MEANS OF ACHIEVING HIGH LOAD FACTORS AT OLKILUOTO 1 AND 2

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Abstract

Teollisuuden Voima Oy operates two BWR units Olkiluoto 1 and 2 that have achieved load factors typically higher than 90%. The operating experiences gained in the 1990s is summarised and the factors contributing to the high capacity factors are addressed. These include the general objectives for operation and maintenance, plant modernisation programme, maintenance principles, and outage policy and experiences. Finally, the international evaluations performed at Olkiluoto are mentioned.

1. INTRODUCTION

Teollisuuden Voima Oy (TVO) is a Finnish power company owned mainly by industry. The company was founded in 1969 primarily to satisfy the electrical power needs of the forest industry. The company aims at developing and operating large-scale power plants and producing electricity for its shareholders at cost price. TVO's first nuclear power plant unit, Olkiluoto 1, was connected to the national grid in September 1978, and the second unit, Olkiluoto 2, in February 1980. TVO's output of nuclear power covers about one fifth of the total national production in Finland.

Olkiluoto 1 and 2 are two identical BWR units with a net electrical output of 840 MW. They have single turbine-generator sets cooled by seawater. In addition to the power plant, the site incorporates an interim storage for spent fuel and a final repository for operating waste. A training centre with a full-scope replica simulator is also located at the site. The final disposal facility for spent fuel will be constructed in Olkiluoto in the vicinity of the power plant.

2. BACKGROUND: PRODUCTION COSTS

Production costs are the key issue in the competitiveness of electricity generation. Although nuclear power is a capital-intensive generation form, low operation and maintenance costs are a mandatory target for every power plant. At Olkiluoto we have been able to keep the fixed O&M costs at almost constant level during the past 15 years, as shown in Fig. 1.

Low O&M costs are the result of disturbance-free and predictable operation, which is promoted by several measures:

- clear organisations and responsibilities, less organisation levels, "simplified" functional processes
- optimisation of maintenance measures
- optimised outage policy
- key competences / outsourcing, partnership
- advanced data systems
- encouraging wages.

In our case, special emphasis is put on plant upgrading with related power uprating. This and other issues mentioned above are discussed below.

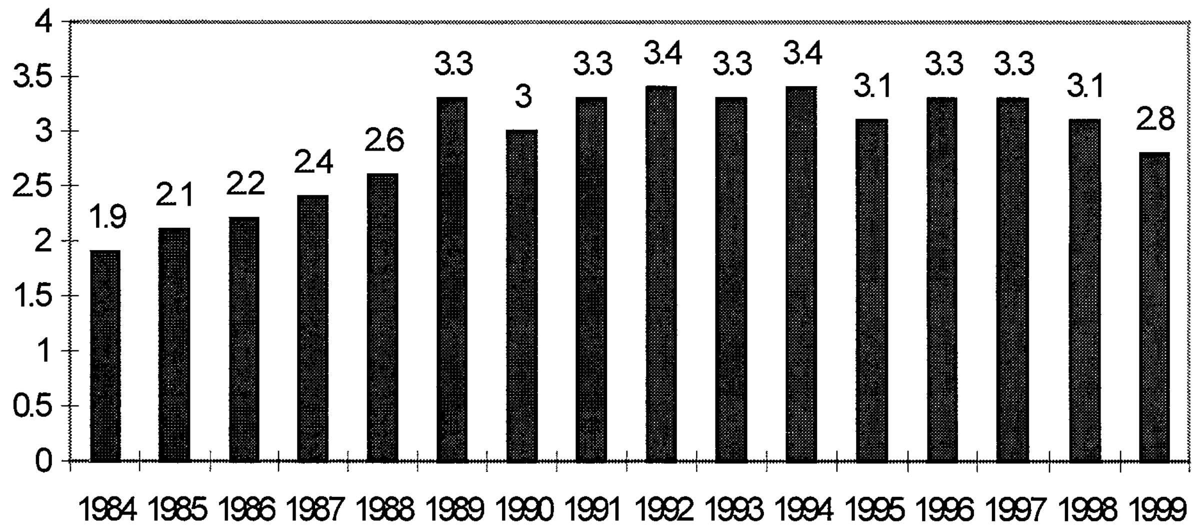

Fig. 1. O & M costs in Finnish p/kWh (including overhead costs, no fuel and capital costs).

