COMPLETION OF ROVNO UNIT 4 AND KHMELNITSKY UNIT 2

PROJECT PRESENTATION

August 1998

1 The Project Objective

The project objective is to complete the construction of two Ukrainian VVER 1000 MW nuclear power plants, Rovno unit 4 and Khmelnitsky unit 2, to an internationally acceptable safety level.

2 Status of the Issue

Nuclear energy today provides about 50% of the general power, produced in Ukraine. Closure of Chernobyl NPP without new sources of energy will lead to further power cuts, which at least, is inconvenient to the population and can lead to dangerous situations at industrial plants. To fulfil the decision to close Chernobyl in 2000 Ukraine needs reliable replacement power sources. Independent studies have shown that the least cost long term development programme for the Ukraine power system is to complete and the reactors at Khmelnitsky 2 and Rovno 4 power units.

Construction of the plants was halted in 1991 under a moratorium introduced by the Verhovna Rada of Ukraine and mainly as a result of Chernobyl accident. In 1995, the government of Ukraine reaffirmed its commitment to resume construction. A Memorandum of Understanding signed between G7 countries, the European Commission and Ukraine stipulates that Ukraine and the G7 countries will work with international financial institutions, EBRD and Euratom, in preparing loan-financed projects based on the least cost principles and complying with Ukrainian energy sector strategy supporting the closure of Chernobyl nuclear power plant.

In 1995, the preparatory phase of the project started when the then Ukrainian ministerial organisation GOSKOMATOM requested assistance from the European Commission to finance - under the TACIS contract-management of the project. The EC subsequently invited Western contractors to bid for the work. A consortium of European power companies, comprising the French utility EDF, the Belgian Company TRACTEBEL and the Finnish engineering company IVO, was eventually selected.

In September 1995, the consortium set up at GOSKOMATOM's offices in Kiev, and became part of a joint integrated team, known as the Project Management Group (PMG), to pilot the project. Made up of Ukrainian and Western experts, the PMG carried out the preparatory work for the project between 1995 and 1998. The expertise of several other parties was also enlisted including:

- representatives authorised by the Nuclear Regulatory Administration of Ukraine
- the staff and expertise of the two NPPs,
- representatives of Technical Safety Organisations led by the Riskaudit organisation
- representatives of the NPP designers: Kiev Energoproject (KIEP), Russian Institues Gidropress, Kurchatov Institute and VNIIAES as well as ENAC which is a consortium of Western nuclear engineering companies.

- Several companies invited by the European Commission to provide specialist support on specific topics included for example:
  - ⇒ STONE & WEBSTER - analysis of the least-cost option
  - ⇒ MOUCHEL -Environmental Impact Assessment
  - ⇒ NNC and other companies - specific audits of the organisations under the EC's contract

In 1997, the Ukraine energy sector was reformed. Ownership of the NPPs was taken over by a new umbrella energy organisation, ENERGOATOM. Under the reorganisation, ENERGOATOM absorbed the corresponding activities of GOSKOMATOM and became the responsible authority for the completion of the NPPs.

International experts have carried out detailed assessments of the current status of the plants, which are 80-85% completed. Based on this work, the proposed project aims to complete and modernise the plants according to all national safety and reliability requirements and international practice.

3. Main design features of VVER-1000 nuclear plants

Unlike Chernobyl, which is of a design unique to the former Soviet Union, K2 and R4 are types of pressurised water reactor (PWR) which are common throughout the world. The first types began operating in the 1950's and since then the design has undergone a process of continuous improvement.

The two power plants are equipped with VVER1000 reactors, which are analogous of western PWRs. Eleven power units with VVER1000 reactors and two units with less powerful VVER 440 reactors are operating in Ukraine.

Series V320, used in the project, was designed at the end of 70's and it is the latest among VVER1000 reactor installations.

The original design of the standard series VVER 1000 type V320 was first installed at Zaporoje unit 1 in 1987. Subsequent units have undergone a process of design upgrades to comply with new regulations as they came into force. In general, there are 27 units in the world operating this standard type of reactor.

Uranium dioxide with low enrichment level of the isotope uranium-235 is used as a fuel for VVER type reactors, fission of which is followed by generation of thermal energy. This heat

is removed by means of light water which flows over the elements within the reactor core. This water serves three purposes:

- it acts as a neutron moderator allowing the fission chain reaction to take place (without water reaction would be impossible)
- it acts as a coolant to remove the heat released by nuclear fission
- it acts as a substance to transfer thermal energy form the core to steam generators.

The primary circuit is leak tight, water within it is kept under pressure to prevent it from boiling. All of these features determine the name of this type of reactor -

water pressurised reactor (VVER, PWR). From the reactor, the water passes to four identical steam generators within which it travels through bundles of tubes immersed in a secondary circuit of water. This water is at a lower pressure so that, as it takes up heat from the ‘primary circuit’ within the tubes, it boils to steam. The primary circuit water is pumped back to the reactor in a ‘closed loop’ to begin its cycle again. The steam produced from the non-radioactive secondary circuit passes to the turbine hall where it drives a turbine coupled to an electricity generator. Having done its work within the turbine the steam passes to a condenser. Within this vessel it is condensed as it flows over cold tubes cooled by water drawn from a cooling tower, river, lake or sea. Condensate is returned to the steam generators via a system of pumps, and pre-heaters to begin the cycle again. The power station therefore, has two ‘closed water cycles’ the primary and secondary circuits, and one open cycle the cooling water used for the condensers. Only the primary circuit, which is restricted to the reactor containment building, contains radioactivity.

The reactor is controlled by raising or lowering neutron-absorbing rods-which if released would drop into the reactor core and halt the nuclear reaction in a few seconds - and by adjusting the concentration of neutron absorbing chemicals in the primary circuit water.

Control systems are designed to automatically control the reactor within specified limits. The instrumentation monitors many parameters and warns operators if any factor is drifting outside operating limits. If no corrective action is taken causing the pre-set limits to be exceeded, the reactor will automatically shut down. Engineered safety features and emergency systems are designed to ensure that, irrespective of the cause, the reactor will always be safely shut down and cooled.

The leak-tight reactor pressure vessel containment with primary coolant system and main auxiliary systems is located inside a containment building designed to withstand increased pressure.

