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MATLAB GUI application for failure analysis of electrical power system faults

Aplicación con MATLAB GUI para el análisis de fallas en sistemas Eléctricos de Potencia

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Abstract

This paper presents a computational algorithm in MATLAB with the Guide tool to analyse symmetrical and asymmetrical faults in electrical power systems. Fault analysis is important in the design, planning and operation of power systems, and is used to specify interrupting devices and define operating strategies that do not violate short-circuit levels. It also highlights the importance of good fault detection and coordination of protections to consider the type of fault, where it occurs, the phases involved and the evolution of the fault type.

Symmetrical faults, Asymmetrical faults, Fault analysis

Resumen

Este artículo presenta un algoritmo computacional en MATLAB con la herramienta Guide, para analizar las fallas simétricas y asimétricas en los sistemas eléctricos de potencia. El análisis de fallas es importante en el diseño, la planificación y el funcionamiento de los sistemas eléctricos, y se utiliza para especificar dispositivos de interrupción y definir estrategias de funcionamiento que no violen los niveles de cortocircuito. También se destaca la importancia de una buena detección de fallas y coordinación de protecciones para considerar el tipo de falla, dónde ocurre, las fases involucradas y la evolución del tipo de falla.

Fallas simétricas, Fallas asimétricas, Análisis de fallas

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Introduction

This paper will analyze the analysis of the current distribution in the network, which allows establishing equations that define the behavior of the system.

A fault in an electrical circuit can be defined as any event that interferes with the normal flow of current.In the design, planning and operation of power systems, fault studies are used for different purposes, such as the specification of interrupting devices or the definition of operation strategies that do not violate short-circuit levels. Faults also occur in distribution systems such as the test systems presented in [9].

The occurrence of faults in a system is inherently random and their study requires a solid basis for problem definition and utilization of the results. When a fault occurs, the type of fault, where it occurs, the phases involved and the evolution of the fault type are some of the characteristics that a good fault detection and protection coordination scheme should consider. Experience has shown that between 70 % and 80 % of line faults are single phase to ground faults that originate in the insulation protection of the line to tower and ground. About 5% of faults involve all three phases and these can be called three-phase faults [1].

A fault is an unplanned connection that disturbs the system balance. The disturbance initiates the dynamic process and the reaction of elements and controls. Faults have different effects over time, with the highest current values in the first cycle [2]. It should be noted here that traditional fault studies consider only a single instant in time, as if the picture of the dynamic response of the system is taken at one point in time.

Most faults occurring in electrical systems are faults consisting of asymmetrical short circuits, asymmetrical faults with resistance or open conductors, and this is where the solution approach considered in electrical systems research is important. Symmetrical components for post-fault analysis, currents and voltages are determined in all parts of the system. A condition for using a symmetrical component sequence network is that the three-phase network is balanced.

A connected three-phase system can be transformed into three disconnected sequence networks by transforming the symmetrical components, which is achieved by diagonalizing the matrix representing the resistance or admittance of the system elements [3].

Fault analysis in electrical distribution systems is a fundamental task to guarantee the reliability and continuity of the electrical energy supply. An electrical distribution system is composed of an interconnected network of transmission and distribution lines, substations, transformers and protection equipment. Over time, these components may fail due to various factors, such as wear, overloads, short circuits, adverse weather conditions or operating errors.

This aims to identify the root cause of a failure, understand its mechanism of occurrence and determine the necessary corrective actions to restore the system to its normal operating state. This involves the early detection of faults, their precise location and the assessment of the damage caused.

Fault analysis in electrical distribution systems is carried out using a combination of techniques and tools, including visual inspections, equipment testing, event logs, data analysis, modeling and simulation. These techniques enable engineers to identify the exact location of the fault and determine whether it is related to generation, transmission or distribution equipment. In addition, fault analysis helps to assess the impact of the fault on the system and to develop mitigation strategies to avoid future outages [4].

