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# Reliability Modelling of Medium Voltage Distribution Systems of Nuclear Power Plants Using Generalized Stochastic Petri Nets

D. C. IONESCU, A. P. ULMEANU AND A. C. CONSTANTINESCU
Department of Reliability, Faculty of Power Engineering
313 Splaiul Independentei
060042 Bucharest, Romania
Paul.Ulmeanu@energ.pub.ro adrianconst@k.ro

I. ROTARU
National Company "NuclearElectrica" Inc.
65 Polona Street, 010494 Bucharest, Romania
office@nuclearelectrica.ro

**Abstract**—The purpose of this study was to obtain a performable tool based on generalized stochastic Petri nets (GSPN), able to join precise results and fast approach. In practice, it is well known that a dependability analysis in the power systems field is often more difficult to perform due to the multiple dependencies on the specific maintenance policies, on the great number of operation conditions, and the possibility to consider overall distributions (nonexponential) of the operation periods of time and the maintenance activities duration. Under these circumstances, the usage of conventional methods of analysis is limited in what the most precise modelling of all the system characteristics are concerned. This study managed by SNN (National Company—"NuclearElectrica" S.A.) in cooperation with the "POLITEHNICA" of Bucharest analyzes and compares different configurations for the medium voltage (10.5 and 6.3 kV) distribution systems (MVDS). It has a practical connotation (SNN application for Cernavoda NNP) and compares four proposed MVDS configurations for the main auxiliary services. After description and implementation through GSPN, each configuration has been evaluated, in order to choose the most appropriate structure. 

**Keywords**—Power system, Petri net, Monte-Carlo simulation, Dependability.

## 1. INTRODUCTION

The need for reliable power to the nuclear plant auxiliaries results in best design and employment of alternate sources of power. The main one-line diagrams for MVDS (10.5 and 6.3 kV) in an NPP must comply with the specific requirements, and must provide accurate dependability indices, both in the cases of "normal power" and "on-site power" [1]. The source of the normal power can be either the off-site grid or the on-site main turbine generator. On-site sources power (diesel generators) are dedicated to restore power promptly to designated essential systems when a loss of Class IV power occurs, when Class IV power availability is threatened, and when power to equipment is needed to maintain the reactor in a safe condition during a extended loss of

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Class IV power. The main contribution of this paper lies in the dependability modeling of MDVS in order to assess its reliability and safety indices and to choose the best design main diagram. The modeling of the reliability of power systems is already a classical issue [2] as the reliability analysis is a compulsory request, and the modeling techniques are characterized by advanced performances. The actual concerns are mostly related to the efficient algorithms field, respectively, to the time consuming and the accuracy of the methods used. Mainly, the requirements of the reliability assessment approach are dealing with:

- the dynamics following an initiating design basis event, and
- the need to consider some important deterministic influences related to the operation planning and maintenance policies.

## 2. DESCRIPTION OF THE MEDIUM VOLTAGE DISTRIBUTION SYSTEM (MVDS)

The MVDS shall provide electrical power to the process, control, and instrumentation, and lighting loads throughout the NPP. To meet nuclear safety requirements for reliability of operation, two 100% redundant power distribution systems shall be provided for nuclear safety related loads. These shall be known as ODD and EVEN load groups. The preferred sources of power to the MVDS shall be the off-site network during start-up and shutdown conditions, and during normal operation it shall be either the main turbine generator (G) or the off-site network, shared on a 50/50 basis.

### 2.1. Main One Line Diagram Description

In Figure 1 the components involved in this analysis are shown. Figures 2–4 propose three alternative solutions for the main one-line MDVS diagram. As it is presented, the MDVS design philosophy is following the class structure, namely the Classes IV and III.

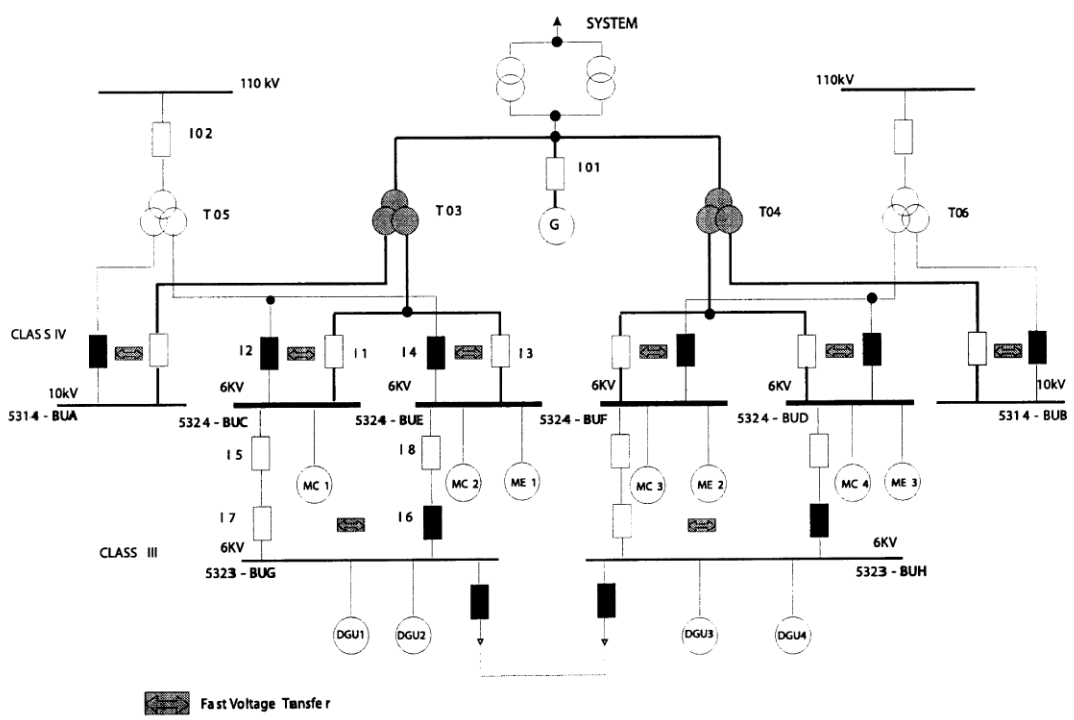


Figure 1. Main one-line diagram MVDS 4B.