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DISTRIBUTION SYSTEMS RELIABILITY ANALYSIS PACKAGE USING MATLAB GRAPHICAL USER INTERFACE (GUI)

H. Shayeghi [1] **Kh. Valipur** [1] **M. Haydari** [1] **H.A. Shayanfar** [2]

1. Technical Engineering Department, University of Mohaghegh Ardabili, Ardabil, Iran, hshayeghi@gmail.com
2. Center of Excellence for Power System Automation and Operation, Electrical Engineering Department, Iran University of Science and Technology, Tehran, Iran, hashayanfar@yahoo.com

Abstract- This paper presents a software package whose aim is to provide a tool to be used for reliability indices analysis in radial distribution system. It contains all the main elements found in practical system. The software package employs the Graphical User Interface (GUI) capabilities of Matlab. The main advantage of the proposed package is that the reliability indices analysis can find in different states for a distribution network. Moreover this software can plot reliability indices in a figure. Thus, it can be a useful tool for operator, manufacture and costumers in distribution network.

Keywords: Reliability Indices, Radial Distribution System, Graphical User Interface.

I. INTRODUCTION

The usage of computer simulations in the classroom is gaining popularity for particularly power engineering education [1, 2]. It is appreciated that, most of the computer simulation studies require a GUI that makes user interaction easier and more effective when compared with classical text based methods [3]. A successful GUI not only assists easy and effective data preparation process but also permits post processing of the results and most vitally permits the user to see everything at once.

The reliability indices analysis is an important issue in distribution network planning and operational studies. The reliability indices that have been evaluated using classical concepts are the three primary ones of average failure rate, average outage duration and average annual unavailability or average annual outage time. Although the three primary indices are fundamentally important, they do not always give a complete representation of the system behavior and response. The additional indices that are most commonly used are customer-orientated indices and load-and energy- orientated indices [4].

In this paper, we describe an educational software package which is called Reliability Distribution Analysis Package (RDAP) and developed in Matlab's GUI. The package allows the student to achieve distribution system reliability analysis using different protective device, loop switches, lines/cables and repair/replacement transformers. The paper is organized as follows: Section II describes Evaluation techniques for radial distribution system; Section III describes GUI in Matlab; Section IV evaluates GUI package in a RBTS test system and Section V summarizes the main point and results of this paper.

II. EVALUATION TECHNIQUES

A radial distribution system consists of a set of series components, including lines, cables, disconnects (or isolators), bus bars, etc. A customer connected to any load point of such a system requires all components between himself and the supply point to be operating. The basic distribution system reliability indices are the three Load Point (LP) indices: (1) Average failure rate λ_s; (2) average outage duration r_s; (3) annual outage duration U_s [4]. The principle of series systems can be applied directly to these systems as follows:

$$\lambda_s = \sum_i \lambda_i \quad (1)$$

$$U_s = \sum_i \lambda_i r_i \quad (2)$$

$$r_s = \frac{U_s}{\lambda_s} \quad (3)$$

In order to measure the system's reliability, certain indices are used. In this section some of most commonly used metrics are described. For any updates on the definitions given below and for some of less commonly used indices. Reliability indices have two categories: System-wide indices and customer indices. The former is used to give an insight of the overall system performance while the latter is more specific and reflects what the individual customer experiences. These are also classified depending on the interruptions dealt with: sustained or momentary. Thus, we have:

$$SAIDI = \frac{\sum r_i N_i}{N_T} \quad (4)$$

$$SAIFI = \frac{\sum N_i}{N_T} \quad (5)$$

$$CAIDI = \frac{\sum r_i N_i}{\sum N_i} = \frac{SAIDI}{SAIFI} \tag{6}$$

$$ASAI = \frac{N_T \times 8760 - \sum r_i N_i}{N_T \times 8760} \tag{7}$$

$$ENS = \sum_i L_i U_i \tag{8}$$

where, N_i is the number of interrupted customers for each interruption event during the reporting period, N_T is the total number of customers served in the area.

The customer-and load-oriented indices described are very useful for assessing the severity of system failures in future reliability predication analysis. They can also be used, however, as a means of assessing the past performance of a system. In fact, at the present time, they are probably more widely used in this respect than as measures of future performance. Assessment of system performance is a valuable procedure for three important reasons [4]:

a) It establishes the chronological changes in system performance and therefore helps to identify weak areas and the need for reinforcement.

b) It creates existing indices which serve as a guide for acceptable values in future reliability assessments.

c) It facilitates previous predictions to be compared with actual operating experience.

