INDEPENDENT POWER TRANSMISSION OPERATOR S.A.
TNPRD/ SUBSTATION SPECIFICATION & EQUIPMENT SECTION

September 2017

TECHNICAL DESCRIPTION TD-31/4
REVISION No. 4

155 KV, 26.7 MVAR SHUNT CAPACITOR BANK AND ITS ASSOCIATED 123KV CURRENT TRANSFORMERS

I. SCOPE

This hereby technical description covers IPTO's requirements regarding design features, technical characteristics and testing of 26.7 MVAR, 155 KV shunt capacitor banks.

II. KEY WORDS

Shunt capacitor bank, capacitor unit, capacitor element.

III. STANDARDS

The shunt Capacitors banks shall conform to the latest edition of IEC 60871-1 standard. Additional applicable standards are IEC-871-3 and IEC-871-4.

IV. USE

The shunt capacitor banks will be used at 150 KV level of IPTO's switching stations in order to provide system voltage support whenever the system voltage is at low levels, which usually happens during summer time. The shunt capacitor banks will be usually switched twice a day (morning and afternoon).
The shunt capacitor switching will be used in conjunction with controlled switching during energization.

V. OPERATING CONDITIONS

1. Installation of the shunt capacitor banks : Outdoors
2. Limits of ambient temperature : -25°C, + 45°C
3. Altitude : Up to 1000 m above sea level

4. Pollution level : moderate

5. Other climatic conditions : Snow and ice

VI. IPTO's 150 KV ELECTRIC SYSTEM CHARACTERISTICS

1. Nominal Voltage (phase to phase) : 150 KV

2. Maximum Operating Voltage (phase to phase) : 170 KV

3. Number of phases : 3

4. Nominal Frequency : 50 Hz

5. Frequency Variation : ± 0.2 Hz

6. Short Circuit Level : 30 KA

7. Basic Insulation Level (BIL) : 750 KV

8. The 150 KV system is solidly grounded

9. Available auxiliary D.C. supply Voltage (for control and signaling) : 110 V D.C. from Substation battery

10. Available auxiliary A.C. supply Voltage (for all other uses) : 3-phase, 4-wire, 230/400 V, 50 Hz

11. Capacitor inrush current (No back to back switching is involved) : (60 – 200)×In depending on location, where In ~ 100 A

VII. REQUIRED CHARACTERISTICS, RATINGS AND CONFIGURATION OF THE SHUNT CAPACITOR BANK

1. Rated Power : 26.7 MVAR

2. Rated Voltage : 155 KV

3. Rated Frequency : 50 Hz

4. Maximum applied Voltage : 170 KV

5. Rated lightning impulse withstand voltage : 750 KV Crest

6. Rated power frequency withstand voltage : 325 KV rms

7. Connection : Star (wye) – grounded

8. Bank capacitor unit characteristics : The shunt capacitor bank shall be build with units of the same capacitance so as to avoid over-voltages.

9. Creepage distance of the bank (sum of creepage distances) : > 5270 mm

10. Phase arrangement of the units in the star-grounded bank. : The capacitor units in each phase shall be arranged in two branches with a current transformer connected between midpoints of the two branches (H bridge connection) as indicated in Fig No 1 below.
Each branch shall consist of eight series groups of capacitor units.

