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Specifični simulator JEK - orodje za učinkovito usposabljanje operaterjev

The Plant-Specific Simulator - A Tool for the Efficient Training of Operators

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Popolni simulator je pomembna pridobitev za Jedrsko elektrarno Krško. Namen tega sestavka je prikazati uporabo simulatorjev na področju usposabljanja in povedati nekaj o specifičnem popolnem simulatorju naše elektrarne. Podanih je nekaj osnovnih informacij o načinu usposabljanja osebja z dovoljenjem za operaterja in vlogi simulatorja za prihodnje usposabljanje v JE Krško.

(Ključne besede: simulatorji, analize, modeliranje, usposabljanje)

The acquisition of a full-scope simulator represents a very important achievement for the Krško Nuclear Power Plant (NPP). The aim of this paper is to present the use of simulators in the training process and to give some basic information about our plant-specific simulator. Some basic information is provided about the training process for licensed personnel and the role of the simulator in the future training activities at Krško NPP.

(Keywords: simulators, analysis, modelling, training)

0 UVOD

Upravljanje s sistemi jedrske elektrarne je nedvomno zahtevno in zapleteno opravilo. Za opravljanje takšnih opravil je seveda najpomembnejše ustrezno usposabljanje osebja, ki upravlja z napravami elektrarne iz glavne komandne sobe. Pri usposabljanju za taka opravila je uporaba simulatorjev bistvena in takega usposabljanja ni mogoče nadomestiti z drugimi tehnikami.

Bistvena vloga simulatorja je, da omogoča hitrejše, kakovostnejše, ponovljivo in nenevarno usposabljanje za upravljanje procesov, ki zahtevajo visoko stopnjo znanja ter veščin za ročne posege. Glavna področja človekove dejavnosti, pri katerih se uporabljajo simulatorji za usposabljanje, so: usposabljanje vojaških in civilnih pilotov, operaterjev jedrskih elektrarn, operaterjev v petrokemijski industriji, operaterjev elektrarn na standardna goriva ter upravljanje železniškega in cestnega prometa.

Glavni namen procesa modernizacije jedrske elektrarne Krško je zanesljivo, stabilno, varno in gospodarno obratovanje. Stabilnost obratovanja, znižanje števila nenačrtovanih zaustavitev, dvig razpoložljivosti, dvig moči (in s tem letne

0 FORWORD

The operation of nuclear power plant systems is a demanding and complex task. The most important element in ensuring that the capability exists for handling such tasks is the efficient training of the operations personnel who manipulate controls in the main control room. The use of simulators during the training process is essential and cannot be substituted by other techniques.

The simulator's advantage is that it enables faster, higher quality, repeatable, and safe training of the personnel responsible for handling the processes that require a high level of knowledge and skills. Simulators are widely used for training purposes in the following areas of human activity: training of military and civil pilots, nuclear power plant operators, operators in the petrochemical industry, operators in conventional power plants, the control of railroad traffic and the control of road traffic.

The main goal of the Krško nuclear power plant (NPP) modernization project is to provide reliable, stable, safe and economical operation. Stable operation, the reduction of unplanned shutdowns, an increase of in availability, power upgrade (and consequentially, annual production) and the organiza-

proizvodnje) ter nenazadnje, zagotovitev mednarodno primerljivega obsega usposabljanja so naloge, ki ob bok in tudi v oporo preostalim projektom modernizacije postavljajo tudi specifični simulator s pripadajočo opremo.

Specifični popolni simulator podrobno ponazarja delovanje jedrske elektrarne Krško. Na taki napravi bo mogoče opravljati usposabljanje operativnega osebja v enakem obsegu, kakor je to praksa v razvitih državah. Veljalo bi omeniti tudi to, da je popolne simulatorje kupilo že kar precej elektrarn iz držav v razvoju. Simulator za JE Krško je izdelalo kanadsko podjetje CAE Electronics, Ltd., ki je eno od vodilnih proizvajalcev različnih tipov simulatorjev in sistemov za upravljanje postrojenj.

1 SPLOŠNO O SIMULATORJIH

Kaj sploh je simulator? Pravzaprav je to vsaka naprava, ki v umetnem okolju ponazarja določen dejanski proces. Industrija si z različnimi simulacijskimi napravami pomaga pri preverjanju in izpopolnjevanju svojih izdelkov. Simulatorji so se pokazali tudi kot zelo učinkovito sredstvo za usposabljanje osebja za upravljanje zapletenih sistemov. Ena od bistvenih značilnic simulatorja za usposabljanje je ta, da mora delovati v realnem času, torej se mora odzivati z enako dinamiko kakor dejanski proces.

