

NEK

Nuklearna elektrarna Krško  
Vrbina 12  
8270 Krško



## TECHNICAL SPECIFICATION

# Refurbishment of Emergency DG Unit Electrical Generator

KRŠKO NUCLEAR POWER PLANT

SP – E5031

Revision 0

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## SAFETY RELATED

Prepared by:

Rajko Petan

Date:

22 / 8 / 2025

Reviewed by:

Klemen Grozina

Date:

26 / 08 / 2025

QA Reviewer:

Roman Semenič

Date:

22 / 8 / 2025

ESD Superintendent:

Peter Jan

Date:

26 / 08 / 2025

ESD Director:

Božidar Krajnc

Date:

27 / 8 / 2025

# TABLE OF CONTENTS

| Section     | Title Description                                     | Page      |
|-------------|---|-----------|
| <b>1.0</b>  | <b>PURPOSE and SCOPE</b>                              | <b>1</b>  |
| 1.1         | <i>Purpose</i>  | 1         |
| 1.2         | <i>General Notes and Requirements</i>                 | 1         |
| 1.3         | <i>Scope of Work</i>                                  | 1         |
| <b>2.0</b>  | <b>DEFINITIONS AND ABBREVIATIONS</b>                  | <b>2</b>  |
| 2.1         | <i>Definitions</i>                                    | 2         |
| 2.2         | <i>Abbreviations</i>                                  | 3         |
| <b>3.0</b>  | <b>CODES, STANDARDS &amp; REGULATORY REQUIREMENTS</b> | <b>3</b>  |
| 3.1         | <i>Applicable Codes, Standards, and Regulations</i>   | 3         |
| <b>4.0</b>  | <b>SUPPLEMENTAL DATA</b>                              | <b>4</b>  |
| <b>5.0</b>  | <b>DOCUMENT SUBMITTAL</b>                             | <b>5</b>  |
| <b>6.0</b>  | <b>DESIGN REQUIREMENTS AND DESIGN INPUTS</b>          | <b>5</b>  |
| 6.1         | <i>The original equipment description</i>             | 5         |
| 6.2         | <i>General requirements</i>                           | 5         |
| 6.3         | <i>Detailed Design Requirements</i>                   | 6         |
| 6.4         | <i>Seismic requirements</i>                           | 7         |
| <b>7.0</b>  | <b>PERFORMANCE REQUIREMENTS</b>                       | <b>10</b> |
| 7.1         | <i>Performance Guarantee</i>                          | 10        |
| 7.2         | <i>Standby and Operating Conditions</i>               | 10        |
| 7.3         | <i>Ratings</i>  | 10        |
| 7.4         | <i>Loading</i>  | 11        |
| 7.5         | <i>Running</i>  | 11        |
| 7.6         | <i>Vibration</i>                                      | 11        |
| <b>8.0</b>  | <b>MATERIAL REQUIREMENTS</b>                          | <b>11</b> |
| <b>9.0</b>  | <b>FABRICATION AND ASSEMBLY</b>                       | <b>12</b> |
| 9.1         | <i>Brazing</i>  | 12        |
| 9.2         | <i>Machining</i>                                      | 12        |
| 9.3         | <i>Standard products</i>                              | 12        |
| 9.4         | <i>Bolts, Studs, Nuts</i>                             | 12        |
| <b>10.0</b> | <b>INSPECTION AND TESTS</b>                           | <b>12</b> |
| 10.1        | <i>General Requirements</i>                           | 12        |
| 10.2        | <i>Acceptance Criteria</i>                            | 13        |

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|      |   |    |
|------|---|----|
| 10.3 | <i>Factory Acceptance Testing (FAT)</i>                                     | 14 |
| 11.0 | <b>ITEM QUALIFICATION</b>   | 15 |
| 12.0 | <b>CLEANLINESS</b>  | 15 |
| 13.0 | <b>CORROSION PROTECTION / COATING</b>                                       | 15 |
| 14.0 | <b>MARKING AND IDENTIFICATION</b>   | 15 |
| 15.0 | <b>PACKAGING, HANDLING AND STORAGE</b>                                      | 15 |
| 16.0 | <b>NONCONFORMING PARTS, COMPONENTS, OR MATERIALS</b>                        | 16 |
| 17.0 | <b>RECORDS</b>  | 16 |
| 17.1 | <i>Record system</i>  | 16 |
| 17.2 | <i>Fabrication, manufacturing, testing, assembling, and quality records</i> | 17 |
| 18.0 | <b>OTHER REQUIREMENTS</b>   | 17 |
| 19.0 | <b>RIGHT OF ACCESS</b>  | 17 |
| 20.0 | <b>QA PROGRAM REQUIREMENTS</b>  | 17 |
| 20.1 | <i>General</i>  | 17 |
| 20.2 | <i>Project Quality Plan (PQP)</i>   | 18 |
| 20.3 | <i>Certificate of Conformance</i>   | 18 |
| 20.4 | <i>Handover Protocol</i>  | 18 |
| 21.0 | <b>SPECIAL HANDLING</b>   | 19 |
| 22.0 | <b>SHELF LIFE</b>   | 19 |
| 23.0 | <b>10CFR21 REPORTING</b>  | 19 |
| 24.0 | <b>DOCUMENTATION REQUIREMENTS</b>   | 19 |
| 24.1 | <i>Documentation required with the proposal</i>                             | 19 |
| 24.2 | <i>Documentation requested after signing the contract</i>                   | 19 |
| 24.3 | <i>Final documentation package</i>  | 20 |
| 25.0 | <b>NEK PROPRIETY DATA</b>   | 20 |
| 26.0 | <b>NON-CONFORMANCE REPORTS</b>  | 20 |
| 27.0 | <b>REPAIR RECORDS</b>   | 21 |
| 28.0 | <b>SOURCE INSPECTION / SURVEILLANCE NOTIFICATION</b>                        | 21 |
| 29.0 | <b>SHIPPING REQUIREMENTS</b>  | 21 |
| 30.0 | <b>DELIVERY SCHEDULE</b>  | 21 |
| 31.0 | <b>WITNESS AND HOLD POINTS</b>  | 22 |
| 32.0 | <b>CONTRACTOR TECHNICAL MANUAL AND REGISTERED UPDATES</b>                   | 22 |

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|             |                    |           |
|-------------|--------------------|-----------|
| <b>33.0</b> | <b>TRAINING</b>    | <b>22</b> |
| <b>34.0</b> | <b>ATTACHMENTS</b> | <b>22</b> |

## 1.0 PURPOSE and SCOPE

### 1.1 Purpose

Krško Nuclear Power Plant (NEK) has two identical Emergency Diesel Generator (EDG) units, where a diesel engine tandem is used to drive a common generator as a single unit.

They are used as emergency standby power sources in case of a station electrical blackout to keep the plant in a safe shutdown condition; therefore, they are classified as "Nuclear Safety Related" equipment. They were commissioned as part of the original plant equipment in the late 1970s per PO 13KRA-168JC.

The original equipment OEM was Portec Inc, Electro-Products Div., Cleveland, OH. It was manufactured under the Sales Order 17605921/922.

Due to aging, NEK decided to replace the Generators of both EDG units to ensure the maximum reliability of the emergency standby power source.

One of the original generators will be completely refurbished upon being taken out of service and will be maintained on-site as a spare unit.

This Specification sets forth the requirements for the refurbishment, (re)qualification, and delivery of one (1) electrical Generator for plant EDG units.

The Specification shall be used in conjunction with all other documents included in the Purchase Order. Any discrepancies between this Specification and the supplementary Purchase Order documentation shall be identified and resolved before the Contractor undertakes any further actions related to the matter.

### 1.2 General Notes and Requirements

The Contractor shall assign a dedicated Project Manager to manage the project together with the NEK counterpart efficiently.

The Design Review and Approval meeting shall be held prior to the commencement of manufacturing, allowing NEK to resolve all outstanding issues, clarify any design ambiguities, and provide final concurrence on the proposed design. The Contractor shall organize the meeting at either their facilities or those of the manufacturer.