A key tool in failure analysis is modeling and simulation of the electrical system. By using specialized simulation software, engineers can create accurate models of the distribution system and simulate different fault scenarios. This allows them to evaluate system behavior under adverse conditions, identify potential weak points and test different mitigation strategies.

In addition, fault analysis benefits from advances in monitoring and diagnostic technology. Real-time monitoring systems, advanced measurement devices and condition sensors can provide valuable information on equipment performance and system integrity.

Analysis of this data in combination with artificial intelligence and machine learning techniques can facilitate early anomaly detection, fault prediction and more accurate and efficient decision making.

Fault analysis in electrical distribution systems relies on a combination of theoretical knowledge, practical experience and the use of advanced tools and technologies. It is essential to have specialized engineers in this field, who must have a deep knowledge of electrical principles, safety regulations, distribution system components and diagnostic techniques.
Asymmetrical Faults in Electrical Power Systems.

Asymmetrical faults, also known as unbalanced faults or sequence faults, are those in which the voltages and currents in the phases of the electrical system are not equal in magnitude and/or phase difference. These faults can occur due to short circuits between phases, short circuits to ground or a combination of both. Asymmetrical faults can cause unbalanced currents and voltages in the system, which can affect the operation of equipment and cause wear or damage to system components [5]. These include the following asymmetrical faults:

- Single-phase line-to-ground fault.
- Line-to-line fault.
- Double line-to-ground fault.
- Current limiting reactance in synchronous generators.
- Short-circuit current limiting resistor for a ground fault.
- Generator grounded by means of a reactance.

Symmetrical faults in electrical power systems

Symmetrical faults, also known as balanced faults or zero sequence faults, are those in which the magnitudes and phase lags of the voltages and currents in the phases of the electrical system are equal. These faults may occur due to short circuits between phases or between one or more phases and ground. Unlike asymmetrical faults, symmetrical faults do not generate unbalanced currents and voltages in the system, but they can generate high short-circuit currents that can damage equipment and devices connected to the system [6]. Asymmetrical faults are as follows:

- Symmetrical faults in power transformers.
- Symmetrical fault, generator no-load short-circuit.
- Symmetrical fault, transients in RL series circuits.
- Symmetrical fault, sub-transient current calculation.
- Symmetrical fault, motor working as generator.
- Symmetrical fault, fault calculation using Zbarra.

Design of Guide for Failure Analysis in Electrical Power Systems

For the realization of the program in MATLAB [7] we used the GUI (Graphical User Interface) tool to facilitate the user the exchange of data, making it easier to understand the results obtained. The platform automatically generates the Matlab code of each block, which allows faster and easier programming of the different internal functions of the components, so the use of GUIDE facilitates the design and programming process of the GUI interface developed in MATLAB for failure analysis in power systems.

The program has several options to perform the calculation of the different symmetrical and asymmetrical faults, a user interface has been created where you can enter some starting data and observe the different results. The main window of the interface is shown in Figure 1, it is a guide that contains two pushbuttons to choose whether to perform symmetrical faults through the submenu shown in Figure 2 or choose the button with the submenu of asymmetrical faults Figure 3.

