# INCREASING RELIABILITY OF NUCLEAR ENERGY EQUIPMENT AND AT NUCLEAR POWER PLANTS

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The article deals with a cooperation of the Institute of Nuclear Energy at the Technical University in Brno, Faculty of Mechanical Engineering, on increasing reliability at nuclear power plants.

Pedagogical Programme: The Institute of Energy, Department of Thermal and Nuclear Power Plant Engineering (further Department only) at the Technical University in Brno offers a wide range of subjects dealing with education in nuclear energy.

The subject "Nuclear Energy" has been introduced and is taught here since 1958. The specialisation of "Nuclear Energy Plants" has been established in 1983. 70 specialists in the Nuclear Energy graduated with M.Sc. Degree (Ing.) since the very beginning of the programme. Their immediate placement is showing a good deal of interest and a sound demand for them in energy industry and in energy engineering as well. The department is offering specialisation's in

- Bachelor study programme (B.Sc.)
- Master study programme (M.Sc./Ing.)
- Post-graduate study programme (Dr.Ing./Ph.D.)
- Continuous education

The study programme a the Faculty of Mechanical Engineering of the Technical University in Brno for master degree is divided into 5 years. First 3 years involve general theory subjects and their application while the last 2 years concentrate on the very specialisation in a great detail. This distribution of the subjects can be clearly seen in the table below showing the situation in the 4th and 5th year of study.

<table>
<tr><td>200 - 400 students<br>in each year of study</td><td colspan="2">basic theoretical subjects<br>and their application</td><td>1., 2., and 3. year</td></tr>
<tr><td colspan="4"></td></tr>
<tr><td>20 - 30 students/year</td><td colspan="2">thermal energy plants</td><td>4. year</td></tr>
<tr><td colspan="4"></td></tr>
<tr><td></td><td>clasical energy<br>10 - 20 students/year</td><td>nuclear energy<br>10 - 20 students/year</td><td>5. year</td></tr>
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The fourth year of study, "The thermal Energy Plants", is common for all students and includes "Nuclear energy" subject in duration of 4 lectures and 2 hours of lab work every week.

**Summary of a subject:**

**Nuclear Power Industry:**

The aim of this course is to acquaint the auditors with general aspects of development of nuclear power industry. It is based on the principles of general theory of nuclear reactor and of cycle of nuclear fuel. Then the lectures focus to basic types of nuclear reactors and nuclear power plants. Using the examples of thermal charts of nuclear power plants, the ways of production of electricity from the nuclear energy are explained, considering methods of nuclear

safety. The students are led to know the basic principles of applications of nuclear energy and, especially, radioactive waste management. By the specifications of mechanical specialities of nuclear energetic equipment the student take in the designing and operation of nuclear power plants.

*Prof. Ass. O. Matal (Department of Heat and Nuclear Power Energy Equipment)*

**Syllabi of the 5th Year's Courses**

**Specialisation of Nuclear Power Plant Engineering:**

**Nuclear Physics and Dosimetry:**

The aim of this course is to repeat basements of nuclear physics, which are necessary to be known for next courses of nuclear physics lines. The auditors take in basic principles of atom and nuclear physics and make a complete imaginations about matter structure and determining of strength acting in it. The structure of the course is drafted in suitable consequences from general characteristics of microworld to concrete macroscopic displays. Phenomena which are connected with operation of nuclear energetic equipment are in the main attention.

*P. Koláček (outside teacher)*

**Nuclear Reactors:**

The object of this course is to acquaint the auditors with progress of development of nuclear reactors and on basement of suitable representatives of particular conceptions teach them about the designs of various types of reactors. Consequently the students will be taught to use results of theory of neutron field and of theory of neutrons multiplied system for two basic conceptions of reactors, it means homogenous and heterogeneous conceptions. Neutron calculations are followed with application of theory of heat and matter transfer to determine temperature field in particular components of core of reactor to dimension it from the thermal and strength views. The auditors with received theoretical knowledge are then acquainted with design and components of reactor to be able to suggest suitable innovations of it.

*Prof. F. Dubšek (Department of Heat and Nuclear Power Energy Equipment)*

**Control of Nuclear Energetic Equipment and Nuclear Safety:**

The course is aimed at pressure water reactors (PWR, VVER), their description, analysing of their properties like controlled object from view of control operation system, particular solution of the system, it's particular parts and reciprocal links. Except reactor and it's control system are also meant the most important sequention technological components of power supply unit with pressure water reactor.

