RELIABILITY & H.V. EQUIPMENT DEPARTMENT

Main Technical Requirements

For 161 kV

POWER TRANSFORMER

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MAIN TECHNICAL REQUIREMENTS FOR 161 KV POWER TRANSFORMERS IN ISRAEL

Scope of work:

This document describes the System data and the main transformers components, focusing on the threshold requirements.

This document should not be considered as a "Power Transformer Specification". The main objective is to serve as a guide to those interested in carry out a detailed Specification for an appropriate transformer that fulfill the Local Regulations and Purchaser requirements.

Notes:

1. *The technical data, procedures and regulations in this document should be considered as part of the Threshold Requirements of the System.*
2. *The final Transformer Specification must be evaluated by the customer and the manufacturer to arrive at the final design of each component, considering the* ***Israel Grid Code*** *requirements (https://www.noga-iso.co.il/grid-code/).*
3. *In the event that there are components where not all requested information is provided or do not reach the appropriate quality level, the equipment or parts thereof may be disqualified for use.*
4. ***This document must be approved and signed by:***
   - *4.1. End Customer or his representative*
   - *4.2. Design body (if applicable)*
   - *4.3. Power transformer manufacturer*

The customer is responsible for providing all data and information requested in this document, as well as ensuring that all technical requirements are fulfilled by the manufacturer in the final supplied product.
The customer will be also responsible for verifying the veracity of all data provided by the manufacturer.

	Name	Company	Date	Sign
End-Customer or his representative				
Design body (if applicable)				
Manufacturer				

General:

- **Location:** This document covers the installation of transformers indoors or outdoors.
- **Required Information and Documentation:** Requirements about documentation are in Clauses 24, 25, 26, 27 & 28

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TECHNICAL REQUIREMENTS AND REQUIRED INFORMATION			
	Description	**Required Value or Applicable Standard**	**Manufacturer's Confirmation or Proposal**
1.	**System data**		
1.1.	**System frequency,** according to definition in:	IEC 60050-421, 421-04-03, modified	
1.1.1.	Rated frequency [Hz]	50	
1.1.2.	Range of frequency variation [Hz]	According to ***Israel Grid code***	
1.2.	**System voltages,** according to definition in:	IEC 60050-421, 421-03-05	
1.2.1.	Rated system voltage (line to line) [kv]	161	
1.2.2.	Highest system voltage (line to line) [kv]	170	
1.3.	**Symmetrical short circuit current [KA rms]**	50	
1.4.	**Methods of the transformer system neutral earthing**	According to ***Israel Grid Code***	
1.5.	**Fault duration [sec.]**	1	
1.6.	**Earth fault factor (EFF)**	1.4	
1.7.	**Line auto reclosing policy (HV)**	Single-phase single shot 0.6 sec.	
2.	**Environment Conditions**		
2.1.	Environment conditions according to:	IEC 60721/3-4	
2.1.1.	8-9 months a year without rain with more than 100 nights with dew and high humidity in the air as experienced in coastal or desert areas in this country.		
2.1.2.	Severe atmospheric and industrial air pollution, dust, salt spray and sandstorms		
2.1.3.	Altitude over the sea level up to [m]	1000	
2.1.4.	**Chemically active substances**: **corrosively category** according to:	ISO 9223, C5	
2.1.5.	**Classification of mechanically active substances** according to:	IEC 60721-3-4 Table 4 4S13	
2.1.6.	Bushings pollution levels: Desert and Coastal types of environments, according to:	IEC 60815-1/ Table 5, E6 E7	
2.1.7.	Type of Pollution: Desert-Coastal, high inert content	Mixed A+B, A prevalent IEC TS 60815-1	
2.1.8.	Site pollution severity (SPS) class	e (very heavy)	

2.1.9.	Non-Soluble Deposit Density (NSDD) [mg/cm^2]	2	
2.1.10.	Equivalent Salt Deposit Density (ESDD) [mg/cm^2]	0.45	
2.1.11.	Annual number of dangerous wetting events	200	
2.2.	**Classification of Climatic Conditions** according to:	IEC 60721-3-4 Table 1 4K26	
2.2.1.	Air temperatures according to:	Clause 2.3	
2.2.2.	No-rain, dry period [months]	7	
2.2.3.	Water from sources other than rain [m/s]	15	
2.2.4.	Classification of special climatic conditions according to:	IEC 60721-3-4 Table 2 4Z5	
2.3.	**Ambient air temperatures:**		
2.3.1.	The indicated temperatures will be considered as default. Other temperatures values must be justified by customer and approved by NOGA	Maximum: 50°C	
2.3.2.		Minimum -5°C	
2.3.3.		Monthly average (hottest month) 40 °C	
2.3.4.		Yearly average 30 °C	
3.	**Seismic Qualification Level**		
3.1.	**The Seismic Qualification Level will be applied to the transformer and all its accessories**		
3.2.	Applicable standard:	IEEE 693-2018	
3.3.	Seismicity of site:	Moderate level	
3.4.	Peak ground acceleration with an 85% probability not to be exceeded over a 50 years period:	0.5g	
4.	**Electromagnetic Environment**		
4.1.	Indicate the time duration that the power transformer can withstand the temperature rise caused by a 50 Amps DC current passing through its neutral point, as a result of Geomagnetic Disturbance (GMD) or Electromagnetic pulse (EMP). (min) according to IEEE standard C57.163-2015		
4.2.	The electronic devices delivered with the transformer shall withstand an electromagnetic environment having the following maximum severity levels according to:	• IEC 60255-26 • IEC 60255-22-part 1-2-3-4	
4.3.	Severity level for electrostatic discharge [kV]	4	