Prve enostavne simulatorje so izdelali za potrebe hitrejšega usposabljanja pilotov za vojaške namene. Lahko bi rekli, da so nastali, zaradi potrebe, da se v čim krajšem času osebje usposobi za obvladovanje določenih zahtevnih nalog. Te izkušnje so se s pridom začele uporabljati v preostali industriji in pričela se je doba, ko simulacijske naprave v čedalje večji meri pomagajo pri usposabljanju osebja, ki nadzoruje in upravlja postopke v zahtevnih tehnologijah.

Razvoj simulatorjev tesno sledi razvoju računalniške tehnologije in elektronike na splošno. Glavne omejitve simulatorjev so bile v preteklosti povezane s pomnilniško in procesno močjo računalnikov. Skokovit razvoj računalništva je pripomogel k temu, da današnji simulatorji uporabljajo zelo podrobne modele, kar omogoča prožnost pri uporabi.

Simulatorje, ki se uporabljajo za usposabljanje osebja jedrskih elektrarn, lahko v grobem razdelimo na tri skupine: simulatorji osnovnih principov, delni simulatorji in popolni simulatorji.

1.1 Simulatorji osnovnih principov se uporabljajo v postopku začetnega usposabljanja in tudi za periodično obnavljanje znanja predvsem za pridobivanje in vzdrževanje teoretičnega znanja. Interakcija med človekom in simulatorjem običajno

tion of training at a comparable level for the nuclear industry, are important plant missions. A full-scope simulator with associated infrastructure, supports the plant's goals and other plant projects.

The plant specific full scope simulator replicates the Krško NPP systems' operation in detail, thus representing a suitable vehicle for performing the training of operations personnel at the same level of quality and quantity as is standard practice in developed countries. It is worth mentioning that a lot of power plants in developing countries have already acquired simulators. The Krško NPP simulator was built by the Canadian company, CAE Electronics Ltd., which is one of the leading manufacturers of simulators and control systems.

1 GENERAL INFORMATION ABOUT SIMULATORS

What is a simulator? As a matter of fact, it is any device that replicates a real process in an artificial environment. Simulation devices are widely used by various industries for functionality verification or research and development of their products. Simulators have proved themselves to be very efficient tools for training the personnel that operate/handle complex systems. One of the essential training simulator characteristics is operation in real time, it must dynamically perform in the same time scale as the real process.

The construction of the first primitive simulators was driven by the need to train military pilots more quickly. We could say that the development of simulators was pushed by a necessity to train people for complex tasks in a short period of time. Good experience with simulation devices encouraged an industry-wide implementation of this method. The use of simulation devices is increasingly helpful in supporting the training of operators for complex technologies.

The development of simulators closely follows the development of computer technology, and electronics in general. In the past, the major limiting factors in simulation were linked to computer memory and processing power. Rapid development of computer technology has facilitated the development of sophisticated models, giving practical flexibility to modern simulators.

The simulators that are used for the training of nuclear power plant personnel can be divided roughly into three categories: basic principle simulators, part task simulators and full scope simulators.

1.1 Basic Principle Simulators are typically used during initial training phases and for periodic refresher training, mainly in the area of fundamental theoretical knowledge. The man-machine interface is usually achieved via a computer keyboard and

omogočata računalniška tipkovnica in grafični monitor. V prvi vrsti so namenjeni za interaktivno ponazarjanje teoretičnih načel, sistemi elektrarne so simulirani v omejenem obsegu.

1.2 Delni simulatorji se prav tako uporabljajo v začetnem in stalnem usposabljanju za pridobivanje in vzdrževanje teoretičnega znanja, obenem pa v omejenem obsegu omogočajo tudi urjenje za upravljanje sistemov elektrarne. Taki simulatorji so običajno kombinacija računalniških prikazovalnikov in poenostavljene komandne plošče, ki navadno nima enakih upravljalnih mehanizmov kakor v pravi upravni sobi.

1.3 Popolni specifični simulator je po videzu stvarna kopija glavne upravne sobe elektrarne z vsemi upravljalnimi mehanizmi in prikazovalniki podatkov, z računalniškim modelom pa stvarno ponazarja obnašanje elektrarne. Simulirani so vsi sistemi, ki se iz glavne komandne sobe upravljajo, ter tudi sistemi, katerih odzivi so bistveni za urjenje v uporabi obratovalnih postopkov. Na takšnem simulatorju je mogoče v celoti izvajati ukrepe v skladu z obratovalnimi postopki. Simuliranja pokrivajo celoten spekter normalnih obratovalnih stanj elektrarne in tudi nezgodne primere. Tak simulator omogoča usposabljanje za pridobivanje in vzdrževanje znanja ter spretnosti, potrebnih za normalno delo v komandni sobi.

2 POPOLNI SIMULATOR JEK

Obseg simuliranja je opredeljen na osnovi namembnosti simulatorja, torej usposabljanja v našem primeru. Simulator JE Krško bo omogočal urjenje za vse dejavnosti operaterjev, ki se izvajajo iz glavne komandne sobe ter iz lokalnih komandnih pultov za zasilno zaustavitev. Zgrajen je v skladu z ameriškim standardom ANSI/ANS-3.5 [1]. Ta standard upoštevajo tudi druge države kot kriterij za ustreznost simulatorja.