3. OPERATING EXPERIENCE

Olkiluoto 1 and 2 have been able to keep very high load factors when compared internationally. The units have been in base-load operation, which means that capacity factor is a suitable performance indicator. The operation record of Olkiluoto 1 and 2 during the past 15 years is presented in Fig. 2. The annual electricity production has risen during the past few years, thanks to power uprating.

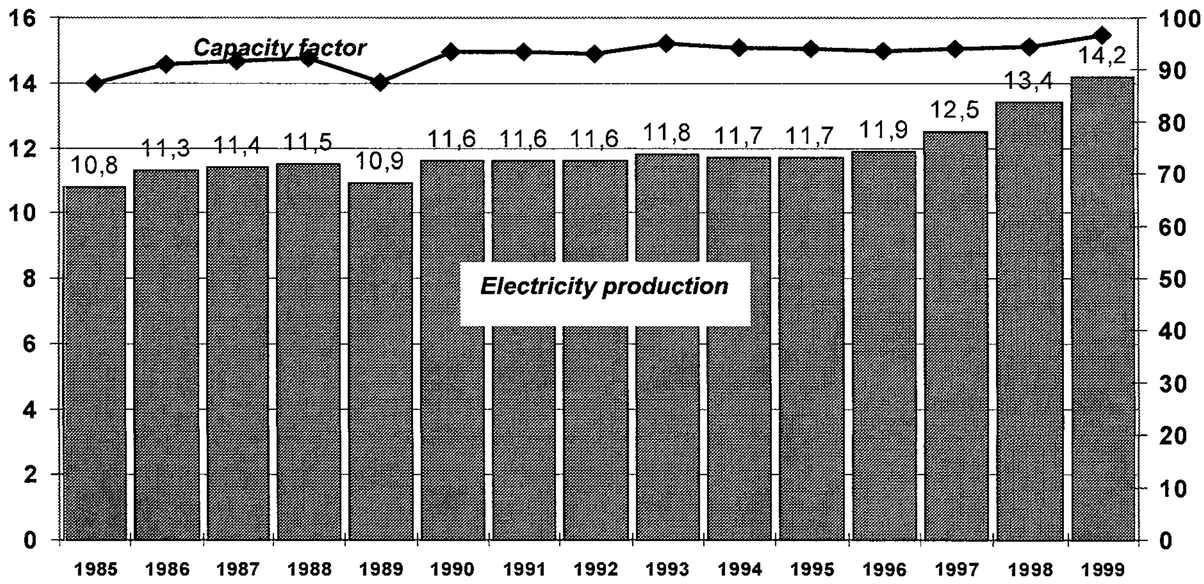

Fig. 2. Electricity production in TWH net (left) and capacity factor in% (right).

Keeping the average load factor for the last ten years over 93% has been possible because of good availability and short annual outages. The operational success is primary attributable to the early elimination of technical problems and preparation for defects beforehand. Development of outage planning and maintenance methods and a low rate of disturbances have also been very significant in keeping load factors high. The non-planned production losses have been typically between 0.2 to 2%, as shown by the statistics of production losses in Fig. 3.