### 1.3 Scope of Work

#### 1.3.1 Refurbishment

The Contractor shall completely refurbish, test, and requalify as necessary one (1) Nuclear Safety Related, 3-phase Generator with a continuous rating of 4900 kVA at 0.8 power factor is required. The rated voltage and frequency of Generator shall be 6300 volts at 50 Hz, with a resistance grounded neutral.

The refurbishment shall include complete disassembly of the Generator, stator rewinding, rotor pole rewinding, bearing and associated insulation replacement, slip ring insulation replacement, painting as necessary, reassembly, and factory testing.

All disassembled components and parts shall be thoroughly inspected and tested as necessary. A separate NCR shall be issued for each part or component found unsuitable for further use or determined to require repair (see also 16.0).

The Contractor shall prepare the Initial Inspection & Test Report, including all NCRs issued, for NEK review and approval prior to continuation of refurbishment activities. Any work conducted without NEK's consent shall be deemed solely at the Contractor's risk.

The refurbished Generator shall retain its full compatibility with the existing equipment, configuration, and design bases, as well as its capability to perform the required safety function under the specified environmental and seismic conditions, including elevated

temperatures, humidity, and mechanical loads associated with normal operation, anticipated operational occurrences, and postulated accident conditions.

The Generator shall be completely assembled in the factory and thoroughly tested in accordance with the applicable standards listed in 3.0.

The Contractor is fully responsible for maintaining the original design, sizing, materials selection, procurement, manufacturing, performance, quality assurance, qualification, testing, documentation, packing, and shipment.

#### 1.3.2 Safety and environmental qualification

The Contractor shall (re)qualification refurbished Generator as needed for use in Safety related application as EDG. The safety (re)classification shall be conducted following the codes, standards, and procedures as indicated in section 3.0. If needed, the seismic (re)qualifications shall be performed according to Attachment 11. In such case, the seismic qualification report must be provided.

All required design data, certificates of compliance, material traceability records, inspection and test plans, qualification reports, and manufacturing records shall be submitted as part of the final documentation package.

#### 1.3.3 Environmental qualification shall be demonstrated per IEEE 323 (ref. [18]) and IEEE 344 (ref. [20]), as needed. The Contractor shall provide complete documentation demonstrating the qualification status, including test reports or validated analysis, to confirm that equipment's capabilities under the required service conditions have been preserved.

#### 1.3.4 Transportation

The Contractor shall be responsible for all packing and shipments from NEK site and back, including loading and unloading.

#### 1.3.5 Documentation & QRP

The Contractor shall submit an updated Instruction Book (see 32.0), if necessary including a long term storage instructions (see 15.0), complete documentation package, as specified further in section 24.0, and any other document related to the project requested in this Specification.

## 2.0 DEFINITIONS AND ABBREVIATIONS

### 2.1 Definitions

#### **Contractor –**

a contracted supplier of refurbished Generator.

#### **Generator –**

a complete and assembled refurbished electrical generator with both couplings installed, but without the exciter, and grounding resistor, which are considered separate items in this specification.

#### **Specification –**

Technical specification SP-E5031 (this document) with all attachments.

## 2.2 Abbreviations

|       |  |
|-------|--|
| CoC   | Certificate of Conformance                             |
| CT    | Current Transformer                                    |
| DGB   | Diesel Generator Building                              |
| E&DC  | Engineering and Design Change                          |
| EDG   | Emergency Diesel Generator                             |
| ESD   | Engineering Service Division                           |
| FAT   | Factory acceptance test                                |
| HOP   | Handover Protocol                                      |
| ITP   | Inspection & Test Plan                                 |
| NEK   | Nuklearna elektrarna Krško (Nuclear Power Plant Krško) |
| NCR   | Non-Conformance Report                                 |
| OEM   | Original Equipment Manufacturer                        |
| PQP   | Project Quality Plan                                   |
| QA/QC | Quality Assurance/Quality Control                      |
| QRP   | Quality Record Package                                 |
| RTD   | Resistance Temperature Detector                        |
| SR    | Safety Related   |

## 3.0 CODES, STANDARDS & REGULATORY REQUIREMENTS

The original Generator to be refurbished under this Specification must remain qualified and commissioned according to the Codes and Standards applicable at the time of original equipment qualification; however, machines must be manufactured and factory tested according to the latest standards applicable.

The Contractor shall control the quality of parts, materials, and services to meet the requirements of this Specification and applicable Codes and Standards as specified in procurement documentation and ensure the SR qualification of Generators.

### 3.1 Applicable Codes, Standards, and Regulations

Unless specifically stated otherwise, the latest revisions of the referenced Codes, Standards, and Regulations shall apply.

#### **General Design and Manufacturing Standards**

- [1] IEEE C50.10 General Requirements for Synchronous Machines
- [2] IEEE C50.12 Salient-Pole 50 Hz and 60 Hz Synchronous Generators
- [3] IEEE C50.13 Cylindrical-Rotor 50 Hz and 60 Hz Synchronous Generators
- [4] NEMA MG 1 & 2 Motors and Generators
- [5] IEEE 115 Test Procedures for Synchronous Machines
- [6] IEEE 275 Recommended Practice for Field Testing Synchronous Machines
- [7] IEEE 4 Standard Techniques for High-Voltage Testing
- [8] IEEE 43 Recommended Practice for Testing Insulation Resistance of Rotating machinery
- [9] IEEE 522 Guide for Testing Turn Insulation of Form-Wound Stator Coils for Alternating-Current Electric Machines
- [10] ISO 21940-11 Mechanical vibration — Rotor balancing Part 11: Procedures and tolerances for rotors with rigid behavior
- [11] ISO 1940-1 Mechanical vibration — Balance quality requirements of rigid rotors — Part 1: Determination of permissible residual unbalance
- [12] ANSI S2.19 Mechanical Vibration - Balance Quality Requirements of Rigid Rotors - Part 1: Determination of Possible Unbalance
- [13] ISO 10816-1 Mechanical vibration — Measurement and evaluation of machine vibration
- [14] ASME Section III, Division 1, Class 1

- [15] ANSI/ASNT CP-1052016 Edition, ASNT Standard Topical Outlines for Qualifications of Nondestructive Testing Personnel
- [16] ANSI/ASNT CP-189 2016 Edition ASNT Standard for Qualification and Certification of Nondestructive Testing Person
- [17] ASME American Standard of Mechanical Engineers  
Section II, Materials  
Section V, Nondestructive examination  
Section IX, Welding and Brazing qualification

#### **Nuclear Safety-Related (Class 1E) Qualification Standards**

- [18] IEEE 323 (1971) Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations
- [19] IEEE 308 (1974) Standard Criteria for Class 1E Power Systems for Nuclear Power Generating Stations
- [20] IEEE 344 (2004) Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations
- [21] 10CFR50 App. B 1971 Edition: Quality Assurance Criteria for Nuclear Power Plants
- [22] RG 1.89 Environmental Qualification of Certain Electric Equipment Important to Safety for Nuclear Power Plants
- [23] RG 1.100 Seismic Qualification of Electrical and Active Mechanical Equipment and Functional Qualification of Active Mechanical Equipment for Nuclear Power Plants

#### **System-Level and Integration Standards**

- [24] IEEE 387 (1972) Standard Criteria for Diesel-Generator Units Applied as Standby Power Supplies for Nuclear Power Generating Stations
- [25] IEEE 741 Standard for Criteria for the Protection of Class 1E Power Systems and Equipment in Nuclear Power Generating Stations
- [26] IEEE Std 421.1 Standard Criteria and Definitions for Excitation Systems for Synchronous Machines
- [27] IEEE Std 421A Guide for Identification, Testing and Evaluation of Dynamic Performance of Excitation Control Systems

#### **Installation, FAT & SAT, Commissioning**

- [28] IEEE115 Guide for Test Procedures for Synchronous Machines Including Acceptance and Performance Testing
- [29] IEEE 275 Recommended Practice for Thermal Evaluation of Insulation Systems for AC Electric Machinery Employing Form-Wound Preinsulated Stator Coils for Machines Rated 6900 V and Below
- [30] RG 1.9 rev.3 Application and Testing of Safety-Related Diesel Generators in Nuclear Power Plants
- [31] ANSI/ASME N45.2.2. Packaging, Shipping, Receiving, Storage, and Handling of Items for Nuclear Power Plants

## **4.0 SUPPLEMENTAL DATA**

Supplemental data to this specification is available throughout the documentation listed in the section 34.0 and shall be considered as part of this specification.