Nivo natančnosti modeliranja posameznih sistemov je odvisen od zapletenosti in pomembnosti posameznega sistema. Zahteve za natančnost modeliranja sistemov so podrobno opredeljene v tehnični specifikaciji za simulator. Sistemi so lahko modelirani popolnoma dinamično, poenostavljeno dinamično ali funkcionalno. Od 80 simuliranih sistemov jih je 48 modeliranih popolno dinamično (primeri: sistem primarnega hladila, reaktorska sredica, hlajenje komponent, turbina, sistem napajalne vode itn.), 14 poenostavljeno dinamično (primeri: sistem pomožne pare, protipožarni sistem, sistem inštrumentacijskega zraka, sistem za vzorčenje itn.) in 18 funkcionalno (primeri: sistem zapornic na Savi, sistem zaznave potresa, dodajanje kemikalij, sistem za pripravo vode itn.). Popolno dinamično

graphical monitor. These simulators enable an interactive representation of theoretical principles, supported by the limited simulation of real plant systems.

1.2 Part Task Simulators are also used during initial training phases and refresher training. These simulators also serve well for training on fundamental theoretical principles. In addition, they enable limited training on plant systems manipulation. Such simulators are typically a combination of computer terminals and simplified control boards. The control boards typically do not replicate real control room mechanisms.

1.3 A Full Scope Replica Simulator is a realistic copy of a real control room. It has all the relevant control mechanisms and data monitoring devices; a computer model realistically reproduces the plant's operational characteristics. All the essential plant systems that have controls in the main control room or respond to operator requested actions, and are essential for training on operating procedures are simulated. Such a simulator enables the full implementation of all actions that are required by operating procedures. The simulation covers the full spectrum of normal operating states and abnormal/accidental conditions. Such a simulator serves for the acquisition and for the retention of the knowledge and skills necessary to work as a control room operator in a NPP.

2 THE KRŠKO NPP FULL-SCOPE SIMULATOR

The scope of the simulation is defined, based on the purpose of the simulator, which in our case is training. The Krško NPP full scope simulator will enable the training of all operator activities that are performed from the main control room and from local shutdown panels. It has been built in accordance with the American standard: ANSI/ANS-3.5 [1]. This standard is used by most counties as acceptance criteria for determining simulator conformance.

The system's simulation modeling fidelity is based on system complexity and importance. Requirements for the system's modeling fidelity are defined in the technical specification for the simulator. Plant systems are simulated either fully dynamically, simplified dynamically or functionally. The Krško NPP simulator has 80 systems simulated. 48 systems are fully dynamically modeled (examples: reactor coolant system, reactor core, component cooling, main turbine, feedwater system, etc.), 14 systems simplified dynamically (examples: auxiliary steam system, fire protection system, instrument air system, sampling system, etc.) and 18 systems are modeled functionally (examples: Sava river dam system, seismic instrumentation system, chemical addition, demineralized water system, etc.). Full dynamic

simuliranje sistemov upošteva fizikalne zakonitosti, kot so: ohranitev mase, gibalne količine in energije, termo- in hidrodinamiko, električne veličine, tehnične korelacije in topologijo sistemov. Fizikalne zakonitosti upošteva tudi poenostavljeno dinamično simuliranje, sistem pa je poenostavljen v delu, ki ne vpliva na odzivanje indikacij parametrov ali stanja mehanizmov za upravljanje na glavni komandni plošči. Funkcionalno simuliranje se uporablja za sisteme, ki imajo na glavni komandni plošči samo omejene indikacije.

Modeli vseh sistemov so ponazorjeni z objektno usmerjenim programskim orodjem. S posebnim programom je modelirana samo sredica. Kakovost objektno usmerjenih orodij za modeliranje je bila ena večjih prednosti izbranega dobavitelja. Vsak sistem je modeliran v treh nivojih: termo- in hidrodinamika, električna napajanja ter upravljanje. Sredica reaktorja je modelirana tridimenzionalno. Zaradi potrebe po potrditvi obnašanja simulatorja je bil osnovni model zgrajen glede na stanje elektrarne v 15. gorivnem ciklu. V končni fazi bo model simulatorja upošteval novo projektno stanje elektrarne z vgrajenima novima uparjalnikoma in z drugimi posodobitvami (17. gorivni cikel). Obratovalno osebje se bo tako lahko usposabljalo na simulatorju pred zagonom elektrarne z vgrajenima novima uparjalnikoma.