There are two basic approaches to conducting system reliability studies. The various methods can be generally divided into the application of analytical models and approaches, and the use of Monte Carlo simulation. The reliability assessments presented in this paper were performed using analytical techniques. The method adopted in the paper does a failure modes and effects analysis which needs the identification of the different component failures modes and the effects of these failure events on load point and system success. It is assumed here that the component failure rates and outage time are exponentially distributed. Two sets of reliability indices have been defined [5] for distribution systems, namely the basic load point indices and the system performance indices. The basic indices are important from an individual customer's point of view, but do not give an overall appreciation of the system performance. The overall distribution system performance is obtained by a weighted aggregation of the individual load point indices [10, 11]. The algorithm for calculation reliability index for contingency j, when alternative path by loop switches is provided is given by:

1. Consider a contingency j
2. Find the first circuit breaker in the path toward feeder
3. Disconnect faulty zone by this CB
4. Find the first sectionalizing switch in the path toward feeder, If there isn't any sectionalizing switch in the path, go to next step else go to 6.
5. Find all load points which are deenergized by CB trip and calculate, reliability index using equations for the repair time required to restore energy (t_{rep}) then go to step 1.
6. Find all load points which are deenergized by CB trip and calculate, reliability index equation for switching time of remote controlled sectionalizes (t_{sec})
7. Disconnect remote controlled sectionalizing switch and connect CB and find new load points which are deenergized and calculate reliability index for the switching time of loop switch (t_{tie}) to restore energy from alternative path.
8. Connect loop switch and determine reliability indexes for repair time required for the remained faulty zone.
9. Total reliability index for contingency j is the sum of three calculated in steps 6, 7, 8, and then go to step 1.

Figure 1 shows step by step switching intervals of breaker, sectionalizes and loop switch when a fault occurred between S_2 and S_3 [6].

III. GRAPHICAL USER INTERFACES

A graphical user interface is a pictorial interface to a program. A good GUI can make programs easier to use by providing them with a consistent appearance and with intuitive controls like pushbuttons, list boxes, sliders, menus, and so forth. The GUI should behave in an understandable and predictable manner, so that a user knows what to expect when he or she performs an action. For example, when a mouse click occurs on a pushbutton, the GUI should initiate the action described on the label of the button.

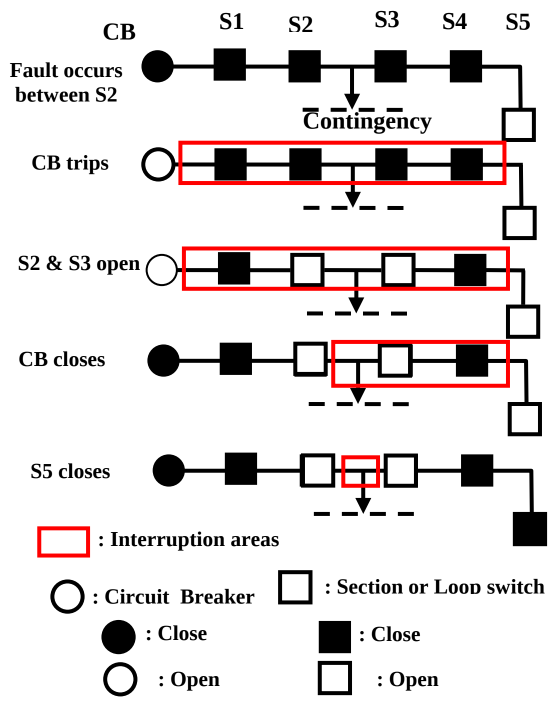

Figure 1. Process of switching intervals to isolate a fault

A graphical user interface provides the user with a familiar environment in which to work. This environment contains pushbuttons, toggle buttons lists menus, text boxes, and so forth, all of which are already familiar to the user, so that he or she can concentrate on using the application rather than on the mechanics involved in doing things. However, GUIs are harder for the programmer because a GUI-based program must be prepared for mouse clicks (or possibly keyboard input) for any GUI element at any time. Such inputs are known as events, and a program that responds to events is said to be event driven.

The three principle elements required to create a Matlab Graphical User Interface are [7]:

1. *Components:* Each item on a Matlab GUI (pushbuttons, labels, edit boxes, etc.) is a graphical component. The types of components include graphical control (pushbuttons, edit boxes, lists, sliders, etc.), static elements (frames and text strings), menus, and axes. Graphical controls and static elements are created by the function uicontrol, and menus are created by the function uimenu and uicontextmenu. Axes, which are used to display graphical data, data, are created by function axes.
2. *Figures:* The components of a GUI must be arranged within a figure, which is a window on the computer screen. In the past, figures have been created automatically whenever we have plotted data. However, empty figures can be created with the function figure and can be used to hold any combination of components.
3. *Callbacks:* Finally, there must be some way to perform an action if a user clicks a mouse on a button or types information on a keyboard. A mouse click or a key press is an event, and the Matlab program must respond to each event if the program is to perform its function. For example, if a user clicks on a button, that event must cause the Matlab code that implements the function of the button to be executed. The code executed in response to an event is known as a callback. There must be a callback to implement the function of each graphical component on the GUI.