The main features of the units with VVER 1000/V320 reactors are as follows:

- a pressurised reactor vessel containing 74 t of enriched uranium dioxide.
- 4 coolant loops at a temperature of 289°C at core inlet and 320°C at core outlet connected to a pressuriser at 15.7 MPa pressure,
- 4 horizontal steam generators producing saturated steam at 6.4 MPa and 278°C,
- a type K-1000-60/3000 steam turbine rotating at 3000 rpm exhausting to a condenser and driving a 1000 MWe generator at nominal voltage 24 kV,
- nuclear auxiliary systems to maintain the water quality and inventory of the primary coolant circuit in all operating modes and also to provide for lubrication and cooling of components,
- an emergency core cooling system comprising three 100% redundant trains,

- turbine hall auxiliary systems to provide the turbine generator set with lubrication and cooling, and recycle the turbine steam condensed in the condenser,
- system of purification, control and residual release of gaseous releases system

After the development of Khmelnitsky 2 and Rovno 4 design, national safety requirements became more strict and higher quality standards were demanded. After completion the two units will have a safety level similar to that of similarly aged but recently re-licensed, western plants.

4. Location of Rovno and Khmelnitsky NPPs

The sites of Rovno and Khmelnitsky nuclear power plants (NPPs) are located in the north-western corner of Ukraine, bordering Poland and Belarus.

Rovno NPP situated 100 km north of Rovno city, is equipped with 4 VVER units: Units 1 and 2 with a design VVER 440 type V213 and unit 3 with VVER-1000 type V320 have been in operation since 1980, 1981, 1986 respectively. Construction of the 4th unit (R4) based on VVER-1000 design has been halted when it was 80% complete.
Khmelnitsky NPP located 120 km north of Khmelnitsky city, is designed to accommodate 4 VVER-1000 units. Unit 1 has been operating since 1987. Unit 2 (K2) is 80% complete similarly to Rovno unit 4 (R4). The construction of the even less complete units 3 and 4 has been stopped.
Appendix 1 shows the drawings of both plants and units. Appendix 2 briefly describes the layout of buildings and facilities on each.

5. Initial Data Analyses

In determining the scope of the completion and modernisation programme, many issues were addressed such as:

- What is the current plant status and what is the condition and quality of installed plant and equipment?
- What is necessary to complete the plant to original design?
- What steps if any, are necessary to bring the plants up to internationally accepted levels of safety for similarly aged plants and do they comply with Ukrainian norms standards and regulations in nuclear safety?
- How reliable will the plant be?
- Does the design, technical and operational documentation meet internationally accepted levels of safety?
- How reliable are the shutdown systems and engineered safety features.
- Will individual plant items and systems operate reliably even under emergency conditions?
- In the unlikely event of a serious accident will the public and operating staff be protected?

This list is not comprehensive but serves as an example of the issues being addressed.

6. Project Scope

Implementation of the completion project requires the following steps:

- **Preparatory phase** - initial estimation of scope and cost of the works, development of basic modernisation programme
- **Improvement of design documents** - development of full document package for construction, commissioning and operation of the new units
- **Completion** - to finish the units according to the original design,
- Rehabilitation- to replace existing degraded equipment and facilities or repair them to a condition suitable for operation.
- **Modernisation, including Branch and Operational Programmes** - to upgrade the safety, quality of operation and the availability of the units.

6.1 Preparatory Phase

The preparatory phase is already finished. At this phase the Engineering Group was set up which comprised experts from the Kiev Institute Energoproect, Russian designers and Western engineering companies. This consortium was involved in activities relative to the qualitative and quantitative inspections, modernisation measures, scheduling, and cost assessment of the programmes. Design documentation produced for the modernisation programme was independently reviewed by a Western quality assurance consultant, other Western experts and by the Riskaudit-led association of Technical Safety Organisations.

6.2 Completion

The completion programme for Khmelnitsky 2 and Rovno 4 includes the following work:

- **Completion** - to complete the units according to original design
- **Repair and replacement of equipment -** replacement of deteriorated equipment or its repair to the status good for operation
- **Modernisation -** to upgrade the safety, quality of operation and the availability of the units, including measures, foreseen by branch and operation programmes

6.2.1 Construction

Completion according to the original design includes the work required to complete the plants to the original design ready for commissioning. However, accumulated experience from similar units, which have been operating since the early 1980’s, is also taken into account.

The completion programme is developed from an assessment of the unit status from quantitative inspections. This is the process of making an inventory of outstanding equipment required and of civil and erection works still to be carried out.

For this work, the installations were assumed to be in good condition and not to require any interventions. The inspection served as a basis for the cost estimate for completion to the initial design.

The scope of the works necessary for unit completion is detailed in appendix 3. It covers outstanding construction work; completion of plant installation and finishing of partially installed plant; electrical wiring; instrumentation and control equipment; bringing the plant to a high state of cleanliness and, equipment commissioning and functional testing.

6.2.2 Repair and replacement

Although the installed equipment has never been used, there is bound to be a measure of deterioration during the years that the plants have stood idle. Since the suspension of construction activities, some plant items may have deteriorated due to atmospheric conditions, others will have become obsolete and warranties will have expired. Qualitative inspections therefore determined the equipment and civil works needing restoration to a state suitable for commissioning and start-up. On the basis of this work the overall inventory was made based on the representative sample of the equipment.

The overall qualitative inspection programme has been performed by 13 contractors at Rovno and by 15 contractors at Khmelnitsky, respectively. The results from the inspections show that the installations are in a good state of conservation and that the necessary repair and replacement works are limited.

Typical repair and replacement tasks include refurbishing and repainting external surfaces on plant and equipment which may have been subject to climatic conditions, preserving other surfaces, refurbishing or repairing individual plant items and obtaining appropriate manufacturer documentation if it was not delivered at the time the plants were halted. The repair and replacement works are detailed in appendix 3.

6.2.3. Modernisation

The Completion and Rehabilitation programmes therefore, will bring the plant back to its intended condition; but that alone is not enough. The plant must comply with the regulations on nuclear and radiation safety valid in Ukraine and should be similar to that of western NPPs. This aim can be reached by means of modernisation of the units. Modernisation means improvement of separate elements in order to upgrade their safety and reliability:

The complete programme of modernisation measures therefore, brings together several separate projects. These are:

- **The ‘Modernisation Programme**
- **The Branch Programme**
- **The two Operational Programmes**
- Other programmes developed to a plant specific basis, such as the waste processing at Rovno and Khmelnitsky NPPs; the installation of a full scope simulator at Khmelnitsky NPP; Improvements to the layout of a switchyard at Rovno NPP.