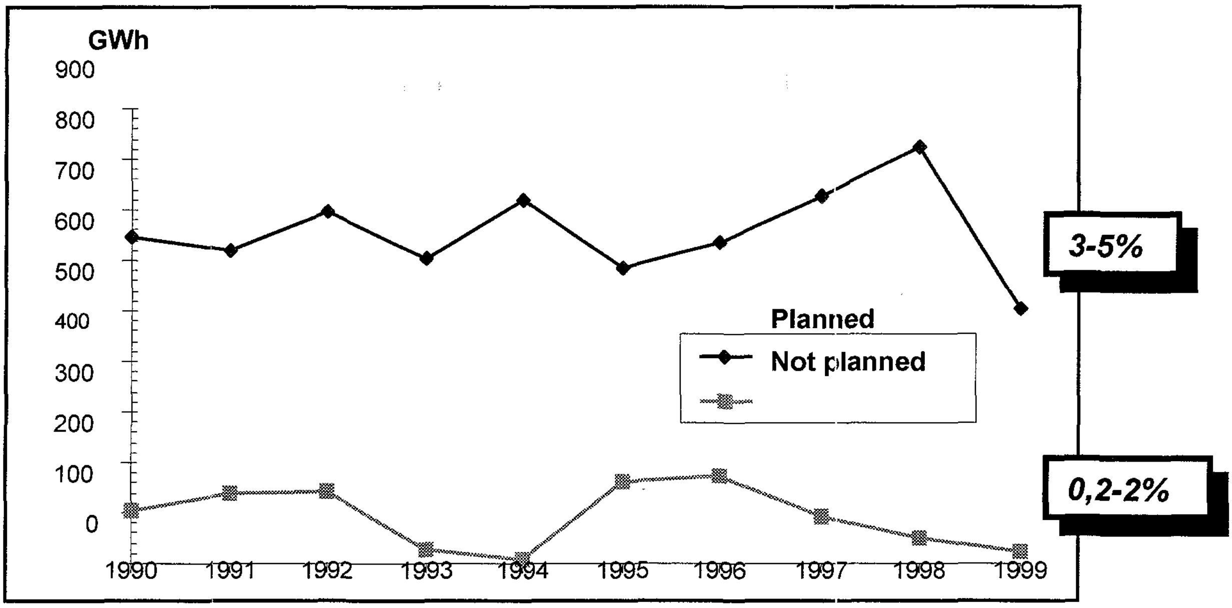

Fig. 3. Production losses in 1990-99 in GWh.

4. GENERAL OBJECTIVES FOR OPERATION AND MAINTENANCE

The following long-term goals are applied in the operation and maintenance of Olkiluoto 1 and 2:

- keeping the load factor over 90% and avoiding operational disturbances
- keeping the technical condition of the plant "as new"
- continuous learning and development of operation and maintenance functions
- reducing the production costs.

With good reason, we can claim that Olkiluoto plant is still reasonably modern. The original ASEA Atom design included several advanced features, and numerous improvements and modifications have been made since commissioning. This would not have been possible without substantial investments to improve the technical quality and design of the plant. Our modification and improvement policy is defined as follows:

- Annual investment level has been 100-150 MFIM (20-30 MUSD).

- 200-300 smaller and bigger modifications/improvements are made yearly. These include also investments to tooling, data systems, infrastructure, spare parts etc.

- The modifications are carried out without major impact on annual outage times.Examples are the exchange of generator and 2 LP turbines, modification of HP turbine and exchange of HP steam control/stop valves in outages of 15-19 days.

- The exchanges are performed in complete packages ("old parts out, new complete parts in") to keep short outage times.
- The design and preparation of outage activities starts one year in advance.

5. MODERNISATION PROGRAMME

A good manifestation of the afore-mentioned company policy is the wide-ranging modernisation programme which was carried out in 1994-1998 with the following objectives:

- reviewing safety features and enhancing safety, if feasible
- improving the production-related performance
- identifying factors limiting the plant's lifetime and eliminating them, if feasible
- enhancing the expertise of the own staff and improving productivity.

Four ways were followed to increase the electricity production:

- reducing the unplanned capability loss factor
- shortening annual outages
- improving thermal efficiency
- uprating reactor thermal power.

In the start-up phase of the programme, the technical development in the branch was exploited. This included mapping of new safety requirements and advanced design solutions. In the decision-making both our own operational experiences and experiences from other plants were considered.