*V. Krček (outside teacher)*

**Secondary Circuits of Nuclear Power Plants:**

Nuclear energy is a new trend in area of electricity and heat supply in our society. The main requirement of primer circuit is safety of operation. As for secondary circuit the main sight is reliability and efficiency of operation. The course acquaints the auditors with particular components of the circuit with connections of operation of secondary circuit of nuclear power

plant. A lot of attention of this course is devoted to operational conditions of the equipment from the view of good economical results.

*Prof. Ass. J. Krbek (Department of heat and Nuclear Power Energy Equipment)*

**Electro-Power Industry:**

Operation and properties of turboalternators, their exciter systems, appliance equipment. Asynchronous generators. Non-regulating, regulating electric drives in thermal and nuclear power plants. Energetic transformators. Electric stations. Electro-schemes of home consumption of power and heating plants and of thermal and nuclear power plants.

*B. Balabán (Institute of Electrotechnics)*

**Designing seminar:**

The content of this course is to practise practically already obtained knowledge form other courses of theoretical basement of this specialisation with form of project bases, drawing documentation and analysis report in these areas:
- primary and secondary circuits of nuclear power plants

*Prof. Ass. O. Matal (Department of Heat and Nuclear Power Energy Equipment)*

**Materials of Energetic Devices:**

The course implies an overview of steels and alloys used in thermal and nuclear energetic engineering. Types of alloy steels for components of turbo-generators, for pipes of superheaters and steam pipes, for boilers and for determined components of nuclear power plants are consecutively gone over. Chemical composition and types and problems of technological treatment, of degradable processes, of limiting stages of individual types of materials are described, as well as their testing. Knowledge from basic courses "Theory of Materials I and II" are supposed.

*Prof. Ass. E. Münsterová (Institute of Materials Science)*

**Designing of Nuclear Power Plants:**

The aim of this course is to acquaint the auditors with the main criteria of designing of nuclear power plants sequencing at formerly received knowledge from the course "Economy and Designing of Thermal Energetic Equipment". The prime criterium is nuclear safety, which results to project of nuclear power plant and to it's localisation. That is resource for next comments of disposal solution of nuclear power plants and technological and economical aspects of their's operation. Then problems of possible internal accidents is gone over.

*Prof. Ass. O. Matal (Department of Heat and Nuclear Power Energy Equipment)*

**Functioning and Water Management of Nuclear Power Plants:**

Terms and limits of operation of nuclear power plants equipped with pressurised water reactors, analysing of operational reliability and thermal efficiency. Starting up and putting out of action of reactor and refuelling. Basic transition processes. Principals of chemistry of power plants, checking of chemical processes and anticorrosive protection. Deactivation of nuclear energetic equipment.

*Prof. Ass. L. Ochrana (Department of Heat and Nuclear Power Energy Equipment)*

**The Final Project:**

The object of this course is to elaborate source documents and to scheme projects and design drawings on dependence of individual problems solving of students, which are closed to their theses. The emphasis is placed on individual solving of the problems using technical literature, computers and consultation of external specialists.

*Prof. F. Dubšek (Department of Heat and Nuclear Power Energy Equipment)*

**Legislation in Power Supply Industry:**

Acquaintance with principles of energetic policy of Czech republic, with it's basic implements and aims and with basic legislative rules.

*Prof. Ass. L. Ochrana (Department of Heat and Nuclear Power Energy Equipment)*

**Scientific research programme of the Department**

Education and research of the Department in the field of reliability is based on a complex systematic concept securing a high level of reliability.

It includes whole range/cycle of origin from its very design to its practical use since the students are involved in this programme working at various working locations ranging from research down to the power plant. Individual phases are illustrated in the following chart:

Ties to the operator

| | | | | |
|---|---|---|---|---|
| research development | design projection | production | assembly | operation |

Feedback to the pre-operational stage

A conception of service of every individual component is very important to secure high reliability of a nuclear power plant. A higher number of preventive service and a lower number of accidental service/repair work after malfunctions of a plant is a characteristic sign of nuclear power stations in comparison to the classical ones. With regard to the number of service work, the prevention involves about 60 - 70 % of this work. A question of economy arises whether the preventive maintenance is necessary and up to what degree it influences the reliability of a plant.