Branch and operation programmes included in the complex are beyond the frames of the project and are now being implemented under ENERGOATOM management, which is, being an operation organisation, responsible for its development and implementation.

The ‘modernisation programme’ was developed on behalf of ENERGOATOM by an international consortium of specialists, led by KIEP, which designed the units. The Consortium includes the Russian institutes and an association of Western nuclear engineering companies. Work under this modernisation programme was carried out between June 1994 and November 1996. IAEA experts performed reviews of the modernisation programs of Rovno unit 4 and Khmelnitsky unit 2 in October 1995 and June 1996 respectively. In November 1996, the programme received approval from the NPPs, the Nuclear Regulatory Authority of Ukraine and was also independently assessed by Riskaudit, acting on behalf of the International Financial Institutions (IFIs). Riskaudit’s report on the project’s safety is also one of the documents issued for public consultation.

The whole set of measures included in the modernisation programme, and the branch and operational programmes contains 173 items. The part to be funded by the International Financial Institutions concerns the 148 measures of KIEP’s and the designers’ modernisation programme, 144 of which are common to both NPPs, two items are specific to Rovno NPP and the other two are specific to Khmelnitsky NPP. The branch and operational programmes will be funded by their responsible entity.

The modernisation programme’s safety objectives include several general provisions and specific issues designed to:

- eliminate deviations from the current national safety norms because the original design was developed before these norms were in force and take into account the IAEA’s recommendations,
- improve reliability of safety related equipment by upgrading design quality, manufacture and installation,
- improve operation quality.

The modernisation programme’s goal is to bring the safety level of Rovno unit 4 and Khmelnitsky unit 2 up to the safety level complying with internationally acknowledged and adopted standards. In practice, the project would allow the safety of the plant to be comparable to that achieved in Western countries at similarly aged NPPs which were recently re-approved by national safety authorities.

6.3 Licensing

The licensing steps for construction, commissioning and operation in accordance with Ukrainian legislation, are prerequisites for commercial operation of the units.

All companies and organisations involved in construction, commissioning and operation have to receive a licence from the Ukrainian Nuclear Regulatory Authority (UNRA) in accordance with the Nuclear Outline Law in Ukraine (Feb. 95).

Equipment must be qualified and certified for procurement in accordance with national regulations.

6.4 Commissioning

Commissioning preparatory phase starts after successful completion of all individual tests of elements and subsystems. According to this project results of the studies made before construction was stopped should be confirmed by correspondent operation tests.

As for the newly constructed buildings and elements their testing will be made after final equipment adjustment according to the instrumentation.

The commissioning tests correspond to the stages as described in the normative Russian document TT86 (technical requirements on preparedness of systems and equipment).

7 Project organisation

The purpose of the project organisation retained is to guarantee that the project is implemented within the quality requirements, the planned cost and schedule. The project organisation scheme is presented in appendix 4 to this presentation. It comprises four entities:

- ENERGOATOM and its Project Management Team (PMT). The PMT is responsible for conducting all project activities.
  The PMT, which is an integrated team consisting of ENERGOATOM specialists and Western experts will be structured on two levels :
  - The central office in Kiev responsible for overall project monitoring and co-ordination,
  - The site offices responsible for managing all site activities until the units are handed over to commercial operation and transferred to NPP operator.
- A General Designer, which will be in charge of providing all necessary design, documents for the implementation of the completion, repair and replacement, and modernisation programmes.
- A General Contractor, whose scope of activities includes full responsibility for procurement, civil and erection work and tests. The

General Contractor is provided with the current documentation of the relevant installations. These installations are handed over by the Owner of the plants. The General Contractor also provides works and services in order to manage and perform the activities relative to his scope of work. Once these activities are completed, the installations are handed over by the General Contractor to the Owner of the plants.

- A Fuel Supplier (FS) who will provide the first fuel load to both units
- The International Financial Institutions which are in charge of financing the project of the NPPs' owner ENERGOATOM by loans,
- The NRA which is a National (State) Regulatory Authority in nuclear and radiation safety and is authorised to review applicants In the case of positive results of review it can grant licences for performing activity in the sphere of nuclear energy utilisation. The applicant, who is responsible for obtaining the licence, may not carry out work without it,

8 Project schedule

The lead-time between the effective availability of the funds and commissioning of the units is 36 months for both units. This lead-time covers the completion, the repair and replacement, and the safety upgrading as defined in the modernisation programme to be implemented before commissioning.

9 Project cost estimate

The overall project cost including physical and price contingencies is estimated at US$ 1250 million.

This estimation includes the costs of:

- The completion programme
- The repair and replacement programme
- The modernisation programme before and after commissioning
- The first fuel load
- The tests and commissioning
- The engineering activities
- The project management
- The licensing and certification
- Miscellaneous costs like customs, insurance, financial engineer for the banks.

10. Public participation

Even before the project starts all NGOs and individuals can express their opinions on the project and its impact on the population and environment, during the public consultation procedure.

