Chapter 37
NPP:
Power Grid Mutual Safety Assessment

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ABSTRACT

The problem of the safe interaction between a Nuclear Power Plant (NPP) and a Power Grid (PG), considering the Fukushima nuclear accident, is becoming topical. There are a lot different types of influences between NPPs and PG, which stipulate NPPs' safety levels. To evaluate the influences, two metrics are proposed: linguistic and numerical. The approach to the NPP-PG safety assessment is based on the application of Bayesian Belief Network (BBN), where nodes represent different PG systems and links are stipulated by different types of influences (physical, informational, geographic, etc). It is suggested to evaluate criticality of the PG system considering the change of criticalities of all connected systems. The total criticality of each node in BBN is assessed considering particular criticalities caused by different types of influence. The complex nature of NPP and PG mutual interaction calls for the need for integration of different methods that use input data of different qualimetric nature (deterministic, stochastic, linguistic). Application of one specified group of risk methods might lead to loss and/or disregard of a part of safety-related information. BBN and Fuzzy Logic (FL) represent a basis for development of the hybrid approach to capture all information required for safety assessment of NPP – PG under uncertainties. Integration of FL-based methods and BBNs allows decreasing the amount of input information (measurements) required for safety assessment, when these methods are used independently outside from the proposed integration framework. An illustrative example for the NPP reactor safety assessment is considered in this chapter.

INTRODUCTION

The reliable and safe operation of the energy sector is of key importance for the any national economic development, as both production and municipal facilities require electric power for their operation. The power industry consists of power generating system, high voltage transmission system, lower voltage distribution system and other support facilities.

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Three types of generation facilities are operated in Ukraine, including thermal power plants (steam turbine and diesel types), hydroelectric plants (hydroelectric proper and hydroelectric accumulating plants) and NPPs. Thermal power plants account for about 50% of the electric power produced in Ukraine. Most of these thermal power plants (TPPs) are old, with antiquated equipment, obsolete technology, and largely lacking modern pollution control equipment. Only about 10% of Ukraine's TPPs had undergone any significant reconstruction.

The major fuel for the plants is natural gas (76-80%), but they also use black oil (15-18%), and coal (5-6%). Most steam power plants have outdated equipment, which does not correspond to present-day environmental requirements, and calls out for reconstruction, upgrade, or complete replacement.

Ukraine's four nuclear power stations operate 15 reactors with a capacity of 13,8 Giga watts (GW), or nearly one-quarter of the country's total. They generate around 88,8 GW of energy, or over 47.9% of the country's power output, with the construction of two reactors with a capacity totaling 2 gigawatts (GW) in its final stages. Power reactors have operated in Ukraine since 1977, and over 300 reactor years of operating experience have been accumulated.

Power resources of Ukraine are mainly formed by domestic generation capacities (nearly 98%), with the import share being insignificant (2%). The power is largely consumed inside the country (97%), with a small part exported (3%). In the future, the need for power is expected to grow calling for intensification of the sector development and optimizing of the organization structure and economic mechanisms of functioning in the market environment.

Ukraine's electric networks are numbered nearly 22, 7 thousand km., 4,9 thousand km. of them are under voltage 400-750 kW (high voltage transmission lines), 13,2 thousand km. – under 330 kW, 4,6 thousand km. 220-110 kW (lower distribution lines). Their conditions are getting more aggravated every year. 34% of overhead transmission lines (220-330 kW) have been operating nearly 40 years. Approximately 52% of them have to be renovated, 76% of transformer substations have reached the end of their service life.

BACKGROUND

All facts mentioned above are given to show the high complexity of Ukrainian energy sector and problem of its reliability assurance. Reliable operation of the NPP implies that PG, to which it is connected, is reliable. Disturbances in PG operation can originate from natural disasters, failures, human factors, terrorism, and so on.

If PG and NPP are considered together as SoS, we can conclude that PG reliability and safety are stipulated by the NPP safety. Outages and faults will cause serious problems and failures in the interconnected power systems. It means that unsafe power grid and NPP could be considered mutual risk factors undermining the safety of both facilities. In order to provide stable and safe operation of NPPs, a systematic way of formalization and evaluating these influences is needed.

The object of the chapter – is to introduce approaches and techniques, which allow to evaluate the mutual influences between NPP and PG, understand the dynamic risks nature caused by their interactions.

The techniques represented in the chapter can be considered an essential part of PG risk management and can serve as a base for decision-making to avoid disturbances or minimize the severity of their consequences considering the interaction between NPP and PG systems. These techniques allow understanding the risk proliferation and develop the recommendations and measures for NPP safety assurance.