IV. SOFTWARE DESCRIPTION

Developed package, called RDAP, consists of one main window that allows user to solve reliability index for radial distribution systems. All program routines of the package use Matlab m-files, version 7.8. The main window, given in Figure 2, divided into three sections called system data, protective devices and reliability index results. The system data section provides user to input the system reliability index and branch data.

In system data, user enter information depended to number section, sending node, receiving node, main or lateral section, protective device (1=breaker, 2=recloser, 3=switch and 4=fuse), exist transformer (1=is, 0=isn't), section length, repair time, switching time, customer number, load and customer types.

After enter data, user can by radio button defined line or cable, repair or replacement transformer, tie points moreover software can plot radial distribution network, with clicking on calculation, software reply reliability index. Now user can see affect protective device. User can evaluate the following cases in distribution network [8]:

1. Case A: Disconnects, fuses, alternate supply, transformer repair.
2. Case B: No disconnects, no fuses, no alternate supply, transformer repair.
3. Case C: No disconnects, fuses, no alternate supply and transformer repair.
4. Case D: Disconnects, no fuses, alternate supply and transformer repair.
5. Case E: Disconnects, fuses, alternate supply and transformer replacement.
6. Case F: Disconnects, no fuses, no alternate supply and transformer repair.

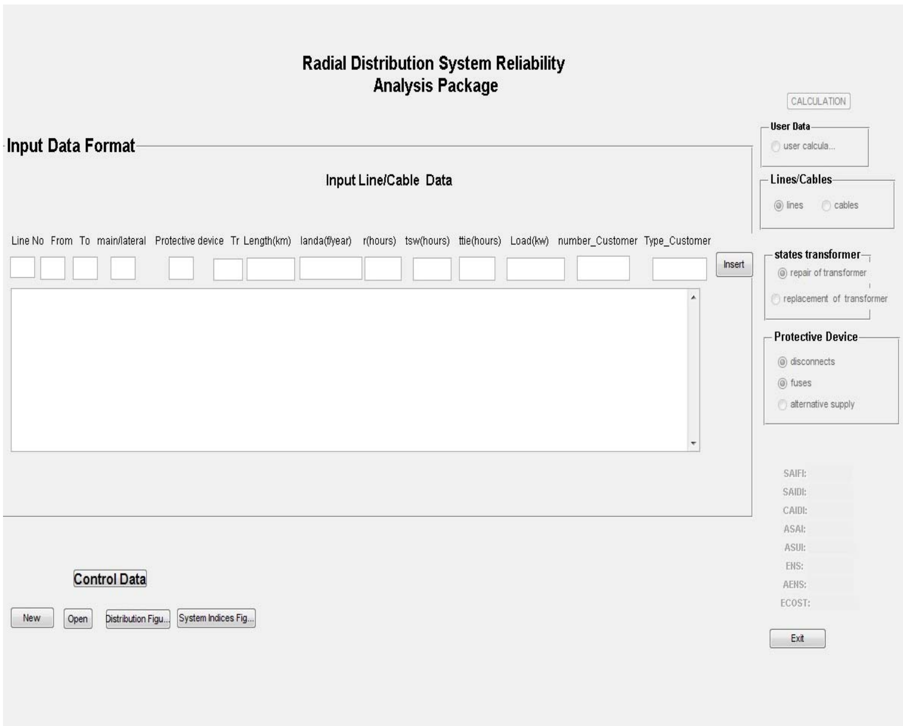

Figure 2. Main windows for reliability distribution network analysis

7. Case G: Disconnects, fuses, no alternate supply, transformer repair.
8. Case H: Disconnects, fuses, no alternate supply, transformer replacement.
9. Case I: No disconnects, no fuses, no alternate supply, transformer replacement.
10. Case J: No disconnects, fuses, no alternate supply, transformer replacement.
11. Case K: Disconnects, no fuses, alternate supply, transformer replacement.
12. Case L: Disconnects, no fuses, no alternate supply, transformer replacement.