11. Conclusions

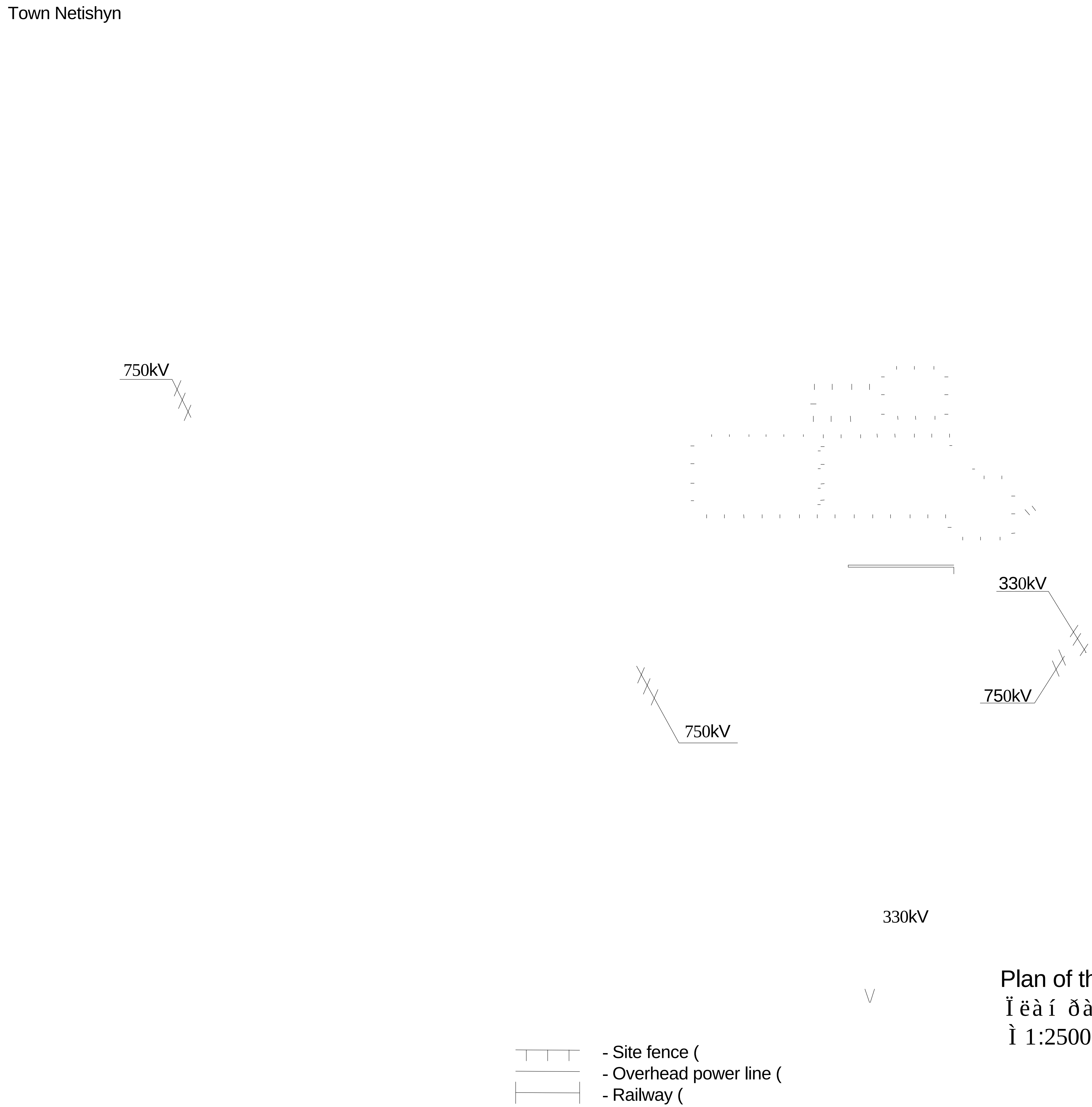
The successful completion of the project would result in the availability to Ukraine of nuclear power plants which would be economically viable and which would achieve a level of safety comparable with Western plants of the same age and comply with all national requirements, norms and rules.

APPENDIX 1

KHMELNITSKY and ROVNO NPPs
SITE DRAWINGS

Khmelnitsky NPP Site map

Rovno NPP Site map



KHMELNITSKY NPP

Plan of the arrangement of NPP objects
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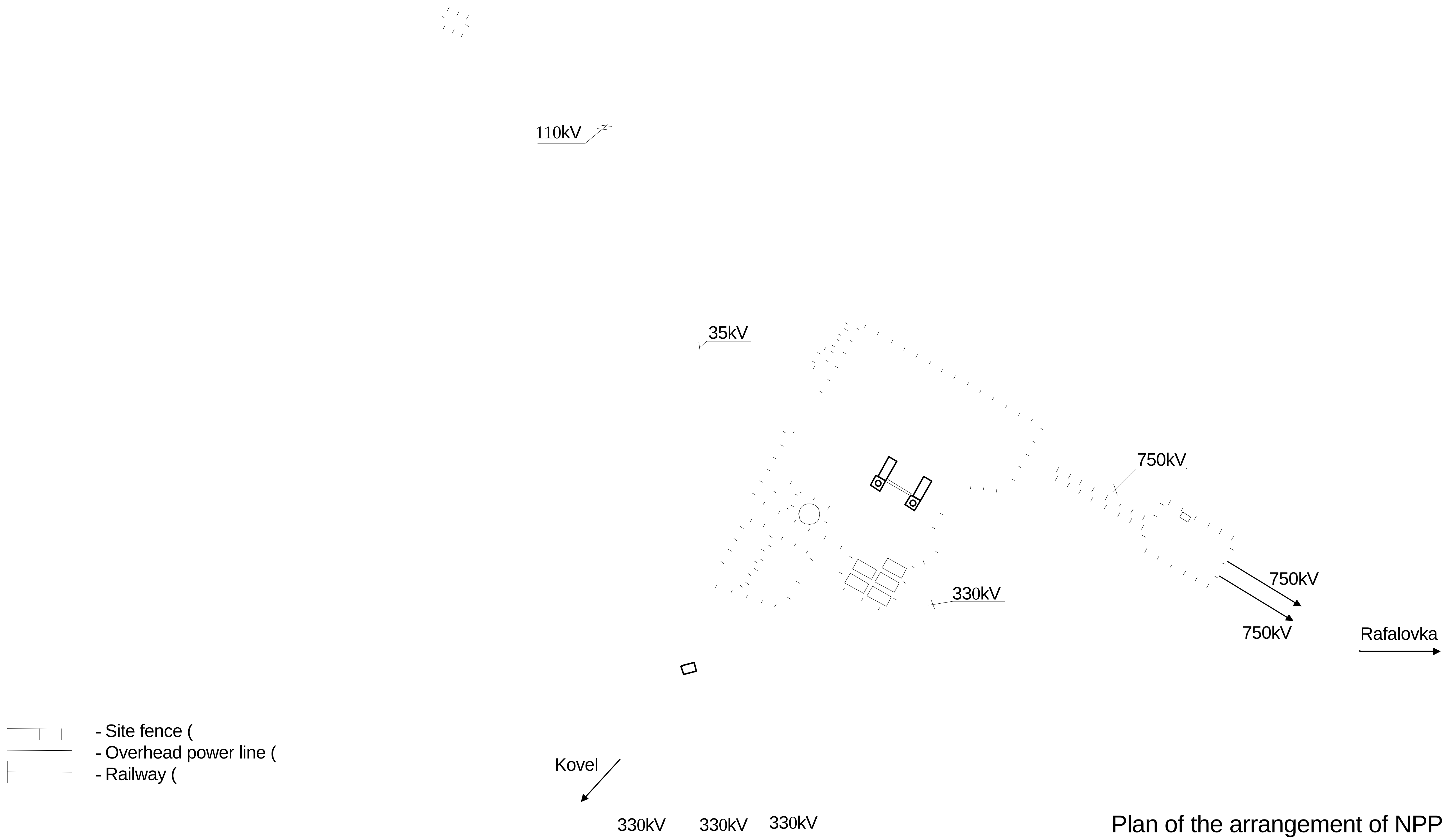