Any data beyond this specification and its attachments is available upon specific request, if in NEK possession.



## 5.0 DOCUMENT SUBMITTAL

Documentation submitted by the Contractor to NEK shall be as requested per this specification and the contract.

Documentation shall be in English.

The layout may follow the Contractor's standard formatting unless otherwise specified.

The Contractor shall submit complete documentation for equipment, as specified in 25.0.

All documents, certificates, and records issued during manufacturing, shall be submitted to NEK in a searchable electronic copy for review in a common electronic format i.e. pdf, doc, jpg, tiff etc... All drawings shall be submitted in pdf file format.

Color copies shall be provided, when applicable.

Acceptance criteria shall be included on test and inspection datasheets, as applicable.

NEK will review the submitted documentation and provide feedback within 10 business days.

Incomplete or insufficient documentation will be rejected.

Revised documents shall clearly mark revision changes. All documents, particularly drawings, shall be clear and legible in all respects.

NEK's review does not absolve the Contractor of responsibility for meeting all specification requirements or ensuring document accuracy.

Any work or shipment initiated before review and concurrence with applicable documents is the Contractor's sole risk.

See section 24.0 for the detailed list of documents required throughout the project.

## 6.0 DESIGN REQUIREMENTS AND DESIGN INPUTS

### 6.1 The original equipment description

Two 16-cylinder diesel engines drive the bracketed type of synchronous generator in a tandem arrangement at a nominal speed of 750 rpm. It features a double shaft extension with one bearing locked to prevent the Generator rotor from thrusting on the diesel engine bearing during seismic conditions. It has two antifriction bearings.

The generator is provided with a drip-proof enclosure and guards conforming to NEMA 12: Ventilated Enclosures.

All the high-voltage connections are brought out into a terminal box by two leads per phase. This terminal box also has surge capacitors, three CTs for differential protection, and one CT for ground fault protection. The generator is also provided with six resistance temperature detectors (2 per phase) to monitor the stator temperature.

The generator is self-ventilated. Stator temperature readout and a high temperature alarm are provided on the local control panel.

### 6.2 General requirements

6.2.1 The Generator is intended for use in a tandem diesel-driven, continuous duty EDG in SR applications (e.g., emergency power, Class 1E equipment). It shall preserve all design basis safety functions, operational characteristics, performance margins, mechanical and electrical interfaces, control logic, and environmental qualifications without any plant modifications or license changes.

6.2.2 It must comply with and be (re)qualified for SR application according to the codes and standards listed in Section 3.0 of this Specification, as well as any additional requirements outlined in this Specification.

- 6.2.3 The Generator must retain its capability of stable operation with the existing static exciter, AVR, grounding resistor, and protective devices without requiring major re-tuning. Minor parameter adjustments are acceptable. The electrical characteristics shall not require changes to the settings or coordination of the existing protective relays beyond minor adjustments.
- 6.2.4 The performance characteristics and capabilities must match those of the original.
- 6.2.5 The Generator must remain fully compatible with the existing EDG, interfacing systems, structures, and components in every aspect. The Contractor may assume that the interfacing components have not been modified during their service life due to modifications or wear.
- 6.2.6 The equipment shall be suitable for continuous operation for 40 years of service life, with consideration for aging mechanisms and environmental exposure expected in DGB or stored in the warehouse according to long-term storage instructions provided by Contractor (see also 22.0).
- 6.2.7 Introducing new failure modes or unverified design changes is not allowed.
- 6.2.8 Any deviations from the original design or the above requirements must be brought to immediate NEK attention, justified, and formally evaluated following applicable change control, engineering evaluation, and regulatory processes.
- 6.2.9 Design and fabrication shall incorporate all available upgrades and improvements that do not conflict with the original design basis or compromise operational requirements. A detailed description of all improvements over the original design shall be provided as part of the Bid submission.
- 6.2.10 The Generator shall be designed to meet all requirements for starting and running with an overhead fire sprinkler system in operation (spraying water onto equipment).
- 6.2.11 The Generator will be directly connected to the diesel engines at both sides. The Generator shall be delivered with coupling hubs installed on both sides.
- 6.2.12 Welding shall be in accordance with ASME Code, Section IX.

### 6.3 Detailed Design Requirements

- 6.3.1 The original Generator data is provided in Attachment 6 while saturation curves are in Attachment 7. All critical design and performance parameters must match the original values, within pre-approved, justified, and documented tolerances, after the refurbishment. The Contractor shall provide the allowable deviation limits for each parameter along with the corresponding parameter curves, in the attachments for NEK review and concurrence.
- 6.3.2 The Generator shall retain its ability to deliver rated power at 0.8 power factor and 95 to 105% of rated voltage, or to operate at no load at 110% of rated voltage.
- 6.3.3 At continuous rating, neither the armature temperature rise shall exceed 70°C above an ambient of 40°C as measured by embedded RTDs, nor shall the field winding temperature rise exceed 70°C above an ambient of 40°C as measured by winding resistance.
- 6.3.4 The stator will be connected in wye configuration, with the neutral point grounded through a resistor rated at 15 A, 240  $\Omega$ , 3637 V, continuous duty.
- 6.3.5 After stripping the winding from the stator core, the initial flux test shall be performed. If the flux test results do not meet the acceptance criteria specified in 10.3.2, the Contractor shall stop work and inform NEK to determine the further course of action.
- 6.3.6 Poles shall be examined and confirmed as suitable for rewinding after the original winding is removed.
- 6.3.7 The stator and rotor poles shall be rewound using Class F insulation as a minimum.

- 6.3.8 The final flux test shall be performed on the fully wound and completed stator. Acceptance criteria are given in 10.3.2.
- 6.3.9 The Generator shall remain suitable for air cooling at the ambient conditions given in Section 7.2.
- 6.3.10 The Generator room heat input shall not exceed 8810 BTU/min.
- 6.3.11 Both bearings shall be replaced. The slip-ring side bearing insulation shall also be replaced; however, an improved design/material shall be used to prevent any shaft elevation decrease<sup>1</sup>.
- 6.3.12 Slip rings shall be thoroughly inspected and replaced, as needed. The slip ring's insulation shall be replaced.
- 6.3.13 The original Cu10 RTDs used for the stator winding temperature monitoring shall be replaced with Pt100 RTDs. Two embedded RTDs per phase shall be installed during the rewinding.
- 6.3.14 The power terminals shall match the original equipment connection location at the bottom of the Generator. Both high voltage and neutral ends of each winding must be brought out. The terminals shall be suitably spaced and arranged to permit connection of the plant cables.
- 6.3.15 The phase rotation must be maintained. The phase sequence, in accordance with NEMA C6.1, shall correspond to counterclockwise (CCW) rotation when facing the end of the generator opposite the drive end; that is, when the machine terminals T1–T3–T2 are connected to the A–B–C phase lead sequence.
- 6.3.16 The Generator, with existing exciter/regulator, shall remain capable of limiting the asymmetrical fault current for a 3-phase bolted fault to the values listed in the Power Systems Division Decrement Curves EM5-68, Sheets 1 and 2, dated January 13, 1976<sup>2</sup>.
- 6.3.17 Season and balance of the rotor shall be performed to remove mechanical creep and verify thermal stability after its refurbishment.

#### 6.4 Seismic requirements

The original Generator covered by this Specification is classified Seismic Category I and is designed to withstand the effects of a seismic disturbance in accordance with the following:

- a) The Contractor shall be responsible for the seismic (re)qualification in accordance with Specification SP-S702 (see Attachment 11) and the Floor Response Spectra for the DGB shown in Figure 1 through Figure 4 below.  
Every effort shall be made to maintain the refurbished generator design as close to the original as practical.
- b) The refurbished Generator shall suffer no damage and perform in accordance with this Specification when subjected to the operational basis (OBE) seismic accelerations acting both horizontally and vertically and occurring simultaneously. In addition, no part thereof shall dislodge nor suffer damage that causes any loss of function when subjected to design basis (SSE) accelerations.

