EXAMPLES FOR COST REDUCTION IN THE DESIGN OF A VVER-1000 NUCLEAR POWER PLANT

T. KUKKOLA
Imatran Voima Oy,
Helsinki, Finland

Abstract

In a design project during recent years, a version for Finnish conditions has been and is being developed based on the Soviet VVER-1000 PWR plant with four horizontal steam generators. The plant will have a double containment. The inner containment will be a dry full pressure prestressed concrete containment with liner and the secondary containment will be made of ordinary concrete. Four train safety approach is adopted. It is supposed that the plant is to be designed according to the present Finnish safety requirements, e.g. severe reactor accidents are considered. When striving at an economic plant no compromises are made as far as safety is concerned. This paper describes possible cost reduction by redesigning the main technical equipments.

1 Introduction

In a design projects during recent years, a version for Finnish conditions has been and is being developed based on the Soviet VVER-1000 plant.

The first version of a VVER-1000 plant was developed in the beginning of 1980. The design was finalized in 1984.

During years 1985-1986 a modified version of VVER-440 plant was developed. Same design approach was followed as in the VVER-1000 plant design, /1/.

The accident in Chernobyl affected that the new government 1987 made a mutual agreement that no decision on nuclear power will be made during the years 1987-1991. The next parliament election will take place in March, 1991. The new government would be hopefully in position to make positive decision on nuclear power. Preparations for the positive decision are made.

One candidate for the possible next plant will be a VVER-1000 type plant on which the design project takes place. There are four other candidates and hard competition is expected between the candidates.

The plant in this context will contain a VVER-1000 type reactor with four horizontal steam generators and one 1500 rpm turbine with three low pressure cylinders. The plant will also have double containment. The inner containment will be a dry full pressure prestressed concrete containment with liner and the secondary containment will be made of ordinary concrete. Four train safety approach is adopted. View from the plant is shown in Appendix.

The plant is designed according to the present Finnish safety requirements, e.q. severe reactor accident are considered.

The assumed plant site is in Loviisa, in the neighborhood of two VVER-440 plants.

When striving at an economic plant no compromises are made as far as safety is concerned.

2 *General principles for economy*

In the plant design it is important to keep harmony between the different design areas. Exaggeration in one area can lead unbalanced plant concept with unnecessary expenditure.

No savings are strived at on the cost of operability and maintainability. For example, access into the containment during power operation will be possible, adequate rooms for overhaul personnel are reserved, a lot of cranes and lifts are reserved, etc. Accessibility during power operation means that improved ventilation systems shall be used as well as improved radiation shielding.

No savings are strived at on the cost of high work quality. To invest on the high work quality will be profitability. For example the proper surface treatment will help to keep plant clean and personnel doses low.

In order to control the investment and the operating costs the following general principles are followed:

2.1 Modular and functional approach

Modular and functional approach are followed. Systems which serve same functions will be located in the same building. This minimizes the connections between the buildings and reduces for example pipe lengths.

Safety and non-safety systems are separated from each other. The safety systems are located only in the safety classified buildings. Thus lower safety standards can be applied in the non-safety classified buildings.

2.2 Keep the building sizes small

Building sizes should be reasonably small to reduce costs. Buildings should be as simple as possible. This promotes competition between the Finnish contractors. If only very large building block would be constructed so only one construction bid would be received by one joint venture company.

2.3 Minimize the building volumes

Total building volume is a good indication of the cost-effectiveness. Also the site area for the plant itself and for the construction work indicates same thing. If one can reduce the building volume indirect saving may also be notable.

Building volume comparison are shown in table below. The older version of the plant had two 500 MWe turbines, the latest design will have one 1000 MWe turbine. In principle the design features are equal in both designs.

The building volumes

Building	Volume m^3 New 91	Volume m^3 Old 84
Reactor building	136550	127400
Steam cell	15290	22720
Control building	41680	31000
Safety building	39140	43670
Diesel building	14420	.3800
Auxiliary building	52710	60140
Waste storage	6730	9750
Fresh fuel storage	7740	10300
Nuclear service building	20450	12590
Turbine building	205000	202800
Cooling water pump building	15000	29350
Water treatment building	10000	6300
Workshop-storage	23770	29000
Office building	14040	10500
Total	602520	612170

2.4 Separate the construction and installation works

Construction and installation works are separated from each other. This means for example that full size material air locks and hatches are reserved, so that even steam generators can be changed during plant life without breaking the structures.