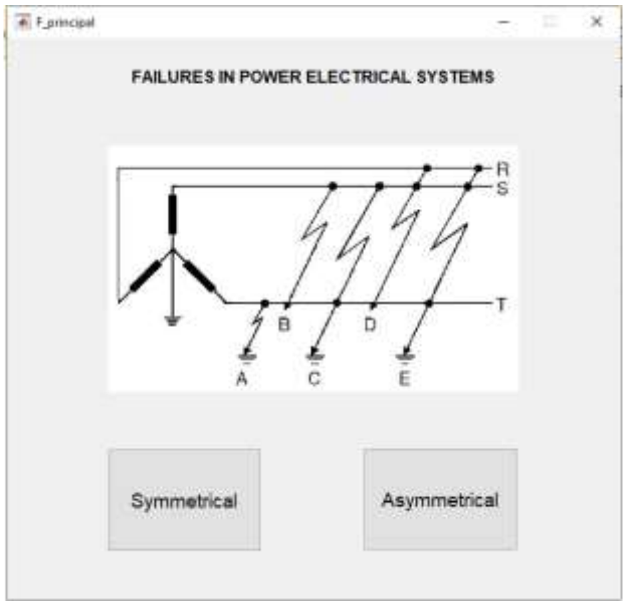

Figure 1 Main menu

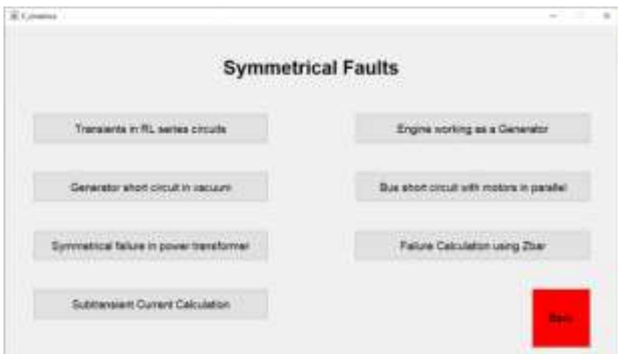

Figure 2 Symmetric faults submenu

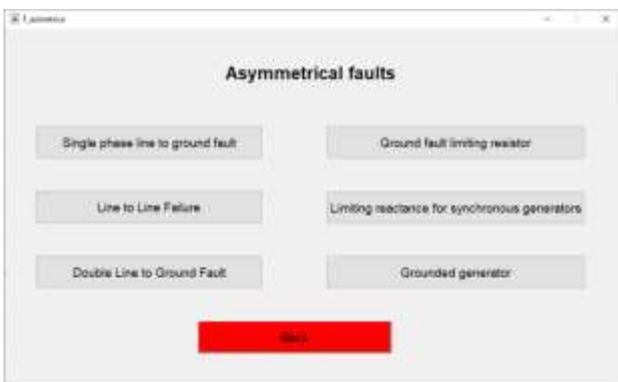

Figure 3 Asymmetric faults submenu

Depending on the option chosen, it will send us to the corresponding guide. In which by means of different pushbotton we can choose the problem to solve and a pushbotton (Back) to return to F_principal [7].

The programs in which the different problems are solved are composed of three pushbottons, one designated as "Calculate" which performs all the operations and sends the results to a table or tables designated as "T_results". Another pushbotton designated as "reset" which erases all the data of the guide for the realization of another different problem and finally a pushbotton designated as "back" which will serve to return to the previous guide and choose another problem to solve [7].

Program Evaluation

The application is validated by entering all the data in the submenus of the GUI program, in this case the short circuit calculation for a no-load generator is shown, it is considered because the short circuit in a no-load generator occurs when the output terminals of the generator are connected directly, without external load. In this situation, the external impedance is very low or practically zero.

The data to be used to validate the GUI application are as follows [8]:

Cycles: 5
Generator power: 100 MVA
Voltage: 18 VK
Sub-transient reactance: 19%.
Transient Reactance: 26%.
Loss Reactance: 130%.

When the application was run with the data input, the following results were obtained as shown in Figure 4.

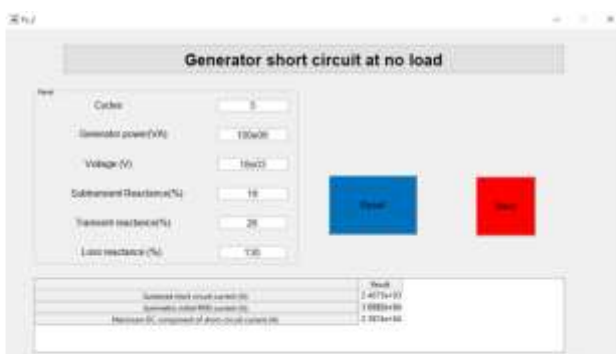

Figure 4 Application data and results for no-load generator short-circuit

Sustained short-circuit current	2.4673 KA
Initial RMS current Symmetrical	16.882 KA
Maximum DC component of short-circuit current	23.87 KA