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<sup>1</sup> See Attachment 9

<sup>2</sup> The requirement is based on the original Gilbert specification for EDG; however, NEK does not possess the actual EM5-68 document.

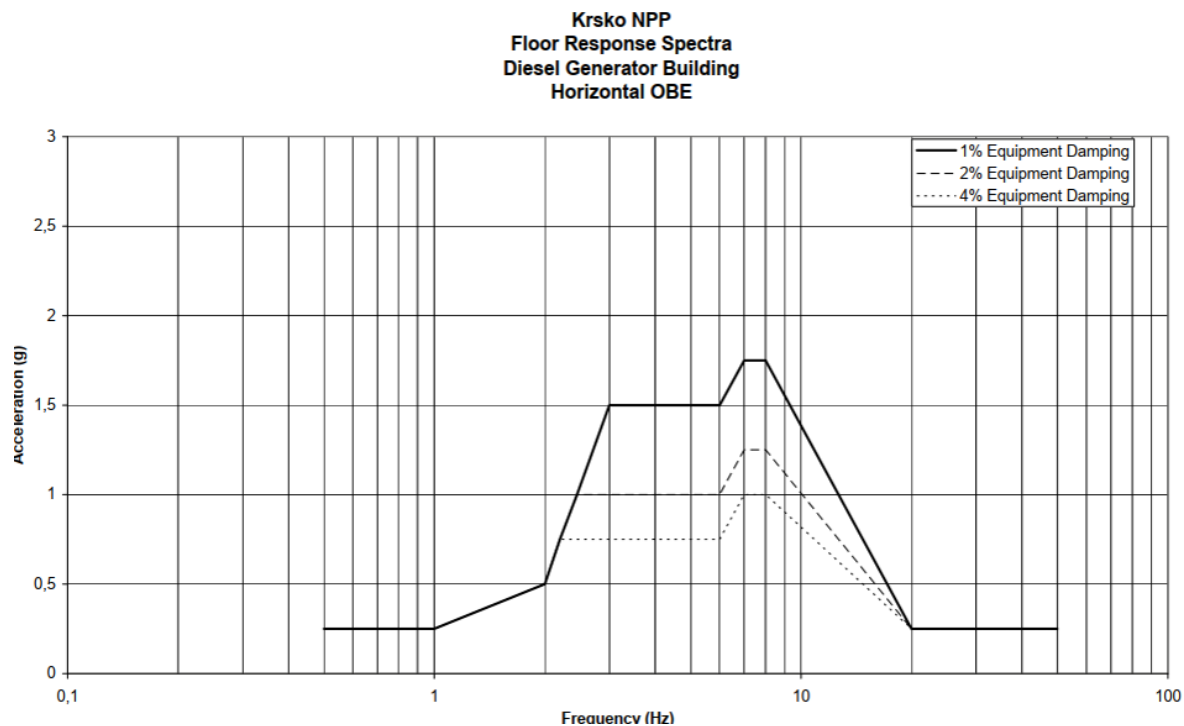


Figure 1: Horizontal OBE

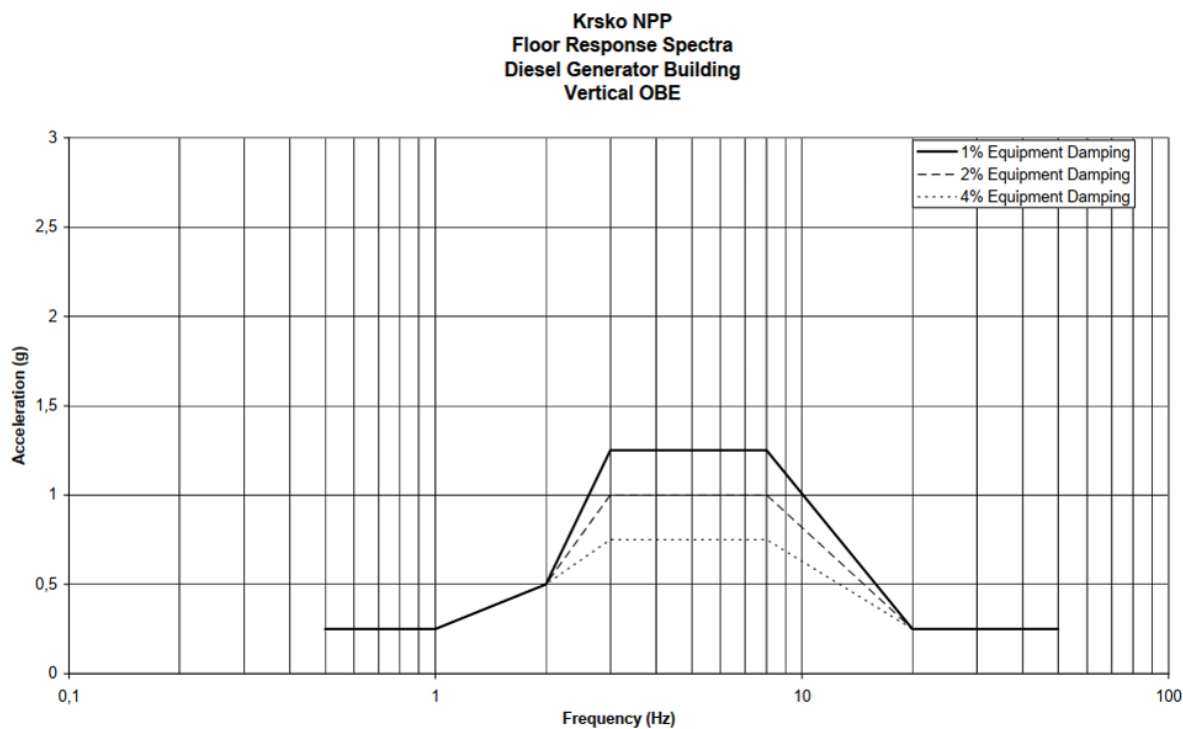


Figure 2: Vertical OBE

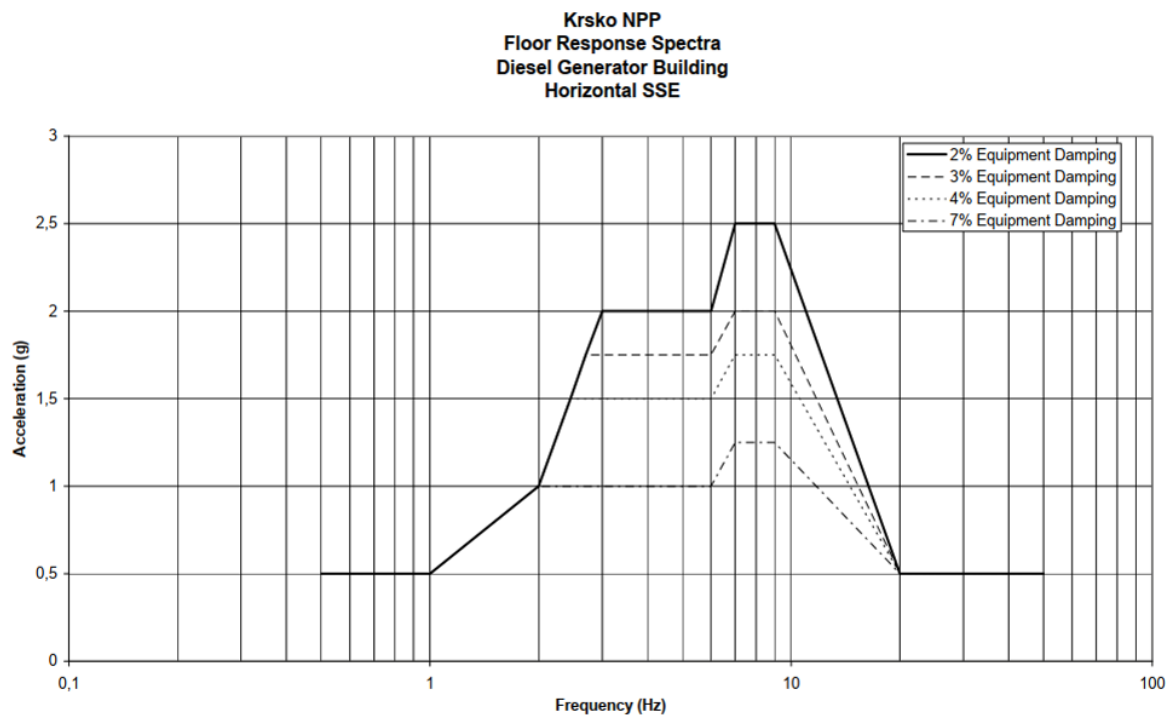


Figure 3: Horizontal SSE

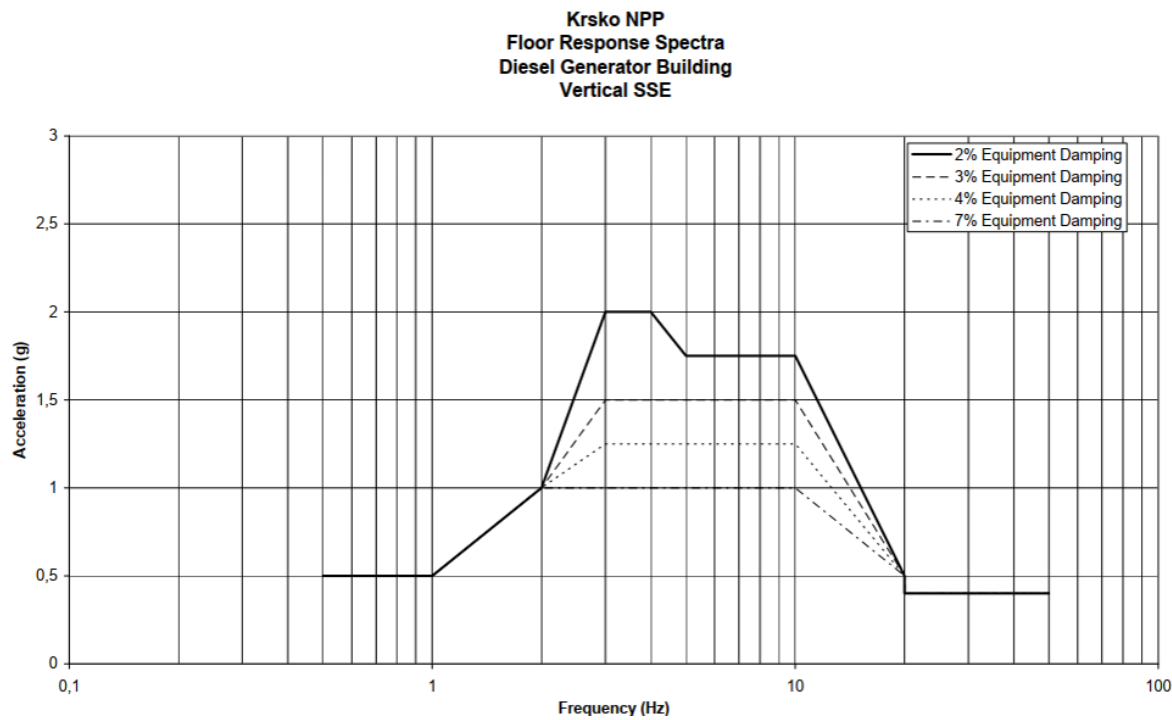


Figure 4: Vertical SSE

## 7.0 PERFORMANCE REQUIREMENTS

### 7.1 Performance Guarantee

The Generator shall be guaranteed to produce the various rated outputs at the plant's power connection when operating under the conditions described in the following items of Section 7.0. Starting characteristics, vibration, and other performance requirements shall be guaranteed to be within the agreed and specified limits. The guaranteed output for the various ratings shall be as defined in the following Section 7.0.

### 7.2 Standby and Operating Conditions

- 7.2.1 The design ambient (room) air for the DGB will have an extreme temperature range of -12°C to 40°C with a maximum daily average of 30°C. The relative humidity range will be 30% to 100%.
- 7.2.2 The barometric pressure will have the normal range of values for an altitude of 509 feet (155.2 meters). However, during a tornado, the barometric pressure may drop as much as 3 psig (0.21 kg/cm<sup>2</sup>) in a 3-second interval.
- 7.2.3 The foundation for the EDG is stationary. However, during an earthquake, the foundation will experience motion as great as the Design Basis Earthquake specified in Section 6.4 and Attachment 11.

### 7.3 Ratings

- 7.3.1 The ratings of the Generator shall remain as of the original one based on operation under all the ambient conditions given in 7.2.  
The Generator shall be rated in accordance with ANSI CS0.10 and NEMA MG 1, Part 22, and must be capable of operating as follows:

Nominal (continuous):

S = 4910 kVA

P = 3928 kW

U = 6300 V

I = 450 A

f = 50 Hz @ 750 rpm

pf = 0.8

$WR^2 = 44500 \text{ lb ft}^2 \text{ (app.)}$

4303 kW - 2000 Hours

4375 kW - 200 Hours

4500 kW - ½ Hour

- 7.3.2 The Generator must remain capable of 10% overload for 2 hours.
- 7.3.3 None of the manufacturer's design limits shall be exceeded during the operation within the given ratings.

#### 7.4 Loading

7.4.1 While the diesel engines are more restrictive regarding starting and loading, the following applies:

- a) The Generator, as an isolated source of electric power, shall be capable of accepting load, including real and reactive power, in accordance with any of the loading schedules in Attachment 9, or similar loading schedules, while maintaining voltage within +12% -20% of rated voltage and frequency with  $\pm 5\%$  of rated frequency. Voltage shall recover to 90% of rated voltage within 1 second of any loading transient. Frequency shall recover to 98% of rated frequency within 2 seconds of any loading transient (in accordance with USAEC Regulatory Guide 1.9).