Za upravljanje samega simulatorja je inštruktorjem namenjena posebna delovna postaja. Ta omogoča zagon, zaustavitev simulatorja, shranjevanje trenutnega stanja v pomnilnik in ponovno proženje s shranjene točke, preverjanje pravilne lege upravljalnih mehanizmov, vrnitev nazaj po poteku dogodkov in ponovni zagon simuliranja, pripravo, shranjevanje in proženje vaj za usposabljanje, vnašanje napak, upravljanje opreme prek interaktivnih shem sistemov itn.

Simulator omogoča tudi pospešeno in upočasnjeno simuliranje nekaterih specifičnih pojavov: gretje primarnega kroga, gretje turbine, vzpostavljanje podtlaka v kondenzatorju, nastajanje in razgradnja razcepkov, ki absorbirajo nevtrone v sredici ipd. Takšna funkcionalnost je zelo pomembna pri usposabljanju, ker omogoči relativno hiter prehod stanj, ki v praksi zahtevajo veliko časa.

Vhodni podatki za projektiranje simulatorja so: dokumentacija elektrarne, podatkovna baza varnostnih analiz, rezultati analiz ter različni standardi. Med elektrarniško dokumentacijo spadajo: pretočne, električne in inštrumentacijske sheme, izometrični načrti, opisi sistemov, inštrukcijske knjige, končno varnostno poročilo, obratovalni postopki, sistemski postopki, obratovalni podatki. Pri pripravi nekaterih podatkov so sodelovali tudi domači inštituti.

Trenutno je simulator v sklepni fazi preverjanja in bo pripravljen za uporabo pri usposabljanju v začetku aprila 2000.

simulation is achieved by the application of the conservation laws of mass, momentum and energy, other physical laws of thermal and hydrodynamics, electric power engineering correlations and system topology. Simplified dynamic simulation is also achieved by the application of physical laws but the systems are simplified in a way that does not impact on parameter indications or control mechanisms on the main control board. Functional simulation is applied for the systems that have only limited indications on the main control board.

All plant system models are built by using object oriented software modeling tools. Special programming has been used for the reactor core modeling only. The quality of the object oriented modeling tools was one of the recognized advantages of the selected vendor. Each system is modeled from three aspects: thermo and hydrodynamics, electrical power and instrumentation as well as control. The reactor core is modeled three dimensionally. The basic simulator model was developed based on a plant configuration in core cycle 15 to enable simulator validation using good, operational plant data for comparison. The final deliverable simulator configuration will take into account new steam generators and major plant modifications (configuration for core cycle 17). Training will be conducted on this configuration prior to plant startup with the new steam generators.

The simulator control is performed through a special instructor workstation. This workstation enables simulator startup, shutdown, current simulation status storage, activation of old stored points, control board switch checks, backtrack capability. It also enables preparation, storage and activation of training exercises and the insertion of malfunctions. The entire simulator can be fully controlled from the instructor station using interactive schematics and a graphical interface.

The simulator has the capability of fast and slow simulation of certain specific evolutions, for example: primary system heatup, turbine heatup, establishing condenser vacuum, neutron absorbers build-up/decay, etc. This functionality is very useful during training as it enables faster passage through certain sequences that would, in real time, take a lot of time.

Simulator design input data were obtained from plant documentation, the safety analysis input database, analysis results and applicable standards. The following plant documentation categories were used: flow diagrams, electrical wiring diagrams, instrumentation interconnecting diagrams, isometric drawings, system descriptions, equipment manuals, safety analysis reports, operating procedures, operational data. Domestic institutes were also involved in the preparation of specific data.

Currently, the simulator is in its final phase of acceptance testing and will be ready for training in the first half of April 2000.

Uporaba lastnega specifičnega popolnega simulatorja vsekakor pomeni dvig ravni jedrske varnosti in izboljšanje kakovosti usposabljanja z namenom, da bi izboljšali razpoložljivosti. Nabava popolnega specifičnega simulatorja pomeni hkrati tudi izpolnitev upravne odločbe [2] Uprave Republike Slovenije za jedrsko varnost ter upoštevanje priporočil mednarodnih misij.

3 SIMULATOR PRI USPOSABLJANJU

Popolni simulator je nenadomestljiv pripomoček pri usposabljanju osebja elektrarne z dovoljenjem za operaterja. Omogoča kakovostno doseganje ustrezne usposobljenosti za opravljanje zahtevnih del. Operativno osebje mora imeti potrebno znanje in spretnosti za hitro in kakovostno prepoznavanje informacij procesa, njihovo interpretacijo, načrtovanje potrebnih akcij, koordiniranje akcij s sodelavci in izvedbo ustreznih manipulativnih posegov prek komandnih mehanizmov glavnih komandnih pultov.

Simulator omogoča urjenje posegov za normalna obratovalna stanja elektrarne, kot so: gretje sistemov, zagon, obratovanje na moči, spremembe moči, zaustavitev in ohlajevanje.