In the execution of the programme, own staff was used as much as possible. Losses in electricity production were avoided. This meant that the plant modifications presupposing shutdown were implemented during normal refuelling and maintenance outages. In this way the average capacity factor stayed at 94% during the programme. Cost/benefit approach was applied, of course.
The programme consisted of about 40 separate projects, and the total costs amounted to 784 MFIM.

The expenditures were balanced by the increase of plant electrical output. In fact, the power level of the Olkiluoto units has been uprated twice:

- in 1984 by 8% from 2000 MW (660 MW(e)) to 2160 MW (710 MW(e)) and
- in 1998 by 15.7% from 2160 MW to 2500 MW (840 MW(e)).

Net electrical power has also increased due to modifications improving plant efficiency. The most important plant modifications contributing to the reactor power uprating are shown in Fig. 4. It should be noted that safety margins were not deteriorated, thanks to technical modifications including new fuel types. Plant technical lifetime of 60 years was found feasible in the studies performed.

6. MAINTENANCE PRINCIPLES

TVO has the philosophy of "rolling 40 years' plant lifetime". This requires that the technical condition of plant is kept at good level and maintenance and modernisation measures are conducted at right time by a cost-effective way, controlling the O&M costs. PSA, modern maintenance analyses methods and operation experience are used to allocate maintenance measures to right components and to keep up the desired plant safety and availability level.

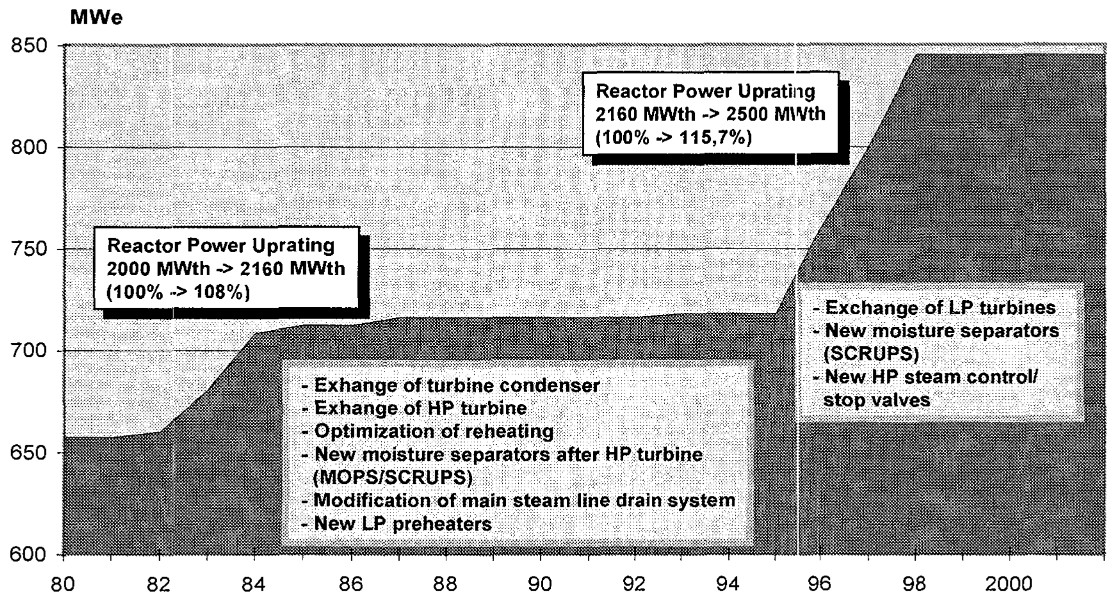

Fig. 4. Power uprating with related main plant modifications

Maintenance planning, execution and follow-up are supported by new and effective data systems.

The maintenance policy is verified in the distribution of maintenance man-hours in Fig. 5. The increased share of modifications in the late 1990s was caused by the modernisation programme.