- b) The Generator shall be capable of dropping all electrical load while maintaining voltage within  $\pm 10\%$  of rated voltage and frequency within  $\pm 5\%$  of rated frequency.
- c) The Generator shall be capable of stable operation at rated voltage and frequency from no load through the highest power rating without exceeding any of the design limits.

#### 7.5 Running

The Generator shall be capable of operating either as an isolated power source or in parallel with the plant distribution system. The EDG will not be operated in parallel with other diesel generators or other small generators.

The Generator shall be capable of starting and loading immediately after being shut down following 8 hours of operation at rated load and conditions.

#### 7.6 Vibration

The Generator shall operate at any load and within  $\pm 10\%$  of rated speed within vibration limits given in ref. [10] to [13]. The Contractor shall state any critical speeds that occur below 110% of the rated speed. No critical speeds are allowed in vicinity of rated speed and 450 rpm.

### 8.0 MATERIAL REQUIREMENTS

The Contractor shall be fully responsible for all materials selection, factory incoming inspection, and procurement, including qualification and certification. Only proven materials of quality specified in Contractor's internal design specifications should be used.

All new parts and components shall be made of new, high-grade quality materials, suitable for the purpose, free from defects and unacceptable imperfections. All materials shall conform to the Contractors' specifications and standards.

The chemical and mechanical properties of all materials shall be verified according to the PQP. The Contractor shall submit inspection reports that verify the materials conform to the specified standards, as outlined in the PQP tests and inspections document.

Traceability of all materials used shall be provided through appropriate documentation.

Wherever possible, materials shall be in accordance with ASTM standards applicable to the specific materials being utilized. A test report shall be submitted to NEK within four (4) weeks after the test is performed. Each test certificate shall identify the component for which the material is to be used and shall contain all information necessary to verify compliance with the PQP tests and inspections document. When requested, tests shall be made in the presence of NEK representative as part of officially agreed witness points.

Materials of limited shelf life shall not be used after their expiration date.