Simulator prav tako omogoča urjenje posegov za reševanje nenormalnih stanj. To so predvsem odpovedi različnih komponent sistemov, odpovedi instrumentarija, pojav manjših puščanj in podobno. To so pričakovani dogodki, ki se v elektrarnah občasno pojavljajo.

Naslednja skupina stanj, ki jih simulator ponazarja, so projektne nezgode. Take nezgode so: zlom cevi v uparjalniku, zlom primarnega cevovoda, zlom parnega voda, zlom napajalnega cevovoda itn. Takšne nezgode so sicer zelo redke. Do sedaj je v nekaj jedrskih elektrarnah prišlo do zloma cevi v uparjalniku.

V nekaterih primerih je za omejitev posledic pomembno časovno pravilno in usklajeno ukrepanje, kar se dosega samo z zadostno pogostostjo urjenj. V procesu usposabljanja je pomembno, da se lahko posamezne vaje po potrebi ponovijo, kar omogoča edino simulator.

Treba je poudariti, da večina jedrskih elektrarn pretežni del gorivnega cikla obratuje pri stalni moči. Manevriranje z močjo se po navadi izvaja načrtovano za potrebe preskušanj ali v primeru motenj v procesu ali v elektroenergetskem sistemu. Število načrtovanih in tudi nenačrtovanih zaustavitev je sorazmerno majhno. Zaradi tega je ravnanje s komandami v normalnem obratovanju relativno omejeno. Nedvomno pa je sposobnost operaterjev, da kar najbolje ravnajo z opremo, ključnega pomena, tako za varnost kakor tudi za razpoložljivost elektrarne. Za vzdrževanje ustrezne usposobljenosti (znanje in spretnost) so torej potrebna ponavljajoča urjenja.

Use of our own, plant specific full scope simulator represents an improvement in the nuclear safety and training system, as well as improving availability. Acquisition of a plant specific full scope simulator also represents the fulfillment of a licensing amendment requirement [2] of the Slovenian Nuclear Safety Administration and the recommendations of international missions.

3 THE SIMULATOR IN THE TRAINING PROCESS

A full scope simulator is an irreplaceable tool in the training process for operations licensed personnel. The preparation for the performance of demanding tasks requires an efficient and high quality training process. Operations personnel have to attain the necessary knowledge and skills in order to be able to: efficiently recognize relevant information from the process; interpret such information; as well as plan, coordinate and perform adequate manipulation of system control mechanisms from the main control boards.

The simulator supports the training of activities during normal plant evolutions such as: plant systems heatup, startup, power operation, power changes, shutdown and plant cooldown.

The simulator also supports training for the mitigation of abnormal plant conditions. Such conditions are: different component malfunctions, instrumentation failures, system leaks and similar problems. Such failures are expected at the plants and do happen occasionally.

The next category of simulated states which the simulator is capable of representing, are design basis accidents. Such accidents are: steam generator tube rupture, a loss of coolant accident, main steam line break, feed line break, etc. Such accidents are infrequent, few nuclear power plants have experienced steam-generator tube ruptures.

When an event occurs, timely performance and coordination of the appropriate actions is important for the successful mitigation of consequences. The necessary skills can be obtained only by the appropriate training. Repetition of such occurrences can only be done safely with a simulator.

It has to be pointed out that majority of nuclear power plants operate at stable power for most of their fuel cycle. Power maneuvers are usually planned because of system testing requirements or are performed due to disturbances on the electrical grid. The number of planned and forced plant shutdowns is relatively low. For this reason, manipulation of real control mechanisms is relatively limited. However, the ability of operators to act and optimally operate the equipment is extremely important for safety reasons and achieve good availability. To maintain the necessary abilities, skills and knowledge to act properly, periodic training must be performed.

4 USPOSABLJANJE KLJUČNEGA OPERATIVNEGA OSEBJA – dosedanja praksa

4.1 Program začetnega usposabljanja

Usposabljanje operaterja reaktorja traja približno dve leti in pol. Usposabljanje je razdeljeno na več faz. V prvi fazi slušatelji pridobijo potrebno teoretično znanje. V drugi fazi pridobijo osnovno znanje o sistemih elektrarne in obratovalnih postopkih. Prvi dve fazi sta izvedeni pretežno v obliki predavanj. V prvo fazo je vključen delež praktičnih laboratorijskih vaj, v drugi fazi pa delež praktičnega usposabljanja na lokalnih delovnih mestih v elektrarni. V prvi in drugi fazi se uporablja tudi simulator osnovnih principov kot podpora predavanjem. V tretji fazi poteka usposabljanje na popolnem simulatorju, ki je kombinacija predavanj in praktičnih urjenj na simulatorju. V četrti fazi poteka usposabljanje v elektrarni. V tej fazi usposabljanje zajema poglobljen in voden individualni študij sistemov in elektrarniške dokumentacije ter praktično usposabljanje v glavni komandni sobi. Usposabljanje se konča z izpitom pred strokovno komisijo Uprave Republike Slovenije za jedrsko varnost (URSJV). Uspešnim kandidatom URSJV podeli dovoljenja za operaterja reaktorja.