4.4.	Severity level for radio frequency interference [V/m]	10	
4.5.	Severity level for electrical 1 MHz burst disturbance [kV)	2.5	
4.6.	Severity level for fast transients according to [kV]	2	
5.	**Acceleration During Transport**		
5.1.	**Typical accelerations expected in transformers during crane loading and transport by rail, road, sea, and air.**	The maximum acceleration values allowed in the 3 geometric axes of the transformer (X-Y-Z) must be indicated by the manufacturer depending on the means of transport that will be used for shipping, and must be at least 1 g according to clause 5.7.4.2 of IEC 60076 -1	
5.1.1.	Longitudinal / Transversal / Vertical [g]	Proposal values	/ /
5.1.2.	At least two impact recorders will be installed at factory. Impact recorders should remain on the equipment until offloading onto the final pad (including)	Section 6.1.3 of IEEE C57-150 (2012)	

6.	**Functional Specifications**		
6.1.	**Ratings of the transformer shall be based on the temperature conditions in clause 2**		
6.2.	**Number of phases:**	1 / 3	
6.3.	**Rated power [MVA]:**		
6.3.1.	Rated power with all cooling system in operation [MVA]		
6.3.2.	Rated power without fans and / or pumps operation [MVA]		
6.4.	Cooling methods	According to IEC 60076-2	
6.5.	Connection phase displacement symbol	• According to IEC 60076-1 and ***Israel Grid Code***. • Shall be considered the possibility of parallel connection with existing or future units.	
6.6.	Insulation level: HV at least 650/275 kV and according to:	IEC 60076-3 cl. 7.2.2 and Table 2	HV: / LV: / N: /
6.7.	Rated Currents with full operation of cooling system and under climatic conditions in Clause 2:		
6.7.1.	Principal tap (Primary/Secondary) [A]		/
6.7.2.	Maximum tap (Primary/Secondary) [A]		/
6.7.3.	Minimum tap (Primary/Secondary) [A]		/

6.8.	**Rated voltages (line to line)**	Should consider the possibility of parallel connection with existing or future units	
6.8.1.	HV [kV]		
6.8.2.	LV [kV]		
6.8.3.	Tertiary (T) [kV]		
6.8.4.	HV or LV Neutral [kV] according to:	• IEC 60076-3, Clause 7.4.2 • ***Israel Grid Code***	
6.8.4.1.	The Neutral shall be brought out through a neutral bushing and shall be suitable for grounding connection		
6.8.5.	Principal tap voltages (Primary/Secondary) [kV]		/
6.8.6.	Maximum tap voltages (Primary/Secondary) [kV]		/
6.8.7.	Minimum tap voltages (Primary/Secondary) [kV]		/
6.9.	**Short-circuit voltage at 75°C, based on rated power between HV and LV winding terminals**	• Tolerances according to IEC 60076-1 Table 1 • Should consider the permissible short circuit currents and the possibility of parallel connection with existing or future units. • The minimum short-circuit voltage will be according to IEC 60076-5 Table 1	
6.9.1.	**In any case, the short-circuit voltage in the principal tap should not exceed the 20%. Any exception must be verified and approved by NOGA**		
6.9.2.	Principal tap [%]		
6.9.3.	Maximum tap [%]		
6.9.4.	Minimum tap [%]		
6.10.	**Zero sequence impedance measured at rated frequency by applying a single-phase voltage**		
6.10.1.	Principal tap (ohm/phase)		
6.10.2.	Maximum tap (ohm/phase)		
6.10.3.	Minimum tap (ohm/phase).		
6.11.	**No-load harmonics**		
6.11.1.	No-load harmonics at 100% rated voltage:		
6.11.1.1.	3rd [%]		
6.11.1.2.	5th [%]		
6.11.1.3.	7th [%]		
6.11.2.	No-load harmonics at 110% rated voltage:		

