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# A new approach for power system online DSA using distributed processing and fuzzy logic

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**Abstract**

In this paper, a new approach for power system online dynamic security assessment, as well as a tool for calculating the proposed fuzzy dynamic security index is presented. This proposal is based on a three-stage fuzzy inference system, which composes the fuzzy dynamic security index making use of seven performance indexes herein defined. The calculation of the performance indexes is based on the results obtained through dynamic simulations of the system behaviour after each one of the credible contingencies in a given operation state. With the aim of reducing the calculation time a novel distributed processing of the dynamic simulations is also developed. High voltage systems are used to illustrate the ideas presented in the paper.


*Keywords:* Dynamic security assessment; Full simulations; Fuzzy dynamic security index; Fuzzy inference system; Distributed processing

## 1. Introduction

Secure operation is one of the most important requirements of power systems. However, due to the competitive conditions of the present-day electrical markets, the security level in which these systems operate has been reduced due to the tendency to make maximum use of the generation and transmission systems. In order to take the control actions necessary to improve security it is essential to assess both the static and the dynamic security level. The static security assessment (SSA) is made by comparing the steady state system variables with their admissible limits. Reduced calculation times allow the implementation of an online SSA analysis. The dynamic security assessment (DSA), in turn, analyzes the transient dynamics developed in the period following a contingency [1,2]. In this way, the stability of the system in each analyzed contingency may be determined. Due to both, the large size of power systems and the large number of components, longer calculation times are required. The time needed for obtaining the results is longer than that available for taking the above-mentioned control actions, in case these are necessary.

The dynamic security assessment may be made by using either approximate methods or full simulations (time-domain numerical integration) [3]. The approximate methods include techniques such as sensitivity methods for assessing the voltage security and direct methods for assessing the transient stability such as Lyapunov-like methods, methods based on the equal-area criterion, etc. Whereas full simulation methods include power flow solutions of PV curves, that is, voltage curves in terms of the active power, used to define the collapse point of the steady-state voltages, time-domain full simulations for transient security and analysis of eigenvalues for assessing the small signal stability. Although approximate methods offer some computational advantages, full simulation methods provide a more precise assessment. Another advantage of full simulation methods is that they make possible both to have knowledge of the post-contingency state of each system variable and to use various models of system components depending on the degree of detail required. When an approximate method is used, some assumptions are made which must be verified in order to confirm the applicability when the system conditions change. This verification is not necessary when full simulation methods are

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used, a fact that is regarded as an additional advantage of these methods [4].

A great disadvantage of the full simulation methods, which is currently rather regarded as a challenge, is the extent of time required for calculation. This difficulty becomes greater when more detailed models are used and also when there is an increase in the size of the power system under analysis. Therefore, in order to exploit the most of the advantages of such indirect methods, the time for the calculation involved must be reduced, both in dynamic simulations and in the analysis of the results. This work presents a DSA methodology, which reduces the calculation time of indirect methods such that it makes possible their use online. This is achieved through the use of both the distributed processing of dynamic simulations and the application of artificial intelligence techniques in the analysis of the results.

The paper is structured as follows: Section 2 briefly describes the methodology for online DSA proposed here. The distributed processing of the dynamic simulations is described in Section 3, and also a brief discussion of the simulation times is included. Section 4 presents the methodology stage for analysis of the results obtained by the dynamic simulations. It includes the definition of the performance indexes and also the description of the fuzzy inference system (FIS) used for the composition of the dynamic security index. In Section 5, the test system model based on the Argentinean power system is described, as well as the results of applying the proposed methodology for DSA are discussed. Finally, Section 6 summarizes the main contributions of this paper.

## 2. Methodology for power system online DSA

The proposed methodology is summarized on Fig. 1. Beginning from an operating state of the system, dynamic simulations are made in order to determine the system behaviour after each of the various critical contingencies considered. The simulated contingencies are events that are completely independent from each other; therefore, the distributed processing may be used for such a task. These simulations provide detailed time-domain descriptions of the physical phenomena developed in the transient period following the contingency. Finally, based on the dynamic responses obtained from the different system variables, results are analyzed. In this module, three actions are taken. The first one is related to calculating the performance indexes, which take account of the post-contingency behaviour of the system variables (angles, frequency, voltage, etc.). The second one is related to composing indexes through the use of a tool based on fuzzy logic. Finally the third one is related to composing tables and graphs in order to show the security assessment results in a clear and efficient way.

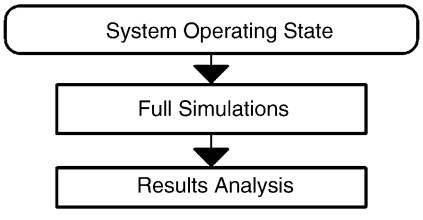


Fig. 1. Methodology for online power systems dynamic security assessment.

In order to determine in an online application the system operating state which dynamic security will be assessed, it is necessary to acquire measuring data from different system variables. This could be made using for example: SCADA systems, Phasor Measurement Units (PMUs), or power system disturbance monitors [5,6]. However, the data acquisition is out of the scope of this work. Here is assumed that the required data are available and the operating state is already determined. In the two next sections are explained in detail the second and third stages of the methodology shown in Fig. 1.

## 3. Full simulations stage

The dynamic simulation module is aimed at determining the system behaviour after each of the contingencies to be assessed for a given operation state. In what follows are presented some features related to the distributed processing program developed, its operation and the resources it makes use of. Finally, calculation times are presented for the distributed program in two power systems, a relatively simple one and a larger system based on the Argentinean electric power system. These calculation times are compared with the time the simulations would take in case they were sequentially executed.

### 3.1. Program features

The distributed processing program used for the dynamic security assessment is in turn made up of two parts, the client program and the server program.

The client program is in charge of building the input file for the simulation process, which contains both the data from the power system under study and a list of contingencies to be simulated. This program is in charge of starting up the dynamic simulations process, including checking up the available servers in order to verify whether they are active and ready. It is also in charge of sending the input file and the contingency that must be evaluated by each server. Once this process is carried out, there is a delay time until all of the contingencies have been assessed. Finally, the client receives the output data of all of the servers and saves them in an output file for further use.

The server program, in turn, is in charge of executing the simulation process. A number of server programs are run in different PCs; the maximum amount of PCs required equalling the number of contingencies that must be assessed. However, there exists the possibility that a server may assess more than one contingency; the number of PCs required being consequently reduced. The various servers are in charge of receiving the input file and executing the dynamic simulator program SiCoDiS, which is in charge of evaluating the system behaviour during the contingency considered. The structure of the distributed processing with the client program and the various server programs are shown in Fig. 2.

SiCoDiS has appropriate models of the power system components, including the generating units, the network and the loads. It also includes appropriate models for load shedding due