Plan of the arrangement of NPP objects

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APPENDIX 2

KHMELNITSKY and ROVNO NPPs
LAY OUT OF BUILDINGS AND FACILITIES

Khmelnitsky NPP Plant map

Rovno NPP Plant map

22. Unit pumphouse.
23. Combined auxiliary building.

24. Special building.
25. Administrative building.
26. Start up-boiler.
27. Fuel-Lubricant material facilities.

28. Waste treatment and storage building.
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29. Spent fuel repository /FSR/.
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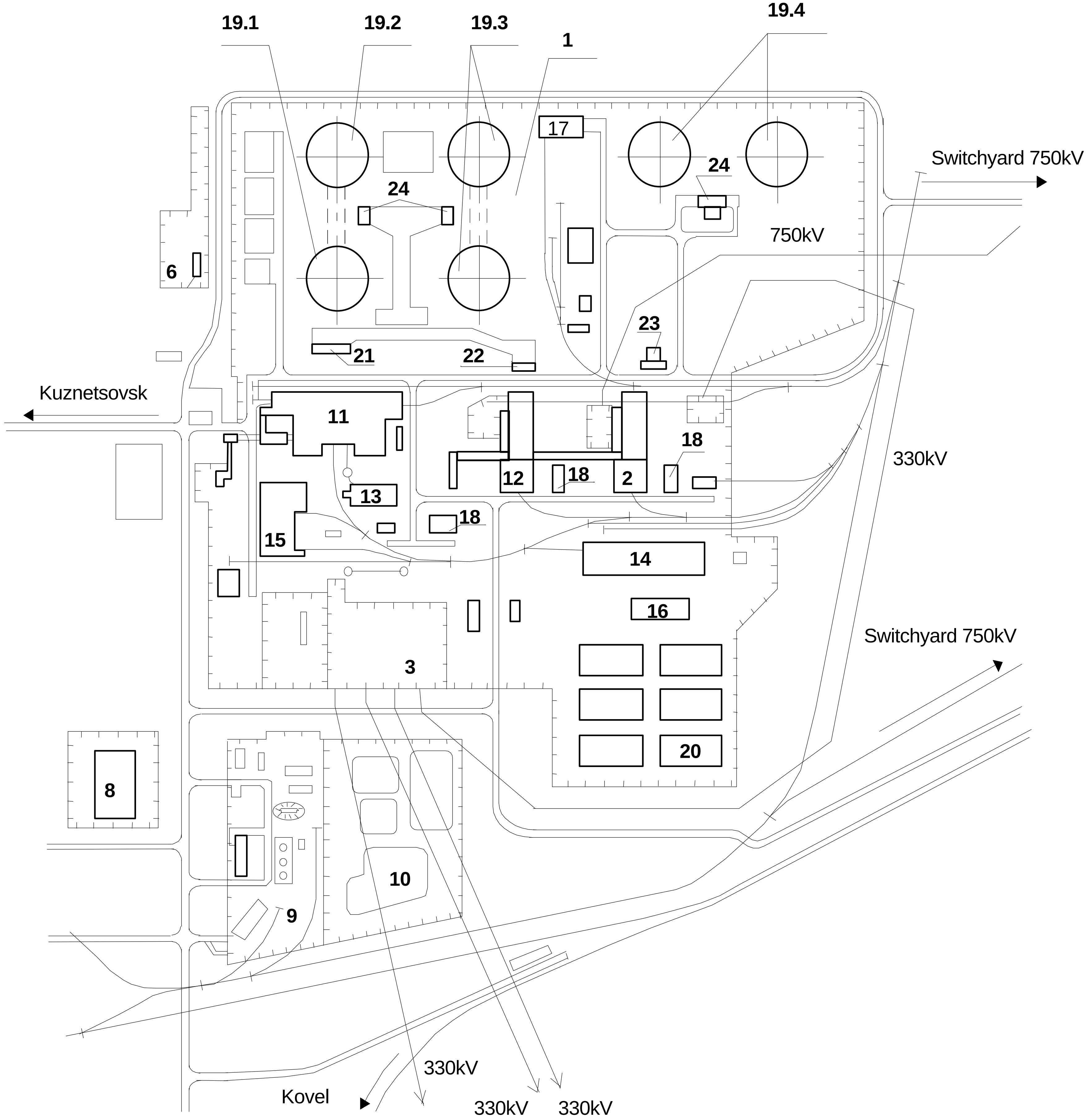
- Site fence (
- Overhead power line (
- Railway (



24. Cooling tower pump stations (

- Site fence (
- Overhead power line (
- Railway (

ROVNO NPP

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Buildings and constructions legend

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APPENDIX 3

KHMELNITSKY and ROVNO NPPs
COMPLETION, REHABILITATION AND MODERNISATION PROGRAMMES

TABLE 1[1]: Completion to the original design

Construction and buildings Complete civil works, surface protection, finishing and roofing,
Mechanical equipment Lay out equipment liaisons, pipes and valves, thermal insulation, align machines.
Electrical equipment Lay out electrical wiring, cables and connections
I&C Install, calibrate and tune instrumentation
Pre-commissioning • Perform nuclear cleanliness, equipment tests and pre-service inspection before commissioning, **Commissioning**Perform tests : • plant overall tests • fuel loading • physical tests • on load tests

[1] The tables are not comprehensive but are included to give an overview of the type of work being carried out.