## 9.0 FABRICATION AND ASSEMBLY

### 9.1 Brazing

The brazing shall be performed per approved Brazing Procedure Specification (BPS). BPS shall be supported by Brazing Procedure Qualification Record (BPQR).

Brazing shall be done only by qualified personnel. Workers, qualified for brazing, shall be identified, with individual qualification certificate provided for each one of them.

All Brazed joints shall be at least visually inspected. Inspection report with description of location and type of joint shall be provided from each joint.

### 9.2 Machining

All surfaces shall be finished per drawing requirements to assure proper operation when assembled.

### 9.3 Standard products

All materials, parts, and components furnished by the Contractor, or its sub-contractor, must be procured per Contractor's requirements. The procurement documentation shall be provided per the PQP.

### 9.4 Bolts, Studs, Nuts

All accessible fasteners shall comply with the Contractor's design requirements.

All pieces susceptible to loosening during unit operation shall be secured by lockwire, pant-leg washers, or locking compound.

9.4.1 Required torques or tensions shall be indicated on transmitted drawings.

## 10.0 INSPECTION AND TESTS

### 10.1 General Requirements

10.1.1 Contractor shall submit the refurbishment Project Quality Plan (PQP) according to Section 20.0 of this Specification.

10.1.2 Tests, measurements, inspections, and acceptance criteria shall conform to the applicable codes and standards listed in Section 3.0. Tests and inspections not covered by these requirements shall be performed in accordance with Contractor's standards.

10.1.3 Each inspection, measurement, test, test conditions, test methods, and test results shall be accurately recorded and appropriate test reports prepared. The final reports shall include a scan of all original data sheets as recorded (i.e., original handwritten record in lieu of transcribed copy). The final reports shall be reviewed by competent technical personnel who shall certify that the equipment tested meets all requirements of this Specification.

10.1.4 Certifications of design tests shall contain statements on when, where, and by whom the tests were performed and shall state the results of the tests. The certifications shall be signed by a responsible individual in the employment of the Contractor.

10.1.5 The results of tests made in the environment of the test site shall be corrected for the conditions of the service environment.

10.1.6 The Contractor shall perform all normally accepted shop testing procedures during or after the refurbishment, whether specifically required herein or not. The Contractor shall perform all standard running tests for Generators used as EDG.



10.1.7 Required testing shall be performed and successfully passed, including all field testing, before acceptance of the equipment by the NEK.

10.1.8 NEK will establish the Customer Witness and Hold points, as defined in Section 31.0, based on the Contractor's ITP.

For any specified test or inspection point where acceptance criteria follow manufacturer standards, the Contractor must provide the NEK inspector with the relevant standard and testing procedure at least three (3) working days prior to execution.

When NEK presence is required at a hold or witness point:

- a) Raw data test reports must be submitted immediately after test completion
- b) All other reports must be delivered within four (4) weeks post-completion, as well as part of the final documentation package

The Contractor shall propose all hold/witness points (including subcontractor activities) in the ITP, subject to NEK's right to modify these proposals before its final approval.

10.1.9 Acceptance of test results and satisfactory completion of inspection by NEK shall not relieve the Contractor of the responsibility for furnishing the equipment complete and correct in all aspects.

10.1.10 NEK shall be informed about the progress of work regularly. The Contractor shall preliminarily inform NEK of the dates of measuring, testing, and inspections in the schedule. The Contractor shall send to the NEK representative at least three (3) weeks prior notice of all tests and other checkpoints in the manufacturing process, specifically requested by NEK in PQP.

10.1.11 Testing procedures shall include all relevant information, such as reference documents, test instructions, test equipment, precautions, preliminary conditions, initial and special condition requirements, description of the tests, normal parameter values/acceptance criteria, measuring data sheets, etc.

10.1.12 In the event of a disagreement between NEK and the Contractor regarding the test results, an independent expert shall be appointed. The selection of the independent expert shall be subject to mutual agreement by both parties. If no amicable resolution can be reached, the Arbitration Clause shall apply.

## 10.2 Acceptance Criteria

10.2.1 The factory test shall prove that the refurbished Generator's operating parameters, design parameters, and curves are within the pre-agreed limits.

10.2.2 NEK will accept only material and equipment that meet this Specification, and the supplementary specifications, codes, and standards as specified in Section 3.0.

10.2.3 The equipment shall operate to the full intent of this Specification. Any material, part, or component that fails to meet the acceptance criteria for any test or inspection shall be reported to NEK as a nonconformance in accordance with Section 16.0 of this Specification.

10.2.4 Acceptance of test results and satisfactory completion of inspection by NEK shall not relieve the Contractor of the responsibility for furnishing the equipment complete and correct in all respects for satisfactory operation.

### 10.3 Factory Acceptance Testing (FAT)

10.3.1 FAT shall include all tests, measurements, and inspections of the functions, performance, and properties of the complete and assembled Generator. FAT shall be performed to the extent practicable at the facilities of the Contractor and his Subcontractors prior to delivery to NEK.

10.3.2 Flux (core loss) test shall be performed immediately before rewinding i.e., after completion of any core repairs, and it has been prepared for inserting new coils. The test shall be conducted under controlled excitation and measured using thermocouples or an equivalent method.

- Average core loss:  $\leq 10\%$  above the manufacturer's baseline value for the core steel.
- Localized hot spots:  $\leq 5^{\circ}\text{C}$  above average.
- The temperature distribution shall be smooth without sharply localized heating.
- No arcing, lamination discoloration, or insulation damage observed during or after the test is permitted.

The test report shall be prepared, including:

- Description of test method and instrumentation
- Measured core losses and temperature rise distribution
- Identification of any defects and corrective actions taken

10.3.3 Rotor pole (drop) test shall be performed on each pole to detect shorted turns in the field winding. At least two test runs are required. DC current, rotor temperature, and stabilization time shall be recorded during each test. The results shall be corrected to  $25^{\circ}\text{C}$

- Uniformity limit: pole-to-pole voltage drop deviation  $\leq \pm 3\%$  at the specified DC test current.
- Repeatability: two successive runs within  $\pm 1\%$  of each other for each pole.

The test report shall be prepared, including:

- Description of test method and instrumentation
- Measured insulation resistance, polarization index, and pole drop data
- Identification of any defects and corrective actions taken

10.3.4 The Generator shall be tested in accordance with the requirements of ANSI C50.10, ANSI C50.12, NEMA MG 1 Parts 1, 2, and 22, and IEEE 115, except as modified or amplified by the following:

- a) The requirements for "Generators Completely Assembled in Factory, Rated Below 6,250 kVA or with a Voltage Rating of Above 5,000 Volts" of ANSI C50.12, Table 3, as applicable to this generator rated 4391 kVA and 6300 volts shall be met. In addition, the following tests of Notes 2 and 4 to Table 3 shall be performed:
  - i. Bearing insulation resistance check
  - ii. Voltage balance.
  - iii. Phase sequence.
  - iv. No load saturation curve.
  - v. Stator Winding impedance and Resistance (corrected to  $25^{\circ}\text{C}$ )
  - vi. Field Resistance (corrected to  $25^{\circ}\text{C}$ )
  - vii. AC Hi-Pot test
  - viii. Shorted Turn-to-Turn Test (Pole Balance Test) / Field AC Voltage Drop Test
  - ix. Recurrent Surge Oscillation (RSO) test (baseline measurement for future reference)
  - x. Partial discharge test
  - xi. Insulation dielectric losses

- b) The following tests of ANSI C50.12, Table 3, shall be performed, or test reports from duplicate equipment shall be provided:
    - i. Short-circuit saturation curve.
    - ii. Temperature test (heat runs).
    - iii. Overspeed.
    - iv. Short-circuit tests at reduced voltage to determine reactions and time constants.
  - c) The air gap of the completed generator assembly shall be measured in at least four locations, approximately at 90° intervals, at each end of the machine.
- 10.3.5 Final run-out readings shall be recorded at essential rotor and coupling hubs locations.
- 10.3.6 Each stationary electrical test, except the RSO test, shall be repeated before and after the overspeed test. The baseline RSO test must be performed as part of the final electrical tests (after balancing and overspeed test) for future reference.
- 10.3.7 Running electrical tests will be performed after the overspeed test.
- 10.3.8 Winding impedance shall be measured during the Rotor acceleration up to 750 rpm.