V preteklosti je JEK za začetno usposabljanje na popolnem simulatorju sklepala pogodbe s tujimi ponudniki takih storitev, kakor sta podjetji Westinghouse in NUS (Nuclear Utility Services). To usposabljanje traja približno štiri mesece in je izredno intenzivno. Za to usposabljanje se morajo udeleženci popolnoma prilagoditi sistemom in odzivom nespecifičnega simulatorja ter anglosaškim merskim enotam. Po koncu te faze je seveda potreben precejšen napor, da se udeleženci miselno prilagodijo našim merskim enotam in sistemom ter komandni plošči JEK. Uporaba lastnega specifičnega simulatorja bo pomenila izjemen pozitiven premik in bo praktično odstranila težave zaradi prilagajanja.

4.2 Program stalnega usposabljanja

Slovenski predpisi trenutno zahtevajo 28 ur urjenj na simulatorju letno za osebje, ki mora imeti dovoljenje za operaterja reaktorja ali glavnega operaterja. Zadnja leta je osebje z dovoljenjem operaterja JEK opravljalo redno letno usposabljanje na simulatorju elektrarne Ginna v Rochestru, ZDA. Pogodbeni izvajalec je bilo podjetje General Physics. V preteklosti sta vsakoletno usposabljanje izvajali še podjetji Westinghouse in NUS.

Nobeden od simulatorjev, do sedaj uporabljanih za usposabljanje naših operaterjev, ne ustreza natančno komandni sobi JEK in odzivom naše elektrarne. V okviru zmožnosti so za potrebe rednega

4 KEY OPERATIONS PERSONNEL TRAINING – practice up to the present

4.1 Initial Training Program

The initial training for a reactor operator lasts approximately two and a half years. The training is divided into several phases. During the first phase, trainees receive the necessary theoretical knowledge. During the second phase, knowledge of basic systems and operating procedures is attained. The first two phases consist mostly of classroom training. The first phase also includes practical laboratory exercises also and the second phase includes practical training on local (field) operator positions at the plant. The basic principle simulator is used during the first two phases to support classroom presentations. The third phase is simulator initial training, consisting of a combination of classroom presentations and simulator practical exercises. The fourth phase is conducted on site. This training includes in-depth guided self study of the plant systems using plant documentation, and practical on-the-job training in the plant's main control room. Training is concluded with a final examination, administered by a special commission, appointed by the Slovenian Nuclear Safety Administration (SNSA). Successful candidates receive a reactor operator license.

In the past, the initial simulator training on a full scope simulator was contracted as a service. Contractors like Westinghouse or Nuclear Utility Services (NUS) were used. This high intensity training lasted approximately four months. For such initial training the trainees needed to adapt to the systems and response of the full scope simulator that was not Krško NPP specific and used British units of measurement. After completion of this phase, considerable effort was required to re-adapt to the metric units and to Krško NPP systems and the main control boards layout. Use of our own, plant specific full scope simulator represents a very positive move and will eliminate adaptation difficulties.

4.2 The Continuing Training Program

Slovenian legislation currently requires 28 hours of simulator exercises per year for personnel holding reactor operator or senior reactor operator licenses. For the last few years, the annual retraining for the Krško NPP licensed personnel was organized at the Ginna plant full scope simulator in Rochester, USA. The contracted company was General Physics. In the past, regular retraining has also been conducted by Westinghouse and NUS.

None of the simulators used in the past for training of our operators was identical to the configuration of the Krško NPP plant control room and to its dynamic behavior. For the annual retraining,

letnega usposabljanja prilagodili računalniški program simulatorja, tako da je obnašanje sistemov podobno kakor v naši elektrarni. V to področje spada prilagoditev karakteristik črpalk, nastavitvene vrednosti za krmilne in zaščitne sisteme in podobno. Seveda je to le približek, ker se osnovni program ne spreminja.

Uporaba nespecifičnega simulatorja ima seveda določene pomembne pomanjkljivosti pri izvedbi stalnega usposabljanja. Udeleženci usposabljanja se morajo vsako leto znova privajati na drugačno komandno ploščo in je tako del časa za urjenje na simulatorju neoptimalno izkoriščen. Odziv sistemov je, ne glede na prilagoditve, različen od odzivov naše elektrarne in seveda obstaja določena stopnja nezaupanja v tisto, kar operater vidi in na kar se mora odzvati. Obstaja tudi nevarnost, da bi operater glede na izkušnje iz nespecifičnega simulatorja pričakoval enako obnašanje naše elektrarne. Problemi se seveda lahko pojavijo tudi v primerih, ko so potrebne akcije časovno odvisne. Kakovostno lahko te probleme rešuje le uporaba specifičnega popolnega simulatorja.