TABLE 2: Repair and replacement program

Construction and buildings

- Repair and preserve containment pre-stressing cables, their protective caps and cover joints
- Finish containment liner painting
- Control containment hatches tightness,
- Complete metalwork painting in reactor building and in turbine hall
- Repair spalled concrete structures
- Replace epoxy paint on floors in reactor building auxiliary rooms

Mechanical equipment

- Paint external surfaces,
- Repair valve manual actuation, gate tightening surfaces, paint external surfaces on pipes,
- Repair metal burn-through, ribs, dents, scratches, metal drops, nicks and cracks on mechanical equipment,
- Realign turbine shaft,
- Paint the internal surface of condenser vacuum system ejector housing ; of valves body, bonnet ; bearings and stems
- Adjust pump electrical motors external fittings and bearings,
- Preserve electric motors in grease - Replace anti-reverse, impeller fixture, rubber seals of primary pumps,
- Repair surface metal defects of steam generator, pressuriser basis metal, ECCS tanks and parts of main circulation pipeline, repair flange threaded jack of reactor vessel, manometer connecting pipe to blow-down separator, repair dent in upper unit cover,
- Replace rubber seal, stop washers and splints in diesel generators, seals and working liquid of snubbers, connecting pieces, coupling nuts and rubber seal of pumps, disc sealing surface of fast acting valves

Instrumentation & Control and electrical equipment

- Provide manufacturers documentation for main power circuit and outdoor switchyard-750 kV
- Repair parts of main power circuit and outdoor switchyard-750 kV,
- Replace deficient parts of I&C, electrical systems, electric cables, sensors, regulation units, power supply units
- Replace deficient parts of the fuel-loading machine.

TABLE 3: Modernisation program

Overview of Safety significant measures to be implemented before commercial operation	
1.	**Reactor core**
2.	Improve reactivity control: • Replace neutron flux control system with modern instrumentation to improve reactivity control at all levels of power, • New fuel loading strategy to optimise use of fuel and reduce the neutron fluence on the Reactor pressure vessel.
3.	Prevent excessive drop time of control rods : • Measures to limit fuel bending, • Introduce heavy weight control rods, • Replacement of control rod drive mechanisms,
4.	**Major unit components**
5.	Mitigate risk of reactor vessel embrittlement : • Heating tanks of emergency injection systems up to 20° C, • Heating emergency injection accumulators up to 55° C, • Improve the reactor vessel neutron flux monitoring to enable its irradiation to be more effectively controlled. • Relocate vessel metal specimens and modify the correspondent vessel surveillance program.
6.	Prevent rupture of main feedwater and steam water lines : • Lay out fixed rigid support of steam and feedwater pipelines at 28.8m level, • Analyse rupture mechanisms of steam and feedwater pipelines at 28.8m level.
7.	Reinforce strength of components : • Recalculate strength of pipes significant to safety and modify their supports if necessary, • Perform strength calculation of the reactor vessel head.
8.	Prevent spillage of radioactive water outside the reactor containment : • Develop procedures to control leakage from primary to secondary circuit in the steam generators, • Implement a detection system for primary circuit leakage , • Ensure tightness by periodical in service inspection of Emergency Core Cooling System suction lines at the bottom of the sumps, • Prevent radioactive release through Main Coolant Pump heat exchangers.
9.	Implement diagnostic systems for inspection of the reactor components : • Determination of residual lifetime of main primary circuit and turbine components. In-service inspection of Reactor Pressure Vessel by TV or ultrasound • Primary circuit coolant leakage diagnosis • in-core noise diagnosis system
10.	Improve preventive maintenance and in service inspection : • Implement an automatic control system of the secondary circuit chemistry to mitigate corrosion in the steam water circuit • Replace steam generator blowdown system to limit corrosion in the steam generators • Implement an annealing machine for conditioning vessel main joint gasket before

Overview of Safety significant measures to be implemented before commercial operation	
	laying out
11.	Improve safety of the units : • Replace safety valves on the low pressure injection lines used for residual heat removal at shutdown and implement procedures to prevent over-pressure at cold shutdown • Replace steam generator safety valves. • Qualify pressuriser safety valves to implement Feed and Bleed procedures • Prevent insulation material from clogging the sumps in case of Loss Of Coolant Agent by replacing the insulation material by a metallic type • Install a hydrogen removal device from primary circuit during cool-down and cold Shutdown • Replace air-conditioners in the reactor building. • Install a position indicator on the pressuriser safety valves
12.	Improve main cooling pump seals : • Upgrade thermal barriers to improve operational reliability and safety of main cooling pumps • Modify auxiliary water make up circuit to increase the time of interruption of make up water to the main cooling pump seals without damages
13.	**Electrical supply components**
14.	Install an additional diesel generator set
15.	Improve power supplies reliability : • Replace inverters of the emergency power supply • Increase battery discharge time • Analyse additional sources of power for safety systems • Improve emergency Diesel Generator reliability • Replace electrical and fire protection devices of the switchboards • Replace High voltage transformers bushings 750kV • Analysis of external power grid • Replace deficient electrical wiring • Implement a multiple channel system recording voltage perturbation in the generator
16.	**I&C components**
17.	Improve I&C efficiency : • Reinforce immunity of I&C components against Electromagnetic Interference of the plant instrumentation and control • Segregate the impulse lines of the three primary pressure sensors against common mode failure. • Detect the presence of a gas-steam volume inside the reactor vessel after an accident • Improve the steam generator water level control
18.	Replace boron-meters by up to date Boron 10 concentration measuring devices.
19.	**Concrete containment**
20.	Control the state of the pre-stressed concrete containment and civil structures