6.11.2.1.	3rd [%]		
6.11.2.2.	5th [%]		
6.11.2.3.	7th [%]		
6.12.	**Temperature rise limit** according to:	IEC 60076-2, Table 1 and Table 2	
6.12.1.	**The temperature rise correction factor must be K = -10 (Table 2 of IEC 60076-2), consequently, the following corrected temperature rise limits will be adopted according to Table 1 of IEC 60076-2. The selection of other K values must be justified by customer and approved by NOGA**		
6.12.1.1.	Top insulating liquid temp. rise, no more than [K]	50	
6.12.1.2.	Average winding temp. rise (by resistance variation), no more than [K]	55	
6.12.1.3.	Winding Hot-Spot temperature rise, no more than [K]	68	
6.13.	Inrush r.m.s. magnetizing current with no residual magnetism at rated voltage (p.u based on full load current) no more than:	7	
6.14.	**Permissible time the transformer can withstand the following power frequency over-voltages at no-load:**		
6.14.1.	135% overvoltage [sec]		
6.14.2.	130% overvoltage [sec]		
6.14.3.	125% overvoltage [sec]		
6.14.4.	120% overvoltage [sec]		
6.14.5.	115% overvoltage [min]		
6.14.6.	110% overvoltage [min]		
6.15.	**Max. Overload capability p.u [MVA]** according to	IEC 60076-7	
6.16.	**Overcurrent capability** according to:	Table 3 of IEC 60076-7	
6.17.	**All associated components of the transformer including bushings, CT's, tap changer, etc. shall withstand the transformer overload and over voltages characteristics.**		

6.18.	**Maximum guaranteed total sound power level under full load, at rated voltage, rated current and rated frequency with all the cooling sections in operation [dB(A)],** according to:	The choice of the transformer "Maximum guaranteed total sound power level" will be based on the results of an environmental survey approved by the **Ministry of Environmental Protection**. The customer understand that the choice of the appropriate sound power level is under his exclusive responsibility.	
7.	**Bushings**		
	The data required for HV bushings in clauses 7.2 to 7.18 must also be provided for secondary, tertiary, and neutral bushings.		
7.1.	Selected bushings:		
7.1.1.	HV	Manufacturer and model	
7.1.2.	N		
7.1.3.	LV		
7.1.4.	T		
7.2.	The bushings shall be designed for the service conditions stated in clause 2 and 3 of this document and according to:	IEC 60137 clauses 4.8, 5.3 &10.1	
7.3.	All bushings shall be tested according to:	IEC 60137	
7.4.	Required minimum values of cantilever withstand load applied on the bushings according to	IEC 60137 clause 4.5 (level II)	
7.5.	Rated voltage [kV]	161	
7.6.	Highest phase-to-phase voltage [kV r.m.s]	170	
7.7.	Rated phase-to-earth voltage min [kV r.m.s]	93	
7.8.	Maximum phase–to-earth temporary over-voltages the bushings can withstand according to:	IEC 60137 cl. 5.1	
7.9.	HV Bushings Insulation levels must be according IEC 60137 Table 3 and at least:		
7.9.1.	Lightning impulse withstand voltage [kV peak]	750	
7.9.2.	Power frequency withstand voltage (dry) [kV r.m.s]	355	
7.9.3.	Power frequency withstand voltage (wet) [kV r.m.s]	325	
7.9.4.	Neutral Bushing	According to the selected Neutral voltage in Clause 6.8.4	

7.10.	Creepage distance [mm] according to SPS class e and RU SCD= 53.7 IEC 60815-3 / 60815-1. For HV bushings, at least:	5270	
7.11.	The bushing profile shall include Alternating Sheds according to:	IEC 60815-3	
7.12.	For HV bushings, the arcing distance must be at least [mm]	1500	
7.13.	Rated current according to:	• Clauses 6.7- 6.16 • IEC 60137 Clause 4.2	
7.14.	Rated thermal short-time current (Ith) at 2 sec, at least:	25 Ir	
7.15.	Dynamic short-circuit withstand current according to:	IEC 60137, clause 4.4	
7.16.	The seismic qualification for all bushings will be in accordance with:	• Clause 3 • IEEE 693-2018	
7.17.	The temperature limits of metal parts in contact with insulating material must be according to:	IEC 60137	
7.18.	The bushing hottest spot temperature above the temperature of the immersion medium in overload condition must be according to:		
7.19.	Required profile parameters for bushings in Annex 4	The required parameters must be completed in the Remarks column of Annex 4	
8.	**Tap Changer**		
	In the case in which the transformer is equipped with an OLTC, it will be equipped with all necessary control, alarm and protection devices		
8.1.	Applicable standard:	IEC 60214	
8.2.	Type:	OLTC / DETC	
8.3.	Location	Primary/Secondary	
8.4.	Voltage range [%]	According to the target voltage desired value and the possibility of working in parallel with existing or future units	
8.5.	Step voltage [V]		
8.6.	Tap No. at nominal ratio (Principal Tap)		
8.7.	Number of taps above principal position		
8.8.	Number of taps below principal position		
8.9.	The isolation level of the tap-changer must be appropriate considering the installation place in clause 8.3.		
8.10.	OLTC maximum rated through current Irm (A) as defined in:	IEC 60214-2	