5 USPOSABLJANJE V PRIHODNJE

Uporaba lastnega specifičnega simulatorja in ustrezna oprema bosta imeli velik neposredni vpliv na usposabljanje operativnega osebja, omogočena pa bo tudi uporaba v druge namene s skupnim ciljem: izboljšati varno in zanesljivo obratovanje elektrarne.

Celotni krog usposabljanja bo lahko izveden bolj optimalno, kakor do sedaj. V začetnem usposabljanju bodo udeleženci uporabljali simulator že v fazi spoznavanja sistemov. Odpadla bo potreba po spoznavanju sistemov, nespecifičnih za JEK. Preverjanje usposobljenosti bo strokovna komisija URSJV opravljala na simulatorju. Redno letno usposabljanje z uporabo simulatorja bo potekalo štirikrat na leto. To pomeni okrog 80 ur urjenja (trikrat več kakor doslej) na simulatorju za vsakega udeleženca. Tolikšno število simulatorskih ur je v razvitih državah standardna praksa. Ob tem pa bo dejanska odsotnost udeležencev od dela v izmeni zaradi rednega usposabljanja enaka kakor doslej.

Uporaba simulatorja, ki specifično modelira sisteme JEK, zagotavlja visoko stopnjo zaupanja v skladnost obnašanja simulatorja v primerjavi z obnašanjem elektrarne. Omogočena je neposredna uporaba obratovalnih postopkov elektrarne.

Lastni simulator, nameščen na sami lokaciji JEK, bo omogočil tudi izvajanje usposabljanja tik pred izvedbo načrtovanih obratovalnih posegov (zagon, zaustavitev), kar bo vplivalo na optimizacijo dela ter zmanjšalo možnost za zakasnitve.

the contractor was responsible for changes to the simulator model to replicate the Krško NPP systems as closely as possible. This included the adjustment of pump characteristics, setpoints for control and protection systems and similar alterations. This was, at best, only an approximation, as the basic system models could not be changed.

Use of a non-specific simulator has various important drawbacks and limitations for the conduct of continuing training. Attendees have to adapt to the non-specific simulator control board each year. Because of this, some of the time dedicated for training was not efficiently used. The system's response, regardless of the implemented changes, was very different. This unavoidably leads to a certain lack of confidence in what the operator sees and what represents the basis for his actions. One other concern is that the operator might expect a response from our plant based on his experience from the non-specific simulator. The problems might also appear in situations when the timing of actions is important. Such problems can be avoided only by the use of a plant specific full scope simulator.

5 TRAINING IN THE FUTURE

Use of our own plant specific simulator and the associated infrastructure will have a significant effect on the operations personnel training process, and in addition, it will also support secondary uses, with the common aim of improving safety and plant reliability.

The simulator will enable the optimization of the entire training cycle. The simulator will be used for demonstrations much earlier in the training process, during familiarization with plant systems. The need to become familiar with the systems of other plants will be eliminated. The licensing examination by the SNSA-appointed commission will be performed with the use of the simulator. Regular, annual, simulator retraining will be conducted four times per year. This means approximately 80 simulator hours (three times more than in the past) for every participant. Such a number of simulator hours is standard practice in developed countries. This will be achieved by using the same amount of time allocated for training as before.

The use of the simulator with software models specifically replicating the plant systems will assure confidence in the consistency of simulator performance compared to the real plant's behavior. Plant operating procedures will also be directly implemented on the simulator.

Having the simulator installed on site will enable just-in-time training. It will be possible to run training sessions just before the execution of planned plant evolutions (startup, shutdown), which will support work optimization in operations, and decrease the possibilities of time delays.

V usposabljanje z uporabo simulatorja bodo v določenem obsegu vključeni tudi strojniki opreme, ki po navodilih osebja glavne upravne sobe lokalno ravnajo z opremo. To bo zelo pomembno za izboljševanje skupinskega dela celotne izmenske skupine.

Simulator se bo uporabljal tudi za podporo pri pripravi in izvedbi usposabljanja po programu, ki izhaja iz načrta ukrepov v primeru izrednih dogodkov v elektrarni. Na ta način bodo scenariji bolj stvarni in s tem izurjenost za ukrepanje še boljša.

Za zagotovitev ustrezne uporabe simulatorja v usposabljanju so pomembni tudi priprava inštruktorske ekipe, prilagoditev učnih programov in prilagoditev sedanjih in priprava novih učnih gradiv. Vzporedno s projektom simulatorja se je JEK pripravljala tudi na uporabo simulatorja.