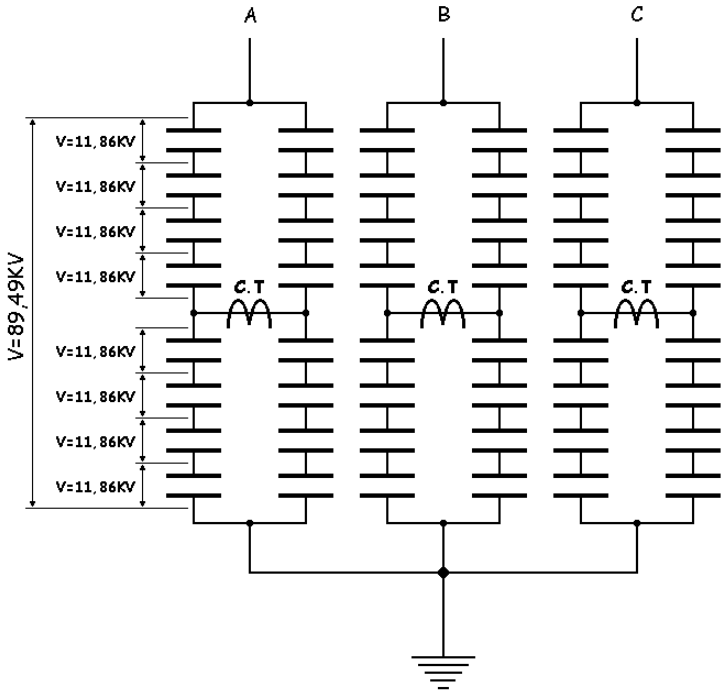

Fig No1 H-Bridge connection for the capacitor bank.

11. Installation : Outdoors.

12. Terminals : Terminals of the bank shall be suitable for connection to Cu tubes or Cu conductors via appropriate connectors (connectors not part of the supply).

13. Insulation level between frames (rack) : 95 KV A.C.

14. Creepage distance between frames : 1300 mm (min)

VIII. REQUIRED CAPACITOR UNIT CHARACTERISTICS AND DESIGN FEATURES

1. Number of Bushings : Two (2)

2. Type of material for the outer housing of the bushings : Porcelain

3. Color of the porcelain : Grey

4. Type of fuses : Each capacitor element of the capacitor unit shall be protected by an internal fuse.

5. Temperature category : - 25 C/B, B = +45 C

6. Rated Voltage : 11.186 KV

7. Rated frequency : 50 Hz

8. Rated power : 556.2 KVAR

9. Rated lightning impulse withstand voltage. : 125 KV crest

10. Rated power frequency withstand voltage between terminals and container : 28 KV rms

11. Creepage of bushings : 660 mm

12. Dielectric fluid : The capacitor units shall be hermetically sealed and the fluid used for impregnation shall be non – toxic and biodegradable.
Dielectric fluids such as polychlorinated biphenyls (PCBs or PCTs) are not allowed due to their toxicity and damage to the environment. Only non – toxic dielectric fluids are allowed.

13. Discharge devices : Each capacitor unit shall contain built-in discharge resistors which shall reduse the voltage across its terminals to 75 V within 600 sec.

14. Insulation level between terminals : 22,4kV AC

IX. REQUIRED CHARACTERISTICS OF THE CAPACITOR ELEMENTS

1. Construction characteristics : All capacitor elements which are to be used for the construction of each capacitor unit must be of the all–film dielectric type (dielectric part) and of pure aluminium foil (the electrode)

2. Protection : All capacitor elements shall be protected by appropriate internal fuses.

X. OVERLOADS AND TOLERANCES

1. Maximum permissible Voltages

Capacitor units shall be suitable for operation at voltage levels according to the table No 1 below:

Table No 1. Admissible Voltage level in service

Type	Voltage factor XU_N (V rms)	Maximum duration
Power Frequency	1,00	Continuous
Power Frequency	1,10	12 h in every 24 h
Power Frequency	1,15	30 min in every 24 h
Power Frequency	1,20	5 min
Power Frequency	1,30	1 min
Power Frequency Harmonics	1,10	-

2. **Maximum permissible currents**

Capacitors units shall be suitable for continuous operation at an r.m.s. current of 1.30 times the current that occurs at rated sinusoidal voltage and rated frequency, excluding transients.

3. **Switching overvoltages withstand**

The capacitors shall be able to withstand with no problems a switching overvoltage of first peak of $\leq 2\sqrt{2}$ U_N for a maximum duration of 1/2 cycle for 1000 times per year.

4. **Transient overcurrents withstand**

The capacitor units shall be capable of withstanding switching overcurrents (inrush currents) up to a value of 100 I_N (r.m.s. value).

5. **Capacitance tolerances**

The capacitance shall not differ from the rated capacitance by more than 0 % to +5%.

XI. Internal fuses

1. All capacitor elements of each capacitor unit shall be equipped with internal fuses which are to be used to isolate faulty capacitor elements in order to allow operation of the remaining parts of the capacitor unit and the bank in which the capacitor units are part of.

2. The fuses are to be connected in series with the capacitor elements and must be of the current limiting type.

3. Throughout the life of the capacitor, the fuses shall be capable of carrying continuously a current equal to their maximum permissible current.