V. TEST EXAMPLES

Several distribution networks can be used to illustrate the effectiveness of the proposed package for calculation reliability index such as RBTS [9] test network. The RBTS has 5 load bus bars (BUS2-BUS5). Two of these bus bars (BUS2 and BUS4) were selected and distribution networks designed for each. Figure 3 and Figure 4 show reliability indices for RBTS BUS2 and RBTS BUS4, Moreover, Figures 5 and 6 show SAIDI for RBTS BUS2 and RBTS BUS4.

Reliability Indices

	SAIFI	SAIDI	ASAI	AENS
Case A:	0.249628	3.61946	0.999587	0.0198568
Case B:	0.606591	22.5176	0.997429	0.121323
Case C:	0.249628	4.17007	0.999524	0.0232771
Case D:	0.606591	6.68802	0.999237	0.034923
Case E:	0.249628	0.772443	0.999912	0.00470906
Case F:	0.606591	9.89794	0.99887	0.0779858
Case G:	0.249628	3.73896	0.999573	0.0214446
Case H:	0.249628	0.891943	0.999898	0.00629692
Case I:	0.606591	3.53256	0.999597	0.0199281
Case J:	0.249628	1.32306	0.999849	0.00812937
Case K:	0.606591	1.33905	0.999847	0.0076284
Case L:	0.606591	1.7841	0.999796	0.0136159

Figure 3. Reliability Indices for RBTS BUS2

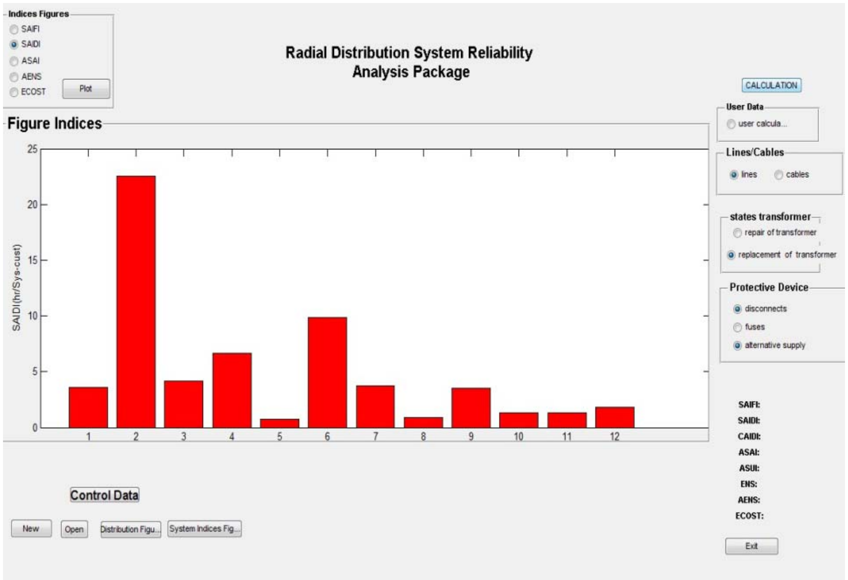

Figure 4. *SAIDI* index for RBTS BUS2

Reliability Indices

	SAIFI	SAIDI	ASAI	AENS
Case A:	0.299656	3.46411	0.999605	0.0113134
Case B:	0.682129	24.6428	0.997187	0.0782769
Case C:	0.299656	4.41777	0.999496	0.015487
Case D:	0.682129	5.31729	0.999393	0.0165806
Case E:	0.299656	0.619473	0.999929	0.00261849
Case F:	0.682129	12.3907	0.998586	0.0471488
Case G:	0.299656	3.99594	0.999544	0.0140716
Case H:	0.299656	1.15131	0.999869	0.00537672
Case I:	0.682129	3.95506	0.999549	0.0150211
Case J:	0.299656	1.57314	0.99982	0.0067921
Case K:	0.682129	1.07121	0.999878	0.00417035
Case L:	0.682129	2.29436	0.999738	0.0101686