8.11.	The maximum rated through current Irm shall be at least 120% from the highest transformer tapping current in Clause 6.7	Irm ≥ 1.2 It	
8.12.	Overload capability of the tap changer according to:	IEC 60076-7	
8.13.	Position of taps in winding:	Line end, middle, neutral point	
8.14.	Rated short-time current 2 sec. and 4 sec. [KA]	According to transformer design and System data	
8.15.	Dynamic short-circuit withstand current [KA peak]:		
8.16.	Voltage class [kV]:		
8.16.1.	Lightning impulse withstand voltage 1.2/50µsec Power frequency withstand voltage 50 Hz, 1 min:		
8.16.2.	Maximum continuously operating voltage:		
8.16.3.	To earth at least [kV peak] / [kV rms]	According to Clause 8.9	/
8.16.4.	Between phases [kV peak] / [kV rms]		/
8.16.5.	Between the first and last contacts of the tap selector or selector switch and, where fitted, of the change-over selector [kV peak] / [kV rms]		/
8.16.6.	Between any two adjacent contacts of the tap selector or selector switch or any other contacts relevant to the tap-changer contact configuration [kV peak] / [kV rms]		/
8.16.7.	Between diverter switch contacts in their final open position [kV peak] / [kV rms]		/
8.17.	At least a PRD protective device shall be installed. The following protection devices can also be considered:	• Gas and oil flow relay • Overpressure relay	
9.	**X/R ratio**		
9.1.	Principal tap		
9.2.	Maximum tap		
9.3.	Minimum tap		
9.4.	Voltage drop [kV]		
10.	**Windings**		

10.1.	Applicable standards for winding wires and cables**:**	• IEC 60317 • IEC 60554	
10.2.	In order to protect the coil copper wire against sulfur corrosion phenomena, the copper wire used for windings production shall be enameled according to:	IEC 60317	
10.3.	Insulation:		
10.3.1.	Thermal insulation class of the winding wire/cable will be at least 120 °C (E) according to:	IEC 60085	
10.3.2.	The winding wire/cable paper insulation material shall be at least Thermally Upgraded Paper		
10.4.	The temperature rise at Rated Power must not exceed the values in:	Clause 6.12	
10.5.	The transformer windings will be able to withstand three-phase short-circuit currents (thermal and dynamic) in all taps.		
10.6.	The transformer shall be able to withstand the stated symmetrical short-circuits for not less than (sec)	2	
10.7.	The maximum permissible value of average temperature of the winding after short-circuit shall be according to:	IEC 60076-5 Table 3	
10.8.	Transformers with primary and secondary windings in Y configuration must be equipped with tertiary windings for stabilizing purposes.		
10.9.	The insulation of the Tertiary winding must be thermally adequate to the transformer's overload capacity.		
10.10.	The dimension of the Tertiary winding must be suitable to withstand the conditions of Clause 10.5, single phase short circuits and unbalanced loads.		
11.	**Insulation oil**		
11.1.	The transformer oil shall meet the requirements indicated in:	• Annex 1 • IEC 60296	
11.2.	The mixability between oils must be in accordance with:	• IEC 60296 • IEC 60422	
12.	**Gas and liquid actuated relay (Buchholz relay)**	According to IEC 60076-22-1	

13.	**Pressure relief devices**		
14.	**Automatic Voltage Regulator (AVR)**		
14.1.	An AVR control system for OLTC shall be provided for voltage control and parallel options connection.		
14.2.	AVR software shall fulfill the CYBER REQUIREMENTS according to:	Israel Grid code	
15.	**Oil Preservation System**		
15.1.	The oil preservation system must include a system that prevents direct contact between the oil and air.		
15.2.	The oil for the OLTC diverter and main tank shall be separated		
16.	**Transformer Cooling System**		
16.1.	The cooling system will be made up of the necessary heat exchangers, fans and/or pumps, which together with automatic control equipment will maintain the transformer temperature within the established limits taking in consideration the environment conditions in:	• According to: IEC 60076-2 • Clause 2	
16.2.	The control of the cooling system will be carried out through a transformer monitoring system	See Clause 17	
17.	**Transformer Monitoring Systems**		
17.1.	A Monitor/s for Oil-Filled Transformer shall be provided for control and monitoring at least the following functions:		
17.1.1.	Winding temperature monitoring		
17.1.2.	Top oil temperature monitoring		
17.1.3.	On-Load Tap changer temperature monitoring		
17.1.4.	Cooling system and fan control.		
17.1.5.	PRD actuation alarms		
17.1.6.	Main and OLTC conservator compartments oil level monitoring.		
17.1.7.	Gas and moisture in oil monitoring		
18.	**Control Box**		

18.1.	All control and protection devices, switches, CT terminals, etc., will be assembled in a dustproof and weatherproof box, with a temperature and humidity control system, mounted directly on the tank walls or in its proximity, considering clauses 2 and in accordance with:	IEC 61439	
18.2.	The degree of protection shall be at least IP 55 According to	IEC 60529	
18.3.	Electromagnetic Control box code shall be at least EM4677xx, according to:	IEC 61000-5-7	
18.4.	The control box shall be supported by suitable vibration damping device designed to withstand the seismic characteristics described in:	Clause 3	
18.5.	The coating must be designed to withstand the Climatic and Environmental Conditions according to:	Clauses 2	
18.6.	Thermal calculations of the control box must be performed according to	IEC 61439	
19.	**Tank**		
19.1.	The transformer tank shall be of welded steel plate construction reinforced to withstand the most severe conditions of operation, transport and vacuum treatment according to:	IEC 60076-1	
19.2.	The transformer tank shall be absolutely water and hot-oil tight and provided with an oil tight cover according to:	IEC 60076-1, Clauses 11.8 and 11.11	
19.3.	The mechanical design of the tank should avoid any accumulation of water.		
19.4.	Tank anchorage design according to:	IEEE 693-2018, cl. D 8.2	
19.5.	Grounding pads should be designed at least for the maximum short circuit current according to:	• Clause 1.3 • IEC 60076-22-7	
19.6.	It is advisable to include in the tank design a suitable support for surge arresters mounting to minimize the distance between them and the bushings.		