Overview of Safety significant measures to be implemented before commercial operation	
	• implement a diagnostic system of forces in pre-stressing cables • Implement diagnostic systems for containment state assessment
21.	Implement equipment for control of containment vacuum test
22.	**Hazards affecting unit integrity**
23.	Assess risk of internal flooding in Reactor compartment and Machine hall
24.	Protect the unit against fire hazard : • Perform systematic fire hazard analysis to improve fire protection if necessary. • Protect the cable bundles with fire resistant coating • Perform an analysis of the possibility of ensuring reactor shutdown in case of fire in cable compartment under Main Control Room and Emergency Control Room and 6 kV switchboards, • Implement a fire extinguishing system with backed up power supply for water distribution • Replace fire resistant doors • Install fire protection valves in air conduits • Improve fire retardant coating on turbine hall roof • Install gas fire fighting in electronic equipment compartments
25.	Analyse hazards external to the units : • Analyse aircraft crash on reactor building • Analyse risk of air borne toxic gases external to the plant on personnel in Main Control Room and Emergency Control Room • Analyse risk of shock wave loads on reactor building in case of explosion external to the plant
26.	**Accident analysis**
27.	Perform analysis of design basis accidents : • Prepare a list of Design Basis Accidents • Carry out the analysis of the design basis accidents not taken into consideration in the former safety analysis report • Carry out the analysis of design basis accidents using modern codes
28.	**Operational safety**
29.	Develop a General Quality Assurance programs for the NPPs based on IAEA recommendations and ISO 9001
30.	Set up Operational procedures : • Improve operating procedures for safety related reactor systems • Improve technical instructions of reactor equipment and systems in normal operation • accidental procedures • List nuclear hazardous works in a regulatory document
31.	**Radiation protection and personnel protection**
32.	Enhance the function of the existing radiation protection
33.	Implementation of a computerised access management system

Safety significant measures to be completed after entering commercial operation	
1.	**Reactor core**
2.	Improve power control of the core : • Introduce a more effective core control strategy to mitigate Xenon oscillations and control power distribution • Optimise accurate engineering margin factors to improve power control Introduce new control rods with burnable absorber • Load new fuel containing Uranium and Gadolinium
3.	Improve diagnostics on fuel : • Implement a device inside the refuelling machine mast to detect fuel rod deficiency, • Determine the correlation between damaged fuel and activity of reference isotopes in primary coolant.
4.	Develop equipment for completing fuel loading procedures in case of loss of power
5.	Enlarge storage capacity of fuel to provide space for fuel charge unloaded in an emergency
6.	Implement equipment to transport the spent control rod clusters from the reactor and for their repository at the NPP site
7.	**Main unit components**
8.	Develop equipment qualification
9.	Prevent risk of reactor vessel embrittlement • Develop a system for monitoring neutron flux on the reactor vessel to determine remaining vessel life time
10.	Prevent risk of multiple rupture of primary high energy pipelines • Implement systems by using « leak before break » concept to detect signs of small leakage indicating imminence of pipeline large break
11.	Increase the means of steam generator make up water.
12.	Implement diagnostic systems : • to detect vibrations in components, • to determine criterion for preventive plugging of SG-tube, • to detect the defects in main coolant pump GCN-195M.
13.	Implement on automatic control system of primary coolant chemistry in normal operation
14.	Reinforce strength of components : • Perform strength calculation of the air duct weld of reactor top head • Strength analysis of make up nozzle thermal shield
15.	Install displacement indicators for piping
16.	Optimise maintenance of pressuriser safety valves
17.	Improve the efficiency of pumps : • Upgrade anti-reverse device of main coolant pumps GCN-195M • Procedure for defects in body components of main coolant pumps GCN-195M • Implement a temperature monitoring system for main coolant pump motor • Introduce an oil lubricated thrust bearing and a sleeve coupling for high head auxiliary injection pump CN-150-110 • Upgrade impeller and sleeve coupling for emergency cooling pump CNR-800-230

Safety significant measures to be completed after entering commercial operation	
	• Introduce an oil lubricated thrust bearing and coupling for spray pump CNCA-700-140
18.	Improve the efficiency of valves : • Upgrade sealing assemblies of fast cut off valves on the steam lines and their maintenance and repair • Upgrade maintenance and repair of fast cut off valves on main steam lines • Replace steam generator feedwater control valves.
19.	**Electrical supply components**
20.	Improve electrical component reliability : • Replace 6 kV switches • Assess residual lifetime of cables and replace them • Install additional battery backed up emergency lighting fixtures
21.	Implement diagnostic systems on windings of : • turbine generator stator • 6 kV motor stator
22.	**I&C components**
23.	Modernise I&C parts : • Replace monitoring device on generator process parameters • Replace in core instrumentation and control, computer and software • Replace turbine control system • Replace power unit display and control computer Titan 2 (mainly before implemented)
24.	Implement a Technical Support Centre for assisting operators in emergency situations.
25.	Implementation television cameras for closed premises
26.	Implement a data storage device monitoring process parameters in case of emergency situation
27.	Introduce diagnostic systems for improving maintenance : • computerised network for diagnosis • vibration diagnosis system in rotating machines (K2 will be before commissioning) loose parts diagnosis system in primary circuit • noise diagnosis system for Steam Generator headers • monitoring of functional parameters :reactivity balance, control rod sticking, number of fuel cycles , heating-cooldown rate, load escalating and dropping rate • back pressure valve diagnosis system • air operated valves diagnosis system
28.	**Concrete containment of the reactor**
29.	Determine the state of the concrete containment : • Analysis of tightness of concrete containment especially at penetrations in order to ensure isolation of reactor in case of emergency • Analysis of state of the pre-stressing cables and fittings, and pre-stressed structures of the concrete containment
30.	**Hazards affecting unit integrity**

Safety significant measures to be completed after entering commercial operation	
31.	Implement equipment to reduce risks : • Physically protect shut-off valves with barriers against internal missiles • Replace combustible petroleum oil by non flammable agent in main coolant pump lubrication system of the • Implement automatic Hydrogen dumping device from generator housing to protect generator against hydrogen explosion • Implement smoke prevention system in rooms and corridors of the reactor building
32.	Install a seismic monitoring and recording device
33.	Analyse air conditions inside safety system rooms with cold weather external to the plant
34.	**Accident analysis**
35.	Perform beyond design basis accident calculations : • List beyond the design basis accidents to be analysed • Perform analysis of hydrogen accumulation inside the reactor plant, •
36.	Carry out level 1 and 2 probabilistic safety analysis.
37.	**Operational safety**
38.	Improve maintenance and in-service inspection : • Improve verification and testing procedure of safety-related reactor systems • Improve maintenance and repair procedures for reactor equipment • Develop a computerised recording of events on NPP equipment.
39.	Develop accidental procedures
40.	Elaborate regulations for metal surveillance of equipment and pipelines
41.	**Radiation protection**
42.	Replace the radiation monitoring system inside the unit