By separating the construction works and the installation works the work quality can be improved and working efficiency is better. This means lower costs.

2.5 Utilize the local conditions

Local conditions are taken into account, like industrial structure, local climate, cooling water conditions, ground quality, etc.

Local companies are planned to be used maximally. Competition between the companies will be promoted. For example when planning the machine shops and storage this feature is taken into account.

In cooling water system design local conditions are very favorable. A lot of cold cooling water is available. The ground allows to use the rock tunnels as cooling water lines. The rock tunnels will need no maintenance and the flow losses are low.

The ground is stable, no seismic activity is recorded. Only thin bottom slabs are required. However, the plant will be designed against a earthquake with 0.1 g horizontal acceleration at ground level.

2.6 Minimize the construction time

Construction time shall be minimized for reducing the capital costs. For example no rooms below the reactor containment are allowed in order to shorten critical path of plant construction. Simultaneous construction of different building will be possible.

2.7 Store the spent fuel in the containment

The refuelling pool should be large enough to cope at least 10 reloading plus the reactor core. Then separate spent fuel storage can be avoided and transport risks eliminated.

3 Examples for cost reduction

In the following there are listed some examples how and where investment cost reductions are obtained by redesigning:

3.1 Reactor building

Major factor in cost reduction is that Leak-Before-Break approach is adopted. This means that no restraints for the piping systems will be installed. Also pressure differential loads in containment sub-compartments can be avoided. On the other hand extra research and development work on materials and fracture mechanics are required.

The inner structures of the containment have been simplified. Straight wall lines with perpendicular wall joints have been used whenever possible.

Building height has been slightly reduced so that containment gross volume is about 84000 m^3. The lowest level of the reactor building is same as the ground level.

Provisions for severe reactor accidents have been made. Total thickness of bottom slab is about 4 m. Below the reactor the slab thickness above the containment liner is 3 m, elsewhere 0.6 m. This gives adequate erosion margin for the molten reactor without increasing the construction costs.

3.2 Auxiliary building

Operating experiences of the Loviisa plant have been utilized. Unnecessary conservatism has been avoided. Reservations for reservations are not made unlike in the latest 440 MWe plant design.

Several process changes and layout arrangements have been made in order to keep the building volume reasonable. Close circuit technic, waste solidification, multiuse of waste water tank, etc have been applied.

3.3 Turbine building

The turbine building will have several improvements. The modifications are to be compared with the standard Russian design.

Water separating and superheating process. Four water separator-superheaters are replaced with two. This simplifies the processes and reduces the space demands considerably.

Low pressure preheating system. In the original design the low pressure preheating system contains three vertical first phase preheaters and two vertical second phase preheaters. All preheaters were connected in each low pressure turbine cylinders with manifold pipe connection. In the latest design the first and second phase preheaters are replaced with a horizontal duplex type preheater, which is located between the LP-turbine and condenser. So the space demand of the preheaters and large pipe manifolds are eliminated completely.

Turbine by-pass. In original design the central valve group were arranged at the end of the turbine hall, from where bypass lines to the condenser were led. The old design were replaced with two collectors which were led directly to the condensers and the valves are installed closely to the condensers. The space demand of the new design is considerably less.

Feedwater system arrangement. The feedwater tank is located at the main floor of the turbine hall. The electric motor driven feedwater pumps are below the feedwater tank at the ground floor. In the original design the feedwater tank and the turbine driven pumps were located in a separate building part.

Ventilation and electric system arrangement. Less space demanding ventilation system are designed. Also switchgear plant for the turbine building is integrated to the turbine building.

Cooling water arrangement. The cooling water pumping building is facing the turbine building. The cooling water is led to the pumping building along a rock tunnel. The fine screen filter are installed directly to the cooling water pipes.

Transport arrangement. In the original design there were the railway through the turbine building for the transports. In the new design only a lifting shaft for the transports are arranged.

3.4 Indirect effects

The indirect effects in cost reductions could be notable.

By reducing the building volumes the savings are obtained in heating, ventilating and air conditioning. Also the power cabling and pipe lengths will be reduced.

When keeping the plant size reasonably small the operating costs are also reduced as well as man-power required.

Reference

/1/ "A Possible Finnish Alternative", Kukkola, T., Nuclear Engineering and Design 109(1988) 155-161, North-Holland, Amsterdam.

APPENDIX