19.7.	Ground connection must be provided to all removable metal parts and accessories of the transformer.		
20.	**Coating Application System**		
20.1.	The coating system shall supply protection against atmospheric erosion and corrosion. The coating type and application system shall be according to environmental condition as described in:	Clause 2	
20.2.	All coating for internal and external parts must be compatible with the transformer oil		
20.3.	Certificates of mechanical inspection and coating must be included in FAT report.		
21.	**Rating plates**		
21.1.	The Rating Plate must include all the information requested in:	IEC 60076-1 cl. 8	
21.2.	Data on the Rating Plate must be engraved with any system that guarantees its readability throughout the transformer service life.		
22.	**Transformer test**		
22.1.	**Routine tests** according to:	IEC 60076-1 cl.11	
	All routine tests and marked (*) special tests shall be performed on each supplied power transformer		
22.1.1.	Measurement of winding resistance according to:	IEC 60076-1 subcl.11.12	
22.1.2.	Measurement of voltage ratio and check of phase displacement according to:	IEC 60076-1 subcl.11.3	
22.1.3.	Measuring of short-circuit impedance and load losses. Shall be performed at principal tap and on the highest and lowest tap	IEC 60076-1 subcl.11.4	
22.1.4.	Measuring of no-load loss and exciting current, according to	IEC 60076-1 subcl.11.5	
22.1.5.	Dielectric Test Sequence:	IEC 60076-3 sub clause 7.2.3	
22.1.5.1.	Full wave lightning impulse test (LI) [kV peak]	IEC 60076-3 cl. 7.3.2.1. a	
22.1.5.2.	Applied voltage test (AV)	IEC 60076-3 cl. 7.3.2.1. b	

22.1.5.3.	Line terminal AC withstand voltage test for non-uniformly insulated transformers (LTAC) according to [kV R.M.S].	IEC 60076-3 cl. 7.3.2.1. d	
22.1.5.4.	Induce voltage test & partial discharges (PD) (IVPD) [kV R.M.S]	IEC 60076-3 cl. 7.3.2.1. e	
22.1.6.	Test on on load tap changer, where appropriate according to:	IEC 60076-1 cl. 11.7	
22.1.7.	Leak testing with pressure according to:	IEC 60076-1 cl. 11.8	
22.1.8.	Check of ratio and polarity of built in CTs		
22.1.9.	Check of core and frame insulation according to:	IEC 60076-1 cl. 11.12	
22.1.10.	Determination of capacitances windings to earth and between windings		
22.1.11.	Measurement of the dissipation factor (tan δ) of the insulation system capacitances	IEEE Std C.57.12.90 subcl.10.10	
22.1.12.	Measurement of dissolved gasses in dielectric liquid according to:	IEC 61181 IEC 60567	
22.1.13.	Measurement of non-load loss and current at 90% and 110% of rated voltage according to	IEC 60076-1 cl. 11.5	
22.2.	**Type test** according to:	IEC 60076-1 cl. 11	
	Type tests and special tests marked (**) shall be carried out on at least one transformer, when one or more transformers are supplied under the same Functional Specifications in clause 6		
22.2.1.	Temperature-rise tests according to:	IEC 60076-2	
	In the case of two or more power ratings indicated on the nameplate (for example, where two or more cooling methods are provided), tests must be carried out for all declared power ratings.		
22.2.2.	A chromatographic analysis of dissolved gases in the oil shall be performed before and after the temperature rise test according to	IEC 61181 IEC 60567	
22.2.3.	Determination of transformer sound level with the OLTC on the principal tapping and other tap position if needed for maximum sound level, and for each method of cooling, including No load excitation and Short-circuit impedance voltage rated current according to:	IEC 60076-10	
22.2.4.	Measurement of the power taken by the cooling system		