Figure 5. Reliability Indices for RBTS BUS4

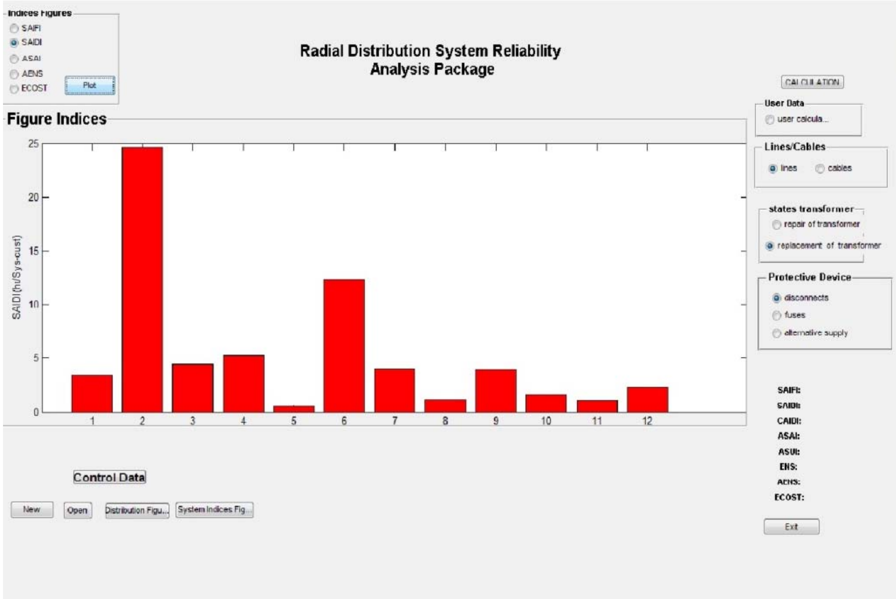

Figure 6. *SAIDI* index for RBTS BUS4

VI. CONCLUSIONS

In this paper, a software package called RDAP for distribution reliability analysis at the graduate and undergraduate levels is developed. It is designed in Matlab's GUI environment and tested on RBTS (BUS2 and BUS4) test system. From the test examples, it is observed that the reliability indexes solution of the systems is same [8]. The package allows students to rapidly gain experience and knowledge for reliability indexes in distribution network.

NOMENCLATURE

λ: Average failure rate
r: Average outage time
U: Average annual outage time
N: Number of customers
L: Average load connected to load point
GUI: Graphical user interface
SAIFI: System average interruption frequency
SAIDI: System average interruption duration
CAIDI: Customer average interruption duration
ASAI: Average service availability
ENS: Energy not supplied
RBTS: Roy Billiton test system

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BIOGRAPHIES

Hossein Shayeghi received the B.Sc. and M.S.E. degrees in Electrical and Control Engineering in 1996 and 1998, respectively. He received his Ph.D. degree in Electrical Engineering from Iran University of Science and Technology, Tehran, Iran in 2006. Currently, he is an Associate Professor in Technical Engineering Department of University of Mohaghegh Ardabili, Ardabil, Iran. His research interests are in the application of robust control, artificial intelligence and heuristic optimization methods to power system control design, operation and planning and power system restructuring. He is author and co-author of six books in electrical engineering area all in Farsi, two book chapters in international publishers and more than 188 papers in international journals and conference proceedings. Also, he collaborates with several international journals as reviewer boards and works as editorial committee of four international journals. He has served on several other committees and panels in government, industry, and technical conferences. He was selected as distinguished researcher of the University of Mohaghegh Ardabili several times in 2007, 2010 and 2011. He was elected as distinguished researcher in engineering field in Ardabil province of Iran. Also, he is a member of Iranian Association of Electrical and Electronic Engineers (IAEEE) and IEEE. Currently, he is head of Ardabil Technology Incubation Center (ATIC) at University of Mohaghegh Ardabili since 2008.

Khalili Valipur received the B.Sc., M.S.E. and Ph.D. degrees in Electrical Engineering, respectively. Currently, he is an Assistant Professor in Technical Engineering Department of University of Mohaghegh Ardabili, Ardabil, Iran. His research interests are in the power systems and electric machines design.

Mojtaba Haydari received the B.Sc. degree in Electrical Engineering from Shahid Rajaei Training Teacher University of Technology, Tehran, Iran in 2009. Currently, He is a M.S.E. student in Technical Engineering Department of the University of Mohaghegh Ardabili, Ardabil, Iran. His areas of interest in research are the application of heuristic optimization to distribution network protective devices placement.

Heidar Ali Shayanfar received the B.Sc. and M.S.E. degrees in Electrical Engineering in 1973 and 1979, respectively. He received his Ph.D. degree in Electrical Engineering from Michigan State University, U.S.A., in 1981. Currently, he is a Full Professor in Electrical Engineering Department of Iran University of Science and Technology, Tehran, Iran. His research interests are in the area of application of artificial intelligence to power system control design, dynamic load modeling, power system observability studies, voltage collapse, congestion management in a restructured power system, reliability improvement in distribution systems and reactive pricing in deregulated power systems. He has published more than 140 papers in international journals and 214 papers in conference proceedings. He is a member of the Iranian Association of Electrical and Electronic Engineers and IEEE.