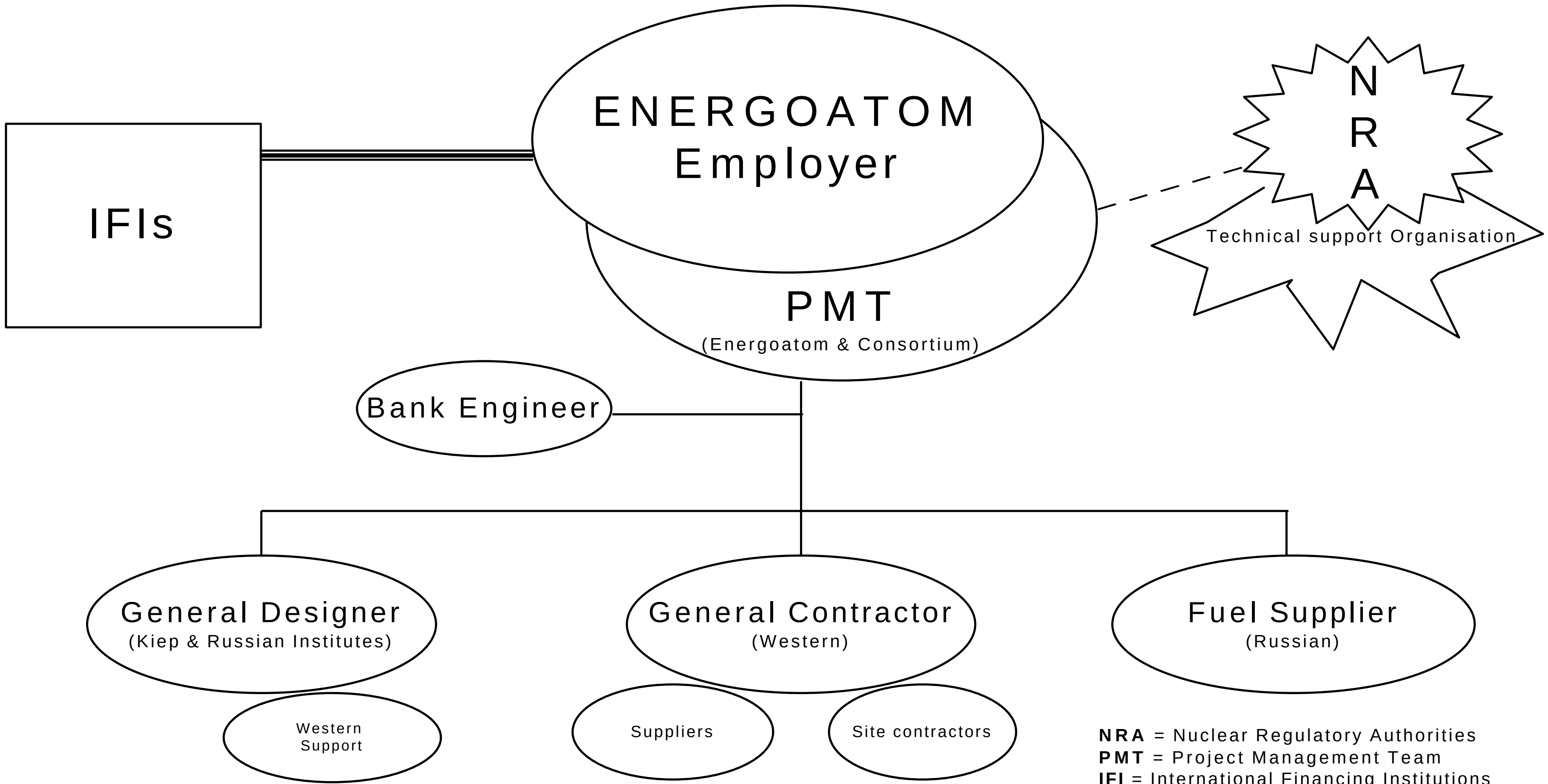
Modernisation measures improving availability and operation to be implemented before commercial operation	
1.	**Reactor core**
2.	Implement devices for sub-criticality control of reactor core at shutdown
3.	**Main unit components**
4.	Install sealed valves 1600 nominal diameter for isolation of ventilation system of reactor compartment
5.	**Electrical supply components**
6.	Exchange sealed cable penetrations
7.	**I&C components**
8.	Redesign cable racks of temperature monitoring measurement system in the core
9.	**Concrete containment**
10.	Calculate containment reliability using modern codes
11.	**Radiation protection**
12.	Implement an automatic radiation monitoring system around the site

Modernisation measures improving availability and operation, to be completed after commercial operation	
1.	**Main unit components**
2.	Implement an appliance to tighten the bolts of main coolant pump main seal
3.	Implement a mock up for quality control of O-rings of main coolant pump seals
4.	Hydraulic adjustment procedure for main coolant pump GCN-195M
5.	Suppress leakage isolation devices in impulse lines of the Steam Generators water level measurement
6.	Replace pump seals, fasteners and pump shaft of feedwater pump PTA 3750-75
7.	Upgrade pump body, sealing and coupling sleeves of booster pump PTA 3800-20
8.	Improve turbine drain lines : • Suppress useless pipe bends in turbine drain lines • Replace sections of drain lines with potential intensive erosion by stainless steel pipes
9.	Replace valves gland package
10.	**I&C components**
11.	Replace obsolete I&C instrumentation of the plant by modern devices
12.	Develop a generalised safety parameter display system
13.	**Concrete containment**
14.	Calculate containment reliability using modern codes
15.	**Hazards affecting unit integrity**
16.	Install hydrogen detection and ignition devices inside the concrete containment
17.	**Operational safety**
18.	Develop maintenance and repair procedures : • Maintenance and repair procedures for main feedwater pump PTA 3750-75 • Maintenance and repair procedures for booster pump PTA 3800-20 • Maintenance and repair procedures for valves gland package

APPENDIX 4

COMPLETION OF KHMELNITSKY UNIT 2 AND ROVNO UNIT 4
PROJECT ORGANIZATION SCHEME

PROJECT ORGANIZATION



Contractual management
Loan agreement
Regulatory Authorities

NRA = Nuclear Regulatory Authorities
PMT = Project Management Team
IFI = International Financing Institutions
Consortium = EDF-Tractebel-IVO