The pre-planned black-outs/switch-offs in a nuclear power plant of electrical energy in the system must be substituted at once. The procedures are as follows:

- substituting energy production from external sources increases the cost by 2-5x higher than in the nuclear power plant
- accidental/non-planned import of electrical energy exceeds the cost probably much higher than in the above mentioned case.

In the view of a nuclear power plant, the financial loss caused by accidental black-outs results in decreased financial inflow from the customer causing so a lower gain for the plant.

In general, correlation between the increased total cost and the increased reliability is not a linear one. With increased reliability the cost is growing progressively. Reliability is then seen as a probability of a non-failure system R.

**Evaluation of the components**

The reliability of a nuclear power plant is given by the reliability of individual components and the way of their integration.

MAAE recommends to use RCM system (Reliability Centered Maintenance) at present, i.e.maintenance directed towards reliability. This method is based on the fact that

- reliability of a plant or a power block is given by reliability of its components
- acquired level of reliability lies in the maintenance/service.

**The RCM method uses a method of predictability rather than a method based on concretely calculated cycles**

Predisposition of RCM method and its use is determined by a perfect knowledge of a plant condition/state at any given time, i.e.

- behaviour of the system/equipment and its reliability characteristics as experienced from the past and from
- results of diagnostic methods, revisions/check-ups, and other testing procedures.

In 1996, the Department worked out a study dealing with evaluation of maintenance system in a nuclear power plant. Source of the information's is based on the following subsystems:

- reliability of maintenance informative system
- work-order of maintenance.

The reliability informative system of maintenance provides information's dealing with failures and mistakes. The following is recorded there:

- number of total and partial failures - $n_{up}$, $n_{cp}$
- time of all occurred failures - $\tau$ (h)
- wasted output due to any failure - $\Delta$ P (MW)
- wasted production - $\Delta$ Z (MWh)

The work orders provide information's dealing with service after failures (O) and preventive maintenance (u). The following is recorded there:

- number of services $A_o$ and number of preventive maintenance inputs $A_u$
- time of service and preventive maintenance inputs
- financial cost/loss due to the service and prevention

If the total number of inputs is marked as $n_{ob}$, then

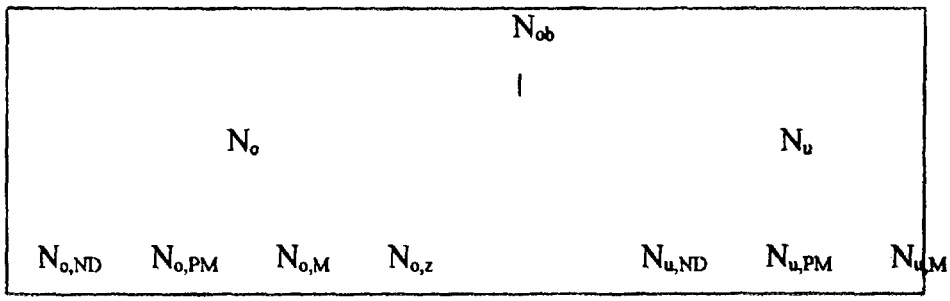
$$n_{ob} = n_o + n_u$$

where $n_{ob}$ is the total of complete inputs for equipment renewal.

Similarly it goes for the cost and for the equipment in any longer time interval

$$N_{ob} = N_o + N_u$$

The $N_o$ and $N_u$ cost is further divided in a cost for spare parts (ND), used material due to operation, salary paid to maintenance workers (M), and financial loss due to any failure ($N_z$) i.e. minimal gain loss for a power plant.




A Proposal of methodics allows to evaluate reliability and maintenance characteristics of any individual component in a nuclear power plant, namely then

- intensity of service $\lambda = \frac{n_{up} + n_{cp}}{1000\tau_p}$
- intensity of maintenance $\mu = \frac{n_u}{1000\tau_p}$
- intensity of renewal $\mu_{ob} = \mu_u + \lambda_p$

## Conclusion

The proposed system will be able to monitor/record and evaluate data in any given time interval as to

- the number of inputs after interventions and during preventive maintenance
- cost for preventive and post-failure maintenance
- failure rate of equipment.

All results from this assembly together with diagnostic results, revisions/check-ups, and various ways of testing will sere and lead to expertise decision process making when any concrete maintenance work/service ought to be done.

## Literature

MAAE Vienna: Maintenance at Nuclear Power Plants, Vienna 1991
MAAE Vienna: Reliability Centered Maintenance, Vienna 1994