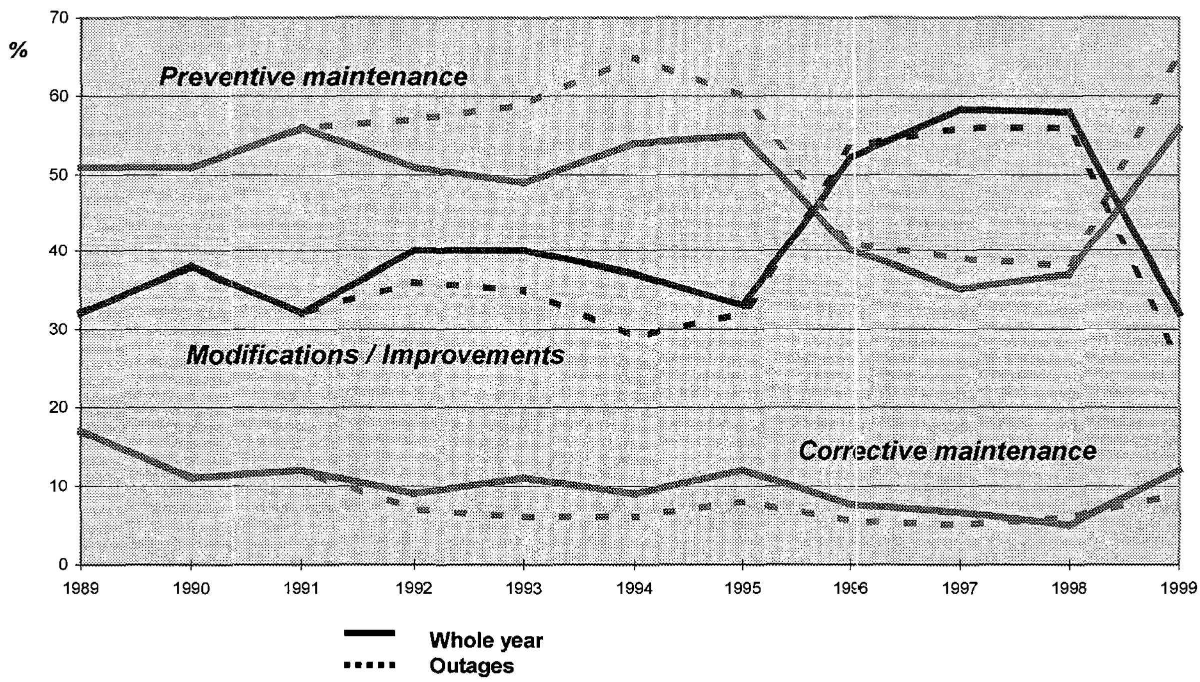

Fig. 5. Distribution of maintenance man-hours

7. OUTAGE POLICY AND EXPERIENCES

The price and availability of the replacement electricity for owners and the fuel economy are the factors determining the length of operating cycle and the time period to carry out outages. At Olkiluoto, regular 12-month cycles are most advantageous. 24-month cycle is not economically justified because of fuel costs and some technical restrictions. 18-month cycle should lead to outages during cold season with higher electricity price. The most important single reason to start outages in the beginning of May is the price of replacement electricity in the Nordic electric market. This time is also convenient for the availability of the competent and common resources used at Nordic nuclear power plants.

The lengths of annual outages in Olkiluoto NPP have decreased during the years from 40 days outage in 1980 to the 10 days (Olkiluoto 2) and 8.5 days (Olkiluoto 1) achieved in 1999, which is shown in Fig. 6.

