteristics (speed and reliability). Among the special methods it is noticeable the ladder method, current summation method, and power summation method. In the following figures it is illustrated comparative results of simulations carried out with a program developed by the authors [7]; they show that the power summation method is the most adequate for the solution of power flows in electrical distribution systems.
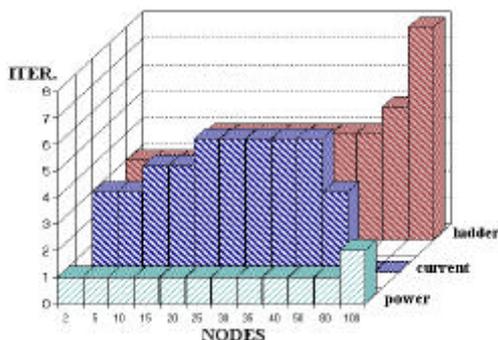

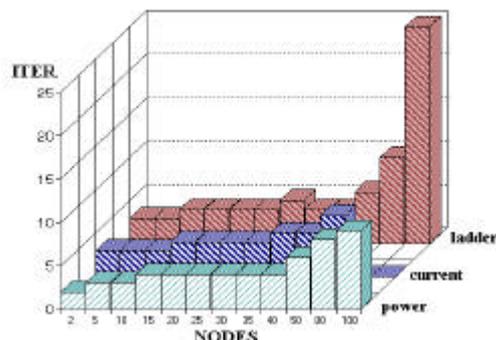**Fig. 2.3** Method comparison considering independent voltage consumption.

Fig. 2.4 Method comparison considering dependent voltage consumption.

3. Graphic Intuitive Interactive Interface in EDS

The concept of "Interactive Graphics" was originated in Palo Alto Research Center of Xerox in the years 70's and has been made popular by Apple Macintosh with its user interface since 1983, as well as by MS-Windows since 1990 [4,14]. Its application to the electrical engineering is attractive, due to the easy representation of a network through the icons, which may be interpreted quickly and easily, identifying elements and connections studies of the human factors in the interaction of men with the computer demonstrated that the application of concepts such as GUI (Graphical User Interface), GUIDE (GUI Developing Environment) and API (Application Programming Interface) is adapted easily to the user if the commands and feedback are related to similar human experiences.

Fig. 3.1 Intuitive Interfaces

This referred to how the user understands the model. Actually, for a GUI to be effective, the icon in the screen should represent something what the user really interprets. The system state must be reflected in images and the command effects should be understood in visual impact term. The development of graphical interactive interfaces for the analysis of EDS, necessarily goes through the use of network drawings and the graphical analysis of the results. The single line diagram is the obvious election for the EDS analysis, since the engineers are used to visualizing this type of systems in this way [3,4,13].
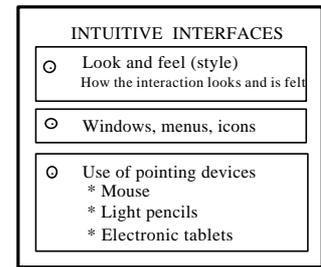
3.1. AIDPRI

It is reported the development of an intuitive interactive graphical software package for personal computers, which is formulated as a tool for the planning design and operation study of electrical distribution systems.

This software has been called **AIDPRI** (Intuitive Interactive Graphical Analysis of Primary Distribution). It is

Fig. 3.2 AIDPRI structure

structured in a modular way including the following functions: network drawing, input and addition of data, storage and recovery of files, three-phase flow analysis, and optimum analysis of reactive location. The package integrates software modules in language C, FORTRAN, PASCAL, and ASEMBLER. It takes the advantages that each compiler offers, in terms of speed and accuracy in the treatment of numbers, treatment of drawings, interruptions to the operative system. This is important in the study of big-sized networks. The development was based on a minimum hardware configuration: compatible PC computer 80386, with a minimum memory of 4MB, VGA monitor, hard disk, mathematic coprocessor, mouse, operative system 6.0 or superior.
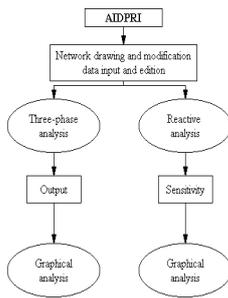
The package integrates three modular programs:

AIDPRI: It is in charge of the distribution network drawing and modification, data input, edition of them, topology determination, connections; it verifies that the data be complete, as well as the storage and recuperation of networks under study[13].

FASETA: It is in charge of executing the analysis of three-phase power flow, applying the dependent load of V and F, and modeling adequately the elements of the network, for example lines and transformers. It permits a graphic analysis of the results [9].

VOLPOT: Determines efficiently the location, dimensioning and the control in the time of condenser and transformer banks with control of derivations under load, so that the economical profits maximize due to a save in energy losses and peak power [10].