Programi usposabljanja osebja z dovoljenjem za operaterja (začetni in redni letni) bodo izpopolnjeni v skladu s sistematskim pristopom k usposabljanju, na podlagi rezultatov analize del in nalog za operaterje. Analiza je bila izvedena po vzoru metodologije ameriškega inštituta za obratovanje jedrskih elektrarn (INPO), ki se uporablja v ZDA. Sistematski pristop k usposabljanju priporoča tudi Mednarodna agencija za atomsko energijo (MAAE) [3]. Analiza temelji na elektrarniških obratovalnih postopkih in drugi dokumentaciji. Rezultat analize je nabor znanj in spretnosti, ki jih mora obvladati oseba z dovoljenjem za operaterja. Program usposabljanja bo oblikovan tako, da bo zagotovljeno izvajanje vseh evidentiranih spretnosti in uporabo potrebnega znanja. Bistvena prednost sistematskega pristopa k usposabljanju je tudi celovito dokumentiranje procesa. JEK si je zastavila cilj, da mora prilagojeni program ustrezati normativom za ugotavljanje ustreznosti usposabljanja, ki jih v ZDA uporablja INPO. Pričakuje se, da bo v prihodnosti v mednarodnem merilu takšno vlogo imelo Svetovno združenje upravljalcev jedrskih elektrarn (WANO). Tako bomo lahko pokazali, da je usposabljanje pri nas popolnoma primerljivo s stanjem v razvitih državah.

JEK je prav tako dopolnila tudi inštruktorsko skupino za obratovalno osebje. Celotna skupina je sodelovala pri projektu simulatorja v fazi izdelave in v fazi sklepnih preskušanj in si s tem pridobila že veliko potrebnih izkušenj za delo s simulatorjem. Seveda inštruktorsko delo zajema mnogo več kakor samo upravljanje s simulatorjem. V podporo lastnih inštruktorjev pa bo JEK v začetni fazi usposabljanja z lastim simulatorjem uporabljala tudi tuje strokovnjake.

6 SKLEP

V načinu usposabljanja operativnega osebja je Jedrska elektrarna Krško vedno sledila oziroma v okviru dejanskih možnosti vsaj skušala slediti

Field operators, responsible for operating plant equipment as directed by the crew of the main control room, will also participate occasionally in simulator training, together with licensed personnel. This will enhance team-work practices of the entire shift crew.

The simulator will also be used to support the preparation and conduction of drills required by the plant emergency response plan training program. In this way, the scenarios for emergency drills will be more realistic, resulting in better preparedness.

Certain prerequisites are essential to assure adequate introduction of our own simulator training. Such prerequisites are: well trained instructors, prepared training programs, written training materials, etc. The preparation for the simulator utilization has been done in parallel with the simulator project.

Licensed operator training programs (initial and continuing training) will be revised in accordance with the systematic approach to training (SAT) methodology, based on the results of job and task analyses that were performed for licensed job duties. The analyses were done based on the methodology developed by the Institute for Nuclear Power Operations (INPO), which is used in the United States. SAT methodology is also used by the International Atomic Energy Agency (IAEA) [3]. The analysis is based on plant operating procedures and other relevant plant documentation. The final result of the analyses is a list of knowledge and skills the licensed person must obtain and retain. The program will be appropriately structured to ensure training on all the identified skills and knowledge items. One essential benefit of using the systematic approach to training is a well documented process. It is Krško NPP's goal to structure the revised training programs in compliance with the criteria for training program accreditation used by INPO in the USA. It is expected that in the future the World Association of Nuclear Operators (WANO) will assume this function on an international scale using practically the same criteria. This means that we will be in position to prove that training is comparable to that in developed countries.

Krško NPP has increased the number of instructors for operations personnel. All instructors were also involved in the simulator project, during the construction phase as well as during the testing. In this way they gained a lot of experience for future work with the simulator. Running the simulator is, of course, just one part of the instructor duties. In the early phases of simulator utilization Krško NPP will use experienced consultants to support the work of our own instructors.

6 CONCLUSION

It was always Krško NPP policy to follow western practices in training. The circumstances in the past did not allow us to fully comply. During the

zahodnemu svetu. V času, ko so zahodne elektrarne nabavljale svoje simulatorje, je neizogibno zaostala.

Elektrarna je tudi v preteklosti že večkrat poskušala uresničiti svojo željo po lastnem simulatorju. Ob pomoči upravne odločbe in z velikim vloženim delom elektrarne je sedaj simulator tukaj. Elektrarna bo v prihodnje imela možnost kakovostno izvajati tako redno usposabljanje kakor tudi usposabljanje novih generacij operaterjev.

period when western countries were building their simulators, we lagged behind.

The acquisition of our own full scope simulator has fulfilled a long held desire of Krško NPP. With the additional effect of the licensing amendment and considerable effort from the plant's side, the simulator has become a reality. Now the plant has in place the requiements for improving the quality of annual retraining and the initial training of new generations of operators.

7 LITERATURA
7 REFERENCES

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