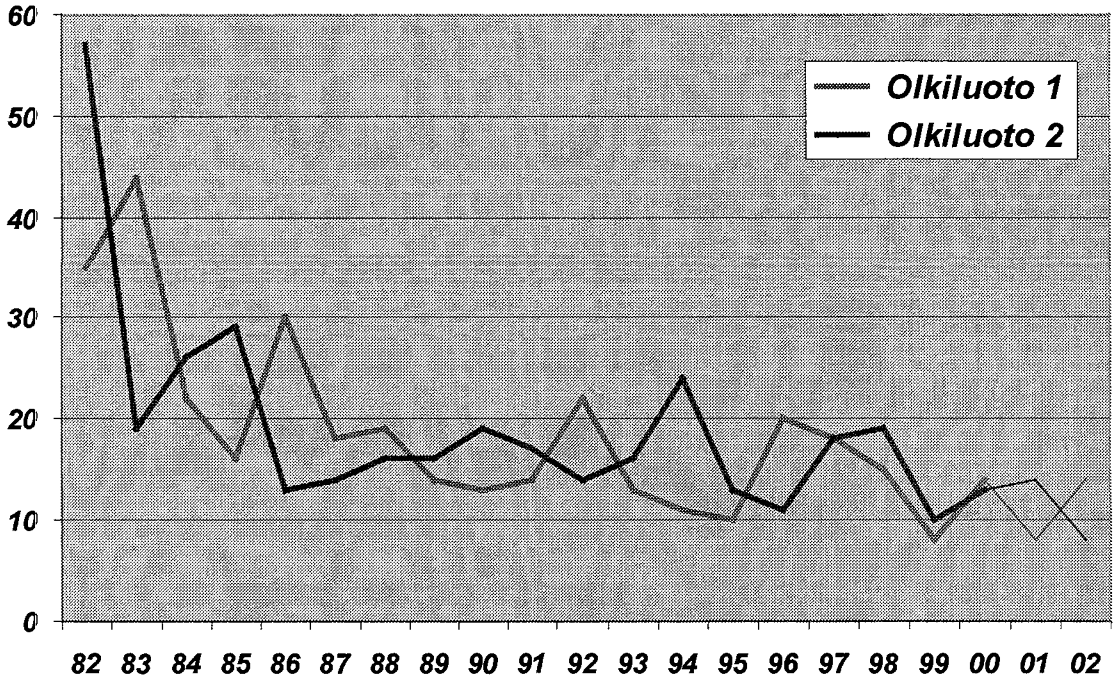

Fig. 6. Lengths of annual outages in days.

In order to optimise the long-term outage lengths and costs the outages are divided to two types: refuelling-only outages (about 9 days) and service outages (about 14 days, including for example the opening and inspection of turbine). They follow each other alternately. Major modification and repair works are carried out in 20-30 day's service outages every 5 years if needed. An interval of 2-4 days is enough between the short two outages.

Planning of outages must be done on several levels: long-term planning (about ten years), mid-term planning (about three years) and detailed planning of the following outages (1-2 years). Of course, short-term planning must also be done during the outages as well as preparedness maintained for unexpected repairs.

Continuous training of own and contractor personnel assure the availability of professional staff. Long-term cooperation with plant vendors and other affiliated companies is ensured by long-term agreements. Special training for plant components has been given to some Finnish affiliated companies. Multi-cycle fixed price contracts are also used, and over 70 per cent of the personnel have experience based on previous outages. Result and quality bonus systems are used for own personnel and partly also for contractor personnel. Coordination of the planning and execution of outage activities must always be the responsibility of the utility, and it must be done in a "partnership" arrangement with the main contractors having the common goals.

8. EVALUATION OF O&M QUALITY AND PRODUCTIVITY

An increasing number of NPPs have enforced different operation evaluation methods. These methods have been very beneficial and increased the understanding of operation and maintenance functions. At Olkiluoto, the following evaluations have been performed by various international organisations:

- IAEA/OSART in 1986
- evaluations by STUK (Finish regulatory body) in connection with the renewal of operation license in 1983 and 1997
- WANO Peer Review type self evaluation
- SCEMM (Scandinavian Center for Maintenance Management) in 1996-97
- SFS in 1997, TTK/INSPECTA in 1997 (Mechanical Maintenance)
- IAEA/ASSET in 1997-98
- INPO (limited extent) in 1998
- WANO Peer Review in 1999.