4. The fuses shall be capable of withstanding the inrush – currents due to the switching operations expected during the life of the capacitor.

5. The fuses connected to the undamaged elements shall be able to curry the discharge currents due to the breakdown of elements.

6. The fuses shall be able to carry the currents due to short – circuit faults on the bank external to the units.

XII. Support structure of the shunt capacitor bank

1. The offer for the capacitor bank shall include a suitable metallic structure.

2. The support structure shall either be of hot-dipped galvanized steel or of aluminum.

3. The capacitor bank shall be placed on the support structure in such a manner so that the base of the lowest support insulators of the bank is at a distance of 2.30 meters above ground level.

4. The entire support structure along with the capacitor units, support (frame) insulators, current transformers and bus-work must be able to withstand the dynamic forces induced by an earthquake producing ground accelerations of 0.5 g horizontally and 0.3 g vertically and with frequency range of 0.3-10 Hz without using special devices (vibration dampers etc.)

XIII ADDITIONAL REQUIRED SHUNT CAPACITOR BANK EQUIPMENT

1. Current transformers for unbalance detection

The three (3) transformers which shall be used for the detection of unbalance when element fuses are blown must be part of the supply.

They will be preferably installed on the same support structure along with the capacitor units.

These current transformers shall have the following characteristics:

a.	CT rated voltage	:	123 KV
b.	Basic Insulation level (BIL)	:	550 KV
c.	Accuracy class	:	10P10
d.	Rated output	:	10 VA
e.	Installation	:	on support structure
f.	Creepage distance of the CT housing	:	3600 mm
g.	Type of housing	:	Silicon rubber
h.	Testing	:	Routine and type testing shall be as per IEC 61869
i.	Ratio	:	1/1 A
j.	Alarm and trip signals	:	The CTs will be used to provide alarm signal after two (2) faulty elements and trip signal after four (4) faulty elements.
k.	Active part	:	The active part of the CT must be preferably located of the lower part of the CT.
l.	Rated frequency	:	50 Hz
m.	Temperature category	:	- 25 / +45 C
n.	Rated short – time thermal current	:	0.6 KA/1sec
o.	Rated dynamic current	:	1.5 KA
p.	Rated lightning impulse withstand voltage	:	550 KV crest
q.	Power frequency withstand voltage of primary and secondary winding	:	230KV rms and 3 KV correspondingly
r.	Static loading withstand	:	2000 N
s.	Type	:	Outdoor, oil immersed type.
t.	Partial discharge level and dielectric dissipation factor	:	5 pc at 85 KV, < 0.005 at 71 KV.
u.	Primary terminals	:	Cu, Cylindrical in shape with

		30 mm in diameter and 80 mm in length.
v.	Chopped impulse voltage withstand	: 633 KV
w.	Required accessories	: Oil level indicator, oil-filling plug, oil-drain plug, lifting lugs, and a special terminal for measuring tan δ, which shall be short-circuited during normal operation.
x.	Sealing and bellows	: The CTs shall be fully protected against humidity. Oil volume changes will be received by bellows, preferably metallic.
y.	Type of oil	: Oil shall be non-toxic and biodegradable as per IEC-60296.
z.	Secondary terminals	: Shall be of the screw type and suitable to be wired with 4 mm^2 size Cu conductors.

2. <u>Support Structure (frame) Insulators</u>

a.	Number of insulators	: The number will be determined by the supplier depending on the number of capacitor unit racks used for the bank, the total creepage distance requirement of the bank and the creepage distance between frames
b.	Creepage distance of insulators	: The creepage distance of each support insulator will be determined by the supplier taking into consideration the total creepage distance requirement for the bank and insulation between frames (racks). In any case it can not be < 600mm
c.	Material of the support insulators	: Porcelain of grey color

3. <u>Bus-work and other connecting components</u>

The supplier must provide all necessary bus-work and connecting components for the assembling the shunt capacitor bank.

XIV. SHUNT CAPACITOR BANK PROTECTION

1. **Element Protection**

Capacitor elements shall be protected be internal fuses as described in paragraph XI.

2. **Unbalance protection**

The shunt capacitor bank shall be protected against unbalances caused by faulty elements (blown fuses) via CTs located in each phase of the bridge connection.
(Two faulty elements-an alarm, four faulty elements-trip).

3. **Overcurrent and overload protection**