4. Package Description

The package was developed under the following principles: usage ease for engineers who do not necessarily know analysis techniques of EDS, modular program of easy maintenance and development, use of specialized algorithms for distribution systems in order to minimize the CPU times.

The user interacts through the mouse, selecting options of the offered menus. For the network construction and the study of power flows, nenotechnic codes are used. The icons which represent the network elements in a single-line diagram agree with the official Chilean standard 712.of72.

The package counts with the option of keeping the networks under study either as a public access document or a private one. Besides the topologic representation of the network, included the bar and element denominations, the parameters of the electric elements are stored. The drawing and modification of the distribution system is made in a simple way; it is enough to indicate the position of the element with the mouse coursor and the letter corresponding to such element. The construction and the connection of the network is done beginning by the power substation, with direction to the consumption centers, that is downstream. The process is direct, it is only needed that the user remember some few nemotechnic symbols, although there is a line help [13]. Zooming options are also incorporated, both approaching and aloofness. When building the graphical representation of the distribution network, this automatically establishes the system topology in a relational data base. The input and edition of data is done a conventional way through the computer keyboard. The associated data are divided in groups as so: nodes, lines, transformers, and power substation data. For the line parameters the user may give the resistance and reactance modules or indicate the type of conductor used. The program resorts to standard parameters stored in memory. The loads may be modeled in four different ways: constant P and Q, residential-type consumption, commercial consumption, and industrial consumption (they correspond to different V and F functions). Three-phase, two-phase and single-phase connections of loads may be represented.

4.1. Three-phase Power Flow Analysis

The analysis module of three-phase power flow used is based on a specialized algorithm for radial distribution networks [7,9,12]. This makes an optimum use of the RAM memory, besides being very fast and precise as demonstrated in [7]. It permits to represent disbalances, returns and couplings and offers a graphical analysis of the results.

4.2. Optimum Analysis of Reactives

The condensers are widely used in the EDS for the reactive power compensation, voltage control and loss reduction. The benefits of its use depend on the type of condensers (fixed or on/off switched) and its control. The program incorporated to the package permits to locate capacitors in the feeders of a radial system, to determine their location (number and location), type, size, and their control scheme [10,11]. The computational program analyzes two problems: the capacitive compensation and the voltage regulation. The compensation problem corresponds to the determination, dimensioning and optimum control in the time of the capacitor banks which will be installed in the system. The regulation problem corresponds to the determination of the location in the feeder of the minimum number of transformers with control on derivations under load, so that the voltage level outline keeps inside the pre-stablished limits. For the three modules it is offered the option of printing the monitor figure. On the other hand, the study modules generate ASCII files, which offer another way of analysis of the results.

5. Sample System

To illustrate the characteristic and kindness of the reported package, it is detailed the study of a typical network of urban-rural electrical distribution. [9,10] corresponding to the CGEI company. This network belongs to a radial feeder of 75 nodes, operated at 15[kV]. Most of loads are three-phased, excepting five of a two-phase nature. The three-phase transformers reduce the voltage to 400 [V] phase-to-phase for the three-phase distribution in low voltage. The single phase transformers used in the two-phase connections reduce the voltage to 231[V] phase-neuter. The feeder does not own ground return in medium voltage.
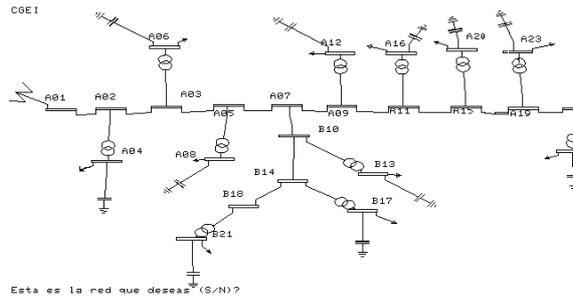
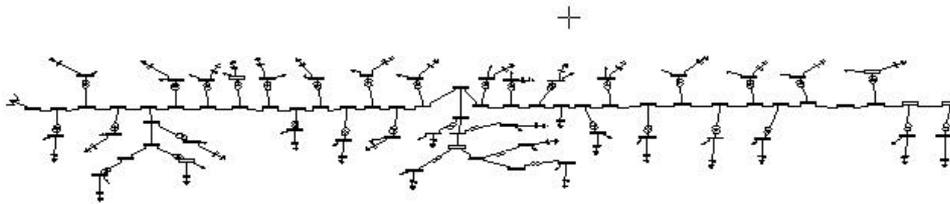**Fig. 5.1** Initial part of the CGEI system

Fig. 5.2 CGEI network

 The program offers the possibility of sliding the image from up to down, from left to right (or viceversa) and of using the zooming of approaching or aloofness. Figure 5.2 shows the use of a scale factor of 0.30. The following figure shows the data window of nominal consumption in nodes. It is used different load models according to the feeder character.The following figure shows the data window of the feeder-lines, shunts and transformers.

