Chapter 8

Overall Instrumentation and Control Systems

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ABSTRACT

Chapter 8 considers design principles of Overall Instrumentation and Control (OI&C) systems implemented at Ukrainian NPPs. The first section provides brief information on controlled objects—power units with reactors WWER, which are operated at Ukrainian NPPs. The main principles and features for modernization of OI&C systems and their components in NPPs in Ukraine that were generated in 2000-2011 are further provided. The third section is dedicated to the architecture of OI&C systems that control technological processes on these power units. After that, the central part of this architecture, a group of the most closely connected individual Instrumentation and Control (further, I&C) systems, for which the general term “reactor control and protection system” is used in Ukraine and Russia, is considered in detail. The purpose, composition, and structure of a modernized reactor control and protection system that are implemented at Ukrainian NPPs with WWER reactors are provided.

INTRODUCTION

Ukrainian and Russian specialists of different branches of industry, including atomic energy, widely use the term “Automated Process Control System” (APCS). In regulation NP, 2008 an implicitly close term “automated monitoring and control system of power unit technological processes” that should provide remote and/or automatic control of technological processes and safety systems, automatic protection of systems, equipment and power unit as a whole, and also monitor that limits of its safe operation are not exceeded, is introduced. In international standards (IEC, 2011), the concept of overall instrumentation and control (OI&C) system that denotes a complete set of all individual instrumentation and control systems of a power unit and covers normal opera-

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tion systems as well as safety systems, is used. In these terms, OI&C system can be considered as an English equivalent of APCS.

In the section that begins this chapter, a short description of a controlled object required for understanding of issues of automatic monitoring and control of power unit technological processes executed by the OI&C system is given. Direct description is premised with consideration of the modernization concept for the OI&C system adopted in Ukraine, which has been almost implemented at Ukrainian NPPs. The stages of modernization of I&C systems of Ukrainian NPPs are described. The first stage (1993-2000) was characterized by use of systems designed by foreign (including USA) companies. The second stage (2001-2012) was characterized by use of systems designed by Ukrainian companies. The modernization strategy is analyzed in two aspects: the strategy of operators and the strategy of I&C designers.

Figure 1 shows graphic symbols and notation conventions used in this and further chapters.

BACKGROUND

The designs of nuclear power units with reactors WWER (water-cooled water-moderated power reactors) operated at NPPs of Ukraine were developed in the 1970-s in the USSR by the Kurchatov Institute of Atomic Energy (now – Russian Scientific Center “Kurchatov Institute”), the Design Bureau Gidropress is the Chief Designer of reactor facilities equipped with reactors WWER.

First reactor facilities with nuclear reactors WWER-1000 (with nominal electrical power 1000 MW) were models V-302 and V-338 (operated at South-Ukrainian NPP units 1 and 2, respectively). Serial (typical) model V-320 of the unit was first implemented in Ukraine in 1984 at Zaporozhe NPP unit 1. As it was mentioned in IAEA, 1997, “in general, 320 design conforms to standards used in the world practice for safety systems and safety important systems. A basic concept of defense-in-depth for safety assurance is implemented in general development criteria, including use of redundancy, diversity, independence and security.”

In 1984-1989, in Ukraine 8 power units with B-320 reactor facilities were produced, in 1995 – one more power unit. The construction of two power units (Khmelnitsky NPP unit 2 and Rovno NPP unit 4) started in 1984, was stopped after the accident at Chernobyl NPP and continued only after 13 years. Both units were completely constructed and commissioned in 2004. In total, at 4 Ukrainian NPPs 13 power units with reactors WWER-1000 (11 of them have serial V-320 reactor facilities) are operated. In addition, two power units Rovno NPP units 1 and 2) with reactors WWER-440 (with nominal electrical power 440 MW) are operating now. The design lifetime of units WWER-440 (30 years) expired in 2010-2011 and after required measured were taken, it was extended for 20 years. Power units with other types of nuclear reactors are not operated in Ukraine (RBMK reactors used at the Chernobyl NPP are now decommissioned).

Russia currently operates 16 power units with reactors WWER-1000 and WWER-440. Similar power units are used in China, India, Finland, Czech Republic, Slovakia, Hungary, Armenia, Bulgaria, and Iran. New power units with reactors WWER in Russia, Ukraine, China, India, and Armenia (where reactors of such types have already been operated) and also in Belorussia, Vietnam, Nigeria, Turkey are at different stages of construction.

The main literature devoted to reactor facilities of operating power units is published (in Russian) in a series of the designers’ monographs “Construction of reactor facilities WWER for NPPs,” which include information on reactors WWER-440 (Bessalov, 2004), WWER-1000 (Rezepov, 2004), control rod drives (Nikituk, 2004) and other equipment used in them. Different aspects of safety assurance of nuclear power plants are considered in the books Nosovsky,
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