22.3.	**Special tests** according to:	IEC 60076-1 cl. 11	
	*** Special tests required by NOGA for all routine and type test transformers** **** NOGA required special test in type test transformers only**		
22.3.1.	Dielectric special test according to:	IEC 60076-3 cl. 7.3.2	
22.3.1.1.	* Lightning impulse test on the neutral terminal (LIN)	IEC 60076-3 cl. 7.3.2.2 d	
22.3.1.2.	Lightning impulses applied to multiple line terminals simultaneously (LIMT)	IEC 60076-3 cl. 7.3.2.2 e	
22.3.1.3.	Switching impulse test (SI)	IEC 60076-3 cl. 7.3.2.2 a	
22.3.1.4.	* Chopped wave lightning impulse test (LIC)	IEC 60076-3 cl. 7.3.2.2 b	
22.3.1.5.	Line terminal AC withstand voltage test (LTAC)	IEC 60076-3 cl. 7.3.2.2 c	
22.3.2.	Winding hot-spot temperature-rise measurement as a part of temperature-rise test according to:	IEC 60076-1 clause 11.1.4 b	
22.3.3.	Determination of the transient voltage transfer characteristics according to:	IEC 60076-3: 2018 Annex B	
22.3.4.	**The thermal and dynamic ability to withstand the short-circuit currents shall be demonstrated by calculation according to:	IEC 60076-5	
22.3.5.	* Measurement of d.c. insulation resistance: each winding to earth and between windings		
22.3.6.	** Measurement of zero-sequence impedance, on each power transformer according to:	IEC 60076-1 cl. 11.6	
22.3.7.	* CT insulation resistance measurement tests shall be performed for each transformer, on the CT terminals block, at [kV r.m.s]	2.5	
22.3.8.	** Vacuum deflection test according to:	IEC 60076-1 cl. 11.9	
22.3.9.	** Pressure deflection test according to:	IEC 60076-1 cl. 11.10	
22.3.10.	* Vacuum tightness test according to:	IEC 60076-1 cl. 11.11	
22.3.11.	* Measurement of frequency response (SFRA)	IEC 60076-18	
22.3.12.	* Check of external coating according to:	ISO 2178 and 2409 or as specified	
23.	**NOGA additional tests requirements**		

23.1.	If the transformer is shipped without oil, the moisture content of the air inside the transformer, as a percentage of the dry weight of the insulation, must be provided for each delivered transformer in accordance with:	IEEE Std C57.93-2019	
23.1.1.	The moisture content in percent of insulation dry weight on each transformer shall not exceed [%]	1	
23.2.	Measurement of the bushing's dielectric dissipation factor (tan δ) and C1-C2		
24.	**Cyber & Information Security**		
24.1.	Security information of the equipment designing and manufacturing according to:	Israel Grid code	
24.2.	Network and security safeguards of the equipment.		
25.	**Required Attachments**		
25.1.	Transformer instruction book		
25.2.	Buchholtz Relay: C.O.T and Type test certificates according to:	IEC 60076-22	
25.3.	PRD: C.O.T and Type test certificates according to	IEC 60076-22	
25.4.	Bushings: Routine and Type Test certificates, data sheet and drawings, including sheds profile drawings according to:	IEC 60137	
25.5.	Bushings seismic qualification test	According to clause 7.16	
25.6.	Tap Changer and AVR: Routine and Type Test certificate according to:	IEC 60214	
25.7.	Calculations demonstrating that the transformer complies with the clause 3: Seismic Qualification Level for the following components:	• Tank • Core and coils • Anchorage • Radiators • Conservators • Control cabinets	
25.8.	Oil certificates according to	Annex 1	
25.9.	Rating plate drawing		
25.10.	Drawing of the transformer general dimensions		
25.11.	Anchoring system drawing of the transformer and pad.		
25.12.	FAT and SAT tests reports		

25.13.	A manufacturer commissioning authorization according to:	Clause 26.3	
26.	**FAT, Arrival test and SAT**		
26.1.	• NOGA must evaluate and approve the content of the FAT and SAT programs. The FAT program must be submitted to NOGA at least 1 month before the scheduled test date and SAT program at least 1 month before the scheduled installation date. • The FAT program and report must include the description of each test, the applicable standard, test voltage (where applicable), acceptance criteria, guaranteed values, and tolerances. The FAT report must include a Rating Plate drawing. • The results of the FAT and SAT must be sent to NOGA for evaluation. • **The transformer will not be shipped to its destination before obtaining the FAT approval by NOGA**.		
26.2.	**Arrival test and SAT**: The manufacturer can suggest alternatives for the Arrival test and SAT. The final content will be agreed between the customer, the manufacturer and NOGA. The Arrival test and SAT programs must include at least the recommendations of standard:	IEEE C57.150	
26.3.	**The manufacturer must grant a commissioning authorization based in the results of the SAT report.**		
27.	**Operational experience**	See Annex 2	
28.	**Reliability, Availability, Maintainability and Safety**	See Annex 3	