Table 1

This data indicates that the sustained short-circuit current of 2.4673 KA would flow in a short circuit after a given period of time, once the short-circuit condition has been established. The initial symmetrical RMS current whose value is 16.882 KA, is the effective current (RMS) that occurs instantaneously in a symmetrical short circuit in the early stages of the short circuit event and finally the maximum DC component of the short circuit current of 23.87 KA is the continuous part of the short circuit current, which is caused by phase unbalance or by some rectifier element present in the system. These results help to evaluate the safety and stability of the electrical system.

The validation of the application was also performed using the asymmetrical faults submenu, using the two-phase ground fault, which occurs when two conductors of one phase are connected directly to ground, generating a short circuit between them and ground. This type of fault can occur due to a variety of reasons, such as damaged cables, faulty insulation or connection errors. The analysis of the two-phase ground fault is important to evaluate the impact it has on the electrical system and to take appropriate mitigation measures. Analyzing the two-phase ground fault current allows evaluating the protection, stability and safety aspects of the power system, and helps to take preventive and corrective measures to maintain the reliability and safe operation of the system.

The data to be used in the GUI application are:

Sequence 1 impedance: 0.20 p.u.
Impedance sequence 2: 0.20 p.u.
Sequence 0 impedance: 0.05 p.u.
Fault impedance: 0.62 ohm
Frequency: 60
Fault voltage: 1 p.u
Power: 100 MVA

Figure 5 Application data and results for two-phase ground fault

Since the fault current is different from zero, a current flow occurs during the fault. This indicates the presence of an unbalance in the system due to the two-phase ground fault. The magnitude and angle of the fault current indicate the amount of current and its phase in relation to the system. In this case, the fault current has a magnitude of 4.3462 p.u. and an angle of -4.9251 rad.

It is important to note that the magnitude of the fault current is determined by the sequence and fault impedances, as well as the fault voltage. The calculations obtained in the application of the fault current calculation in a two-phase to ground fault allow us to evaluate the unbalance and the magnitude of the current during the fault. This is crucial for the design and proper coordination of protective devices and mitigation of the adverse effects of the fault on the electrical system.

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Conclusions

Fault analysis is an essential component in the design, planning and operation of electric power systems. It is used to quantify the impact that faults can have on the system and to specify the protection devices, as well as their settings to avoid equipment damage in the face of high short-circuit current levels.

It also allows defining adequate operation strategies that guarantee the timely interruption of faults without exceeding the capacities of the equipment involved. This is crucial to maintain the reliability, safety and stability of the electrical system, prevent the propagation of faults and minimize the interruption time of the service in case of eventualities.

By means of the GUIDE tool, it has been possible to program the different internal functions of the graphical user interface in order to obtain an application that allows data entry to calculate and analyze symmetrical and asymmetrical faults in electrical distribution systems. GUIDE facilitated the programming of the interface with buttons, text boxes, menus and other functions that make possible the interaction with the user and the input of data required to perform the calculations and analysis of faults in electrical power systems. This led to the development of a practical application that gives the user the possibility to evaluate different fault scenarios and their impact.

Fault detection and protection coordination are important aspects to consider in fault analysis, since they allow identifying the type of fault, where it occurs, the phases involved and the evolution of the type of fault.

This article emphasizes the importance of having a clear and precise definition of the problem, as well as a plan for the utilization of the results, which are fundamental for a proper failure analysis. It provides valuable information regarding fault analysis in electrical distribution systems, detailing key concepts and steps to follow to carry it out correctly. It also presents a useful tool to facilitate this analysis, which is a necessary process for the evaluation of the impact of faults, the diagnosis of possible problems and the planning of corrective actions to improve the performance and reliability of electrical distribution systems.

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