## 11.0 ITEM QUALIFICATION

The Generator to be refurbished under this Specification is Class 1E. It shall be qualified for the intended use and to the requirements of this Specification in accordance with IEEE 323.

## 12.0 CLEANLINESS

All parts shall be free from dirt, scale, and excess grease.

Foreign material exclusion program shall be in place throughout all phases of production, assembling, packing, and shipping.

## 13.0 CORROSION PROTECTION / COATING

The Contractor's standard painting specifications for the indoor units shall be applied.

The internal parts of the Generator should be re-painted, as needed. Touch-up painting is acceptable for internal parts if it provides sufficient coverage.

The external housing surface shall be completely repainted. Nameplates and markings shall be temporarily removed during the painting process and restored to the original locations afterward.

## 14.0 MARKING AND IDENTIFICATION

All components must be identified, and match marked in such a way to prevent use or erroneous assembly of parts and components, as well as to provide their permanent identification throughout the documentation and subsequent maintenance or repair.

Marking and identification shall ensure that the lot number, serial number, or other appropriate means, either on the item or on records, maintains identification of items traceable to the item throughout design, purchasing materials and/or components, fabrication, shipment, and use of them.

All original nameplates and markings shall be returned to their original locations

## 15.0 PACKAGING, HANDLING AND STORAGE

Packaging, shipping, receiving, and storage shall be according to [31] to assure the safe transportation, handling, and receiving of undamaged equipment.

The Contractor shall prepare, pack, and load the Generator in such manner that it is protected from damage during transportation. Moreover, the Contractor shall be responsible

for any damages resulting from improper packing. When transported on open vehicles or stored in open air, the Generator shall be suitably protected from damage that may occur due to bad weather.

The shipment shall be marked for proper warehousing. Marking shall include, at least the total weight, center of gravity, lifting points etc.

The Contractor shall inform NEK of any special storage requirements. The Contractor shall verify the warehouse conditions and shall provide a written procedure for receiving, unpacking, handling, and long-term storing the Generator at least three (3) months before shipping.

The Contractor shall specify any additional requirements necessary to maintain the Generator's qualifications and warranty during the long-term storage.

## **16.0 NONCONFORMING PARTS, COMPONENTS, OR MATERIALS**

Any deviations or design changes, which are not fully in accordance with the technical or quality assurance requirements of the procurement documents, and which Contractor desires to accept, shall be approved by NEK.

Any such deviation request shall be filed through Deviation / Change Request Form and submitted to NEK for approval prior to proceeding with work.

Non-conformance with Specification requirements or applicable codes and standards invoked by this Specification will not be accepted until approved by NEK.

An NCR shall be issued for each part or component found unsuitable for further use or determined to require repair and shall be reported to NEK for approval. In such case, the Contractor shall initiate Non-Conformance Report (NCR) using the Contractor's standard non-conformance document form, which describes the non-conformance and proposes a disposition with technical/engineering justification while submitting it to NEK for approval. NEK shall process the recommended disposition within three working days.

## **17.0 RECORDS**

All records shall be submitted to NEK immediately when prepared, each as a standalone document in line with the requirements given in 5.0. All Inspection/Testing Records shall be included in the Final Document Package.

### **17.1 Record system**

A record system shall be established and maintained by the Contractor to provide documentary evidence of the quality of items and activities affecting quality. Quality assurance records shall include results of reviews, inspections, test, audits, monitoring of work performance, material analysis, etc..

Records shall, as a minimum, identify the Contractor's name, order number, inspection and data record, inspection date, type of observation, procedures used, results, acceptability, and action taken with deficiencies noted. The record of inspection shall also identify drawings and procedures utilized, along with the revision level.

All quality verification records, procedures and qualifications shall be identifiable to the item or activity involved.

QRP content shall be mutually agreed prior to the start of activities on quality kick-off meetings with the Contractor and any subcontractors (if applicable).

All this record shall be submitted to NEK and included in the final QRP.

## 17.2 Fabrication, manufacturing, testing, assembling, and quality records

Additionally, the Contractor shall prepare and provide all initial condition (as-found), fabrication, manufacturing, testing, assembling, etc. records related to NEK equipment.

Tests, inspections and measurements records/reports shall be included in Final QRP as well as material certificates, certificates of conformance etc... As found and as left conditions for components that are part of refurbishment process shall be recorded and documented.

## 18.0 OTHER REQUIREMENTS

### 18.1 Project management

The Contractor shall assign a dedicated Project Manager for coordinating all project matters with the NEK Project Manager.

### 18.2 Progress Tracking

Regular project status tracking meetings shall be conducted throughout the project on mutually agreed intervals.

## 19.0 RIGHT OF ACCESS

Following the minimum 5 days advance notice, the NEK representatives must be granted access to all Contractor facilities where design, fabrication, manufacturing, or assembly of specified equipment occurs for QA program monitoring and documentation review. The same applies to the Sub-contractors' facilities; however, the Contractor shall arrange the appointment for NEK visit.

Surveys may be conducted at any time upon NEK request, periodically per the Product Quality Plan (PQP), or during specific project tasks when mutually agreed.

NEK reserves the right to require work suspension if major contractual deviations are identified in manufacturing, procurement, or quality control processes. Such QA oversight does not relieve the Contractor or subcontractors of their obligation to perform all required inspections and tests.

## 20.0 QA PROGRAM REQUIREMENTS

### 20.1 General

- 20.1.1 The Contractor shall maintain QA program that complies with 10 CFR 50 App. B and NEK Quality Specification QS-610, rev. 2, respectively. The Contractor's QA program must be approved by NEK.
- 20.1.2 The Contractor's QA program shall assure that major components listed in the Inspection and Test Plan, manufacturing practices, examinations, and testing conform to the requirements of this Specification.
- 20.1.3 One (1) copy of the Contractor's QA program manual shall be submitted to NEK with the Bid. If the Contractor's QA program was already submitted to NEK the Contractor's QA program designation and revision number shall be submitted to the NEK with the bid. All portions of QA program that have been revised during the period of this specification must be accepted by NEK beforehand.
- 20.1.4 The Contractor is responsible for QA and QC activities according to this Specification. All technical and quality requirements shall be met. QA and QC activities, survey activities or failure to discover deviations or other deficiencies by NEK shall not relieve the Contractor from responsibility to meet such requirements, to perform inspections and tests required by this specification or governing codes and standards.

- 20.1.5 All work performed by subcontractors shall be subject to the technical and quality requirements of this Specification as well. The Contractor shall be responsible for all subcontracted activities.

## 20.2 Project Quality Plan (PQP)

- 20.2.1 The Contractor shall submit refurbishment PQP for review and approval. PQP shall describe Contractor's QA-QC approach (including treatment of Non-Conformances, reporting of deficiencies, and corrective actions implementation).
- 20.2.2 PQP shall include Inspection and Test Plans (ITP) for as-found condition assessment, design, procurement, qualifications, and manufacturing. Each plan shall indicate a sequence of activities, material acquisition, qualification, manufacturing, and testing activities.
- 20.2.3 NEK will identify witness (W) and hold (H) point steps. The ITP with identified W/H points shall be approved before proceeding with any activity.
- 20.2.4 Test and Inspection Plan (ITP), which shall be used as a traveler with the following sections:
- a) Initial inspections & tests
  - b) tests of raw materials,
  - c) tests and inspection during design, manufacturing,
  - d) tests on fully assembled Generator,
  - e) test and inspections before shipment.
- 20.2.5 The following shall be specified for each item in the ITP:
- a) component (i.e. material/part/assembly/complete Generator),
  - b) type of test, activity and method (e.g. destructive/non-destructive; visual, liquid dye-penetrant, magnetic particle, X-ray, ultrasonic, probes; analysis for chemical composition; mechanical and electromagnetic properties of materials and components, etc),
  - c) standards according to which new material, construction and other parts shall be purchased, or standards/procedure according to which a test, measurement, or inspection shall be performed,
  - d) procedure with acceptance criteria according to the applicable standard.