**Fig. 5.3** Consumption Data

Fig. 5.4 Line Data, shunts and transformers

The line data are input with codes which represent standard conductors, or by means of resistances or reactances given by the consumer. When the initial node is similar to the final one, it is being considered a shunt installed in that place. Following it is illustrated the graphical results of the study of the CGEI system. The data are used in [9,10], with disbalances of 0.33 and 0.30, without ground return, active and reactive load factor of 0.4.
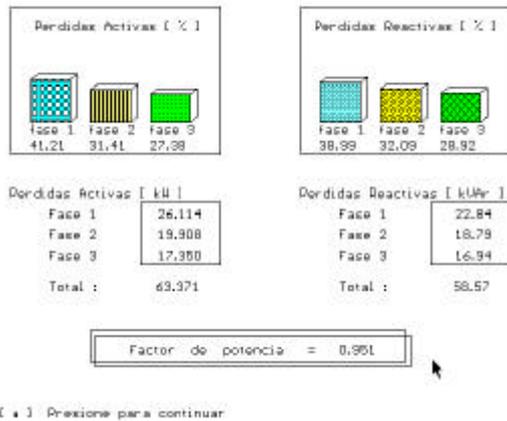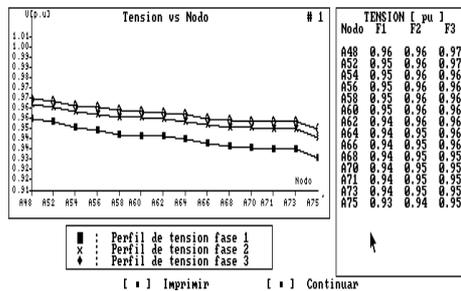
Fig. 5.5 Losses and load factor in the CGEI system
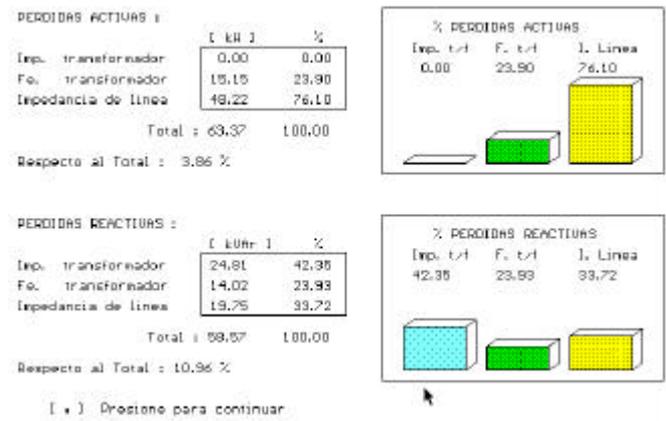
Fig. 5.6 Losses in the CGEI system
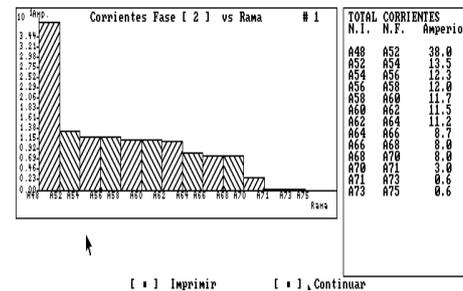

Fig. 5.7 Voltage level vs. node

Fig. 5.8 Current phase two vs. branch

The voltages in a primary feeder should not pass certain limits established by standards +7.5% in the electrically farthest node. The study of reactives is in charge of the option corresponding to the package. Further details in Volt/var Control with Interactive Graphics Interface on Distribution Systems by Vilcahuamán et al.

6. Conclusions and comments

The present work presents the development and use of a computational package for the electrical distribution network design and study, usable in personal computers. The use of interactive and intuitive interfaces in the network drawing and creation of the data base and in the calculus of three-phase power flow and the reactive analysis, make the program an easy-to-use tool in distribution companies and universities. The application of interactive graphic interfaces, plus the use of single-line diagrams, icons and tabulated data make the distribution engineer's labor easy. An effective feedback is produced in the construction of a network model, since the image lets the topologic verification, location of consumptions and shunts. Its value at the level of university students is evident. The package may be accessed by many students, through a terminal computer network. Among the options to be considered include in a future program, it is studied the optimum reconfiguration of feeders and the optimum location of substations. It also seems attractive the possibility of relating the package with geographic bases, type GIS (Geographic Information Systems).

8. Acknowlegements

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