Annex 1: Insulation oil

Insulation oil

1.	The transformer oil shall meet the requirements indicated in:		IEC 60296
1.1.	The mixability between oils must be in accordance with:		• IEC 60296 • IEC 60422
1.2.	**Requirements for Insulation Oil:**		
	Property	**Test method**	**Limits**
1.2.1.	**Function**		
1.2.1.1.	Viscosity at 40 °C	ISO 3104	Max. 12 mm²/s
1.2.1.2.	Viscosity at -30 °C	ISO 3104	Max. 1 800 mm²/s
1.2.1.3.	Pour point	ISO 3016	Max. -40 °C
1.2.1.4.	Water content	IEC 60814	Max. 30 mg/kg [a]/40 mg/kg [b]
1.2.1.5.	Breakdown voltage	IEC 60156	Min. 30 kV/70 kV [c]
1.2.1.6.	Density at 20 °C	ISO 3675 or ISO 12185	Max. 0.895 g/ml
1.2.1.7.	DDF at 90 °C	IEC 60247 or IEC 61620	Max. 0.005
1.2.2.	**Refining/stability**		
1.2.2.1.	Appearance		Clear, free from sediment and suspended matter
1.2.2.2.	Acidity	IEC 62021-1	Max. 0.01 mg KOH/g
1.2.2.3.	Interfacial tension	EN 14210 or ASTM D971	Min. 40 mN/m
1.2.2.4.	Corrosive sulfur	DIN 51353	Not corrosive
1.2.2.5.	Anti-oxidant inhibitor	IEC 60666	0.08 - 0.40%
1.2.2.6.	Dibenzyl Disulfide (DBDS)	IEC 62697-1	Not detectable (<5 mg/kg)
1.2.2.7.	Metal passivators additives according to:	IEC 60666	Not detectable (<0.05 mg/kg)
1.2.2.8.	2-Furfural content	IEC 61198	Non-detectable (<0.05 mg/kg)
1.2.3.	**Performance**		
1.2.3.1.	Oxidation stability [f]	IEC 61125 (method C) Test duration: 500 h	
1.2.3.2.	Total acidity [f]	IEC 61125	Max. 1.2 mg KOH/g
1.2.3.3.	Sludge [f]	IEC 61125	Max. 0.8%
1.2.3.4.	DDF at 90 °C [f]	IEC 61125	Max. 0.5
1.2.4.	**Health, safety, and environment**		
1.2.4.1.	Flash point	ISO 2719	Min. 135 °C
1.2.4.2.	PCA content	BS 2000 Part 346	Max. 3%
1.2.4.3.	PCB content	IEC 61619	Not detectable (<2 mg/kg)
1.2.4.4.	[a] For bulk supply, [b] For delivery in drums, [c] After laboratory treatment,		[d] Information must be provided [e] At the end of oxidation stability test [f] To be performed at the end of oxidation stability test.

1.3.	**Requirements for Insulation Oil After Filling a New Equipment:**	
	Property	**Requirement**
1.3.1.	Appearance	Clear, free from sediment and suspended matter
1.3.2.	Colour (on scale given in ISO 2049)	Max. 2.0
1.3.3.	Breakdown voltage [kV]	>55
1.3.4.	Water content [mg/kg] [g]	< 20
1.3.5.	Acidity [mg KOH/g]	Max. 0.03
1.3.6.	DDF at 90°C and 40 to 60 Hz	Max. 0.015
1.3.7.	Resistivity at 90°C [GΩm]	Min. 60
1.3.8.	Interfacial tension [mN/m]	Min. 35
1.3.9.	Total PCB content [mg/kg] [h]	Not detectable (< 2 total)
1.3.10.	Particles (counting, sizing)	Should be made as baseline for future comparation
1.3.11.	Inhibitor content [h]	-
1.3.12.	Total gas content according to IEC 61181 [i]	< 1%
1.3.13.	DGA according to IEC 61181	-
1.3.14.	[g] The values should be without temperature correction [h] Shall be similar to the value before first filling. [i] By vacuum extraction.	
1.3.15.	The transformer oil COT shall be approved by Purchaser before delivery according to:	IEC 60296

Annex 2: Operational experience

1. Operational experience

1.1. The proposed Manufacturer's plant should have at least 9 years of experience in production of at least 170 kV to 245 kV POWER TRANSFORMERS

1.2. The bidder will provide contact details of at least 5 different customers of the bidder's 170-245 kV POWER TRANSFORMERS, whose purchase from the last 7 years (more than 1-year experience with bidder's 161 kV POWER TRANSFORMERS).

The reference list for the last 9 years shall include at least 50 units of such equipment supplied for at least 3 different countries and operated successfully for at least 1 year, and purchased during last 7 years. At least one of the countries must be from the EU (European Union) and/or OECD.

Only countries with an electrical transmission system of 170 kV and above will be accepted.

1.3. In order to prove compliance with above mentioned, the bidder is required to submit (for example) the following table, duly filled and signed by a qualified officer.

No.	170-245 kV Power Transformer data (kV, MVA)	Quantity	Purchaser name & address	Supplied date	Energizing date	Contact details
1						
2						

SPARE PARTS - Spare parts shall be available for a period of life duration of 161 kV POWER TRANSFORMERS

Annex 3: RAMS

Reliability, Availability, Maintainability and Safety (RAMs) for 161 kV Power transformers

1. Reliability:

The Bidder shall present the reliability tasks and methods which are used to improve the design for reliability, and evaluate the MTTF/MTBF for (***) Major Failures** only, of the 161 kV POWER TRANSFORMERS components.

The Bidder shall provide expected values for the relevant parameters of the 161 kV POWER TRANSFORMERS components, and shall add their distribution whenever possible.

2. Failure Analysis:

From his Failure Reporting Analysis and Corrective Action System (FRACAS), Bidder shall present a failure report and the analysis of the failures which occurred during the service life of similar 161 kV POWER TRANSFORMERS components manufactured by him. The report should include the withdrawn conclusion and the corrective actions subsequently undertaken.

*** Major failure:** Failure of a Transformer which causes the cessation of one or more of its fundamental functions.
A major failure will result in an immediate change in the system operating conditions,
e.g the backup protective equipment will be required to remove the fault, or will result in mandatory removal from service within 30 minutes for unscheduled maintenance

3. 161 kV Power transformer RAM Data

Bidder shall submit the following 161 kV Power transformer RAM Data:

	Component	MTBF (Yrs)	EOL (Yrs)	MTTR (Hrs)	
1	Three Phase Power Transformer				
2	Oil Air HV Bushing				
3	HV Bushing Current Transformers				**Where**:
4	On Load Tap Changer				**MTBF**: Mean Time between Failures, For *Major Failure
5	Tap Changer Motor Drive				**EOL**: Expected Operating Life.
6	Voltage Regulator				**MTTR**: Mean Time To Repair, for Major Failures
7	Tap-Changer Position Indicator				
8	Pressure Relief Valve				
9	Buchholtz Relay				
10	Protective Relay for OLTC				
11	Winding				

4. Field data

The bidder will fill the following table:

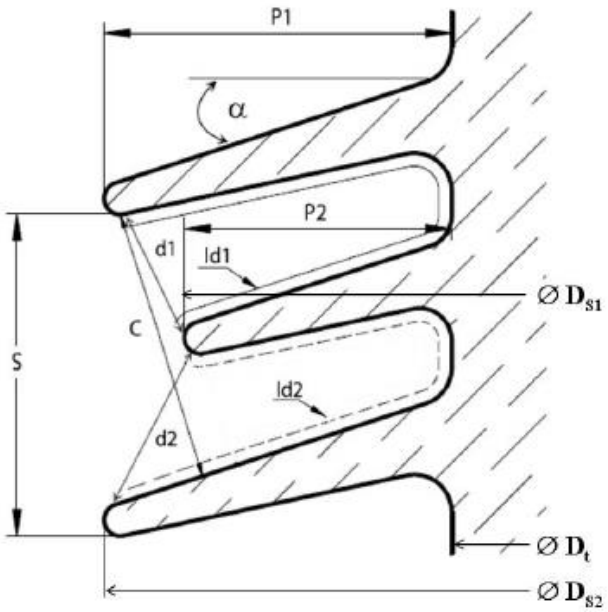
Field RAM Data		2016	2017	2018	2019	2020	2021	2022	2023	2024
Total number of installed Power Transformers 170-245 kV Voltage [kV/kV] Power [MVA]										
Total No. of Major Failures										
Specific part which undergo Major Failure	Oil Air Bushing									
	Bushing Current Transformers									
	On Load Tap Changer									
	Tap Changer Motor Drive									
	Voltage Regulator									
	Tap-Changer Position Indicator									
	Pressure Relief Device									
	Buchholtz Relay									
	Protective Relay for OLTC									
	Winding									
	Other: _____									
Mean Time to Repair/Replace										

5. Unreliability Demonstration Procedure (UDP)/Reliability Test

NOGA IISO could conduct an Unreliability Demonstration Procedure (UDP)/Reliability Test, according to NOGA IISO's Judgement. The manufacturer may request NOGA to see example for a UDP . The final UDP could be change according to each individual case and circumstances, as to be decided by NOGA IISO.

Annex 4: Bushings required profile parameters

	Required Data and Documentation	
	Flat Alternating Sheds	
	The profile parameters shall be according to the following values	



P_1-P_2	> 15 mm
S/P_1	> 0.75
C	> 40 mm
α	7° ≤ α ≤ 14°
D_a	< 300 mm
K_{ad}	1
USCD	53.7 mm/kV
A	> 1500 mm
CF = L/A	3.0 < CF < 4.5
l_1/d_1	2.5 ÷ 4.5
l_2/d_2	2.5 ÷ 4.5

P_1, P_2, S, C, α, ld_1, d_1, ld_2, d_2, D_{s1}, D_{s2}, D_t: see drawing.

$$D_a = \frac{D_{s1} + D_{s2} + 2D_t}{4}$$

L: creepage distance.

A: arcing distance.

Revision Control Table:

Rev	Date	Revision description	Approve by
01	30-08-2023	• The Environmental Conditions requirements were presented in a simplified way. • A NOGA requirement was introduced to allow the use of a temperature rise correction factor other than K = -10. • Was added a requirement for the Maximum guaranteed total sound power level	Carlos Lisman
02	29-11-2023	• The seismic qualification for all bushings will be in accordance to IEEE 693-2018 • Major Failure definition in Annex 2	Carlos Lisman Shay Reis
03	05-06-2024	Changes were made to the following clauses: • 6 Functional Specifications • 21 Rating Plates • 22 Tests • 25 “Required Attachments” • Annex 2 “RAMs” • Annex 3 “Bushings parameters”	Carlos Lisman
04	13-01-2025	Changes were made to the following clauses: • 6 Functional specifications • 19 Tank • 22 Tests • 25 Required Attachments • 26 FAT, Arrival test and SAT • Annex 4, Bushings required profile parameters • Addition of Clause 27 and change of the annexes numbering	Carlos Lisman