## 20.3 Certificate of Conformance

- 20.3.1 The Contractor shall submit a CoC to certify that the refurbished Generator meets the requirements of this Specification and the Contract.

CoC shall be part of the Final Document package.

## 20.4 Handover Protocol

The Contractor and NEK shall sign the Handover Protocol upon successful delivery of the refurbished Generator to the NEK site in order to certify that the Generator was manufactured and installed in full compliance with the contractual scope, schedule, delivery time, and other terms and conditions stipulated in the Contract. This certification shall also confirm that the Generator meets all operational and functional requirements specified in this Technical Specification.

The warranty period shall commence upon mutual signing of the Handover Protocol (HOP), as stipulated in the Warranty Section of the Contract.

## 21.0 SPECIAL HANDLING

The scope of work includes all lifting activities related to the manufacturing and delivery of the Generator to the NEK site.

## 22.0 SHELF LIFE

The Generator will be stored indoors in a warehouse that complies with ANSI Storage level B at the NEK site.

The Contractor shall provide long term storage instructions and in-storage maintenance instructions to support forty (40) years of operation.

## 23.0 10CFR21 REPORTING

The Contractor shall comply with the requirements of 10 CFR Part 21.

Reporting pursuant to 10CFR21 shall be made to: Stanko Manojlović, Engineering support for long term operation superintendent.

tel: ++386 748 02 527;

E-mail: [stanko.manojlovic@nek.si](mailto:stanko.manojlovic@nek.si)

## 24.0 DOCUMENTATION REQUIREMENTS

Documents shall be submitted, as requested in 5.0.

### 24.1 Documentation required with the proposal

As a minimum, the Contractor shall submit the following documentation with the Proposal:

- [1] Technical description of Services and Scope of Work, including:
  - a) A detailed description of proposed improvements over the original design
  - b) Operating parameters, machine design parameters, and curves tolerances, limits, or deviations from original values.
  - c) The statement that is fully aware and will comply with the requirements of 10 CFR Part 21.
- [2] Preliminary refurbishment schedule
- [3] Preliminary ITP (see 20.2) with references to applicable procedures
- [4] QA manual (see 20.1.3)
- [5] List of exceptions from this specification, including detailed reasoning (if applicable)
- [6] List of Subcontractors

### 24.2 Documentation requested after signing the contract

Contractor shall submit the following documentation within six weeks after signing the contract:

- [1] Refurbishment schedule
- [2] Refurbishment PQP per requirements of 20.2 for NEK review, comment and approval.
- [3] Factory Acceptance Test (FAT) plan

### 24.3 Final documentation package

Contractor shall submit the final revision of all requested documentation.

All documents shall be delivered in an appropriate electronic form, if not specified otherwise.

[1] Quality Record Package (QRP):

Tests, inspections, and measurements records/reports shall be included in Final QRP as well as material certificates, certificates of conformance, etc...

Changes in characteristics affecting unit operation, if any, shall be identified.

The QRP shall include:

- a) Incoming inspection & testing report
- b) Material certificates and standard OEM records/reports issued for major components during manufacturing.
- c) All tests, inspections, and measurements records and reports
- d) Repair records and reports
- e) Tests of the fully assembled Generator,
- f) Final production and test reports
- g) Flux (Core Loss) Test Report (see 10.3.2)
- h) Pole Drop Test Report (see 10.3.3)
- i) FAT report
- j) Non-conformance reports
- k) Release for shipment
- l) Any other standard Contractor's documentation related to the project

[2] Final report:

Final report shall be submitted to NEK for review and concurrence prior to issuing in electronic format.

New or revised drawings shall be included when applicable.

Final report shall be provided containing the following:

- a) Documented scope of work with photos that are cross-referenced with text
- b) Engineering evaluation and Generator final Certificate of Conformance
- c) Report of corrective action(s)
- d) Replaced parts list with corresponding part numbers
- e) Non-conformance reports
- f) Test and inspection plans with sign-offs
- g) Design Approach Report to Fulfil 40 Years Service Life

[3] Updates to the Generator Instruction Book, including Spare Parts List, if any

[4] Long-term storage instructions

[5] All Qualifications Certificates

[6] Certificate of Conformance with this Specification and related Contract.

[7] Handover Protocol according to 20.4.

## 25.0 NEK PROPRIETY DATA

Proprietary data requirements shall be followed as agreed in the Contract.

## 26.0 NON-CONFORMANCE REPORTS

Refer to Section 16.0



## 27.0 REPAIR RECORDS

All repair records shall be included in the final quality release documentation. As a minimum, following information shall be provided in each of those:

- a) Summary of repair work that has been performed with reference to the associated NCR
- b) Brief root cause analysis for cases considered significant issues according to section 16.0
- c) Details about any "special process" used during such repairs
- d) A list of replacement parts installed in the repaired equipment, when applicable

## 28.0 SOURCE INSPECTION / SURVEILLANCE NOTIFICATION

The Contractor shall grant access to Contractor's plant facilities and records pertaining to the purchase order as defined in 19.0 for the purpose of planning and performing source inspection/surveillance activities.

Inspections or examinations performed by NEK representatives or designated representatives do not relieve the Contractor of its responsibility to meet the requirements of this specification and purchase order.

## 29.0 SHIPPING REQUIREMENTS

The Contractor shall be responsible for the packaging and shipping of the equipment to and from the NPP Krško site and the refurbishment facility.

The Supplier shall provide all means necessary for packaging and shipping, including protection against elevated temperature, humidity, transit shocks, and inappropriate handling.

Appropriate means for recording tilts and shocks during transport shall be provided when shipping the complete Generator.

## 30.0 DELIVERY SCHEDULE

The final production and delivery schedule shall be mutually agreed upon in the bidding phase.

| Description                      | Milestone Date           |
|----------------------------------|--------------------------|
| Pick-up & shipment               | T <sub>0</sub>           |
| Approved PQP                     | T <sub>0</sub> + 1 mth   |
| Initial inspection & test report | T <sub>0</sub> + 3 mths  |
| FAT                              | T <sub>0</sub> + 10 mths |
| Delivery on Site                 | T <sub>0</sub> + 12 mths |

T<sub>0</sub> – (expected) January, 2029

### 31.0 WITNESS AND HOLD POINTS

NEK shall have the right to establish witness and hold points, which will be designated in the ITP, as stated in 10.1.3.

NEK keeps the right to cancel the presence in such activities.

NEK keeps the right to request additional witness and hold points, if found necessary, to ensure the resolution of unexpected quality problems or any other technical issue.

NEK shall be advised about all witness and hold points three weeks in advance.

### 32.0 CONTRACTOR TECHNICAL MANUAL AND REGISTERED UPDATES

The Generator Instruction Book shall be updated, if needed.

### 33.0 TRAINING

No special training is required.

### 34.0 ATTACHMENTS

Attachment 1 6003F02001 General Arrangement Tandem 18-645E4 Generator Set

Attachment 2 6003F02002 Plant Layout

Attachment 3 6003F12001 Foundation Layout

Attachment 4 6003F12002 Generator Base Details

Attachment 5 8365588 Engine Coupling<sup>1</sup>

a. PDK-PDJ-8537T

Attachment 6 4687-36-016-0 AC Synchronous Generator Data

Attachment 7 4687-36-014-0 Saturation Curves

Attachment 8 Miscellaneous Generator Drawings (package)

a. A-66885 8 Pole Stator Conn Diagram

b. A-66951 8 Pole Rotor Conn Diagram

c. 9322602 Drive Line Apl

d. D09236 Generator Outline

e. D65022 AC Outlet Box Ass'y

f. 69117 Generator Shaft

g. Curve No.2812 Generator Capability Curve (calculated)

Attachment 9 IN 86-26 Potential problems in generators manufactured by Electrical Products Inc.

Attachment 10 EDG Loading Schedule

Attachment 11 SP-S702 rev.11 Seismic analysis, testing, and documentation

Attachment 12 QS-610 rev.2 NEK Quality Specification

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<sup>1</sup> Additional info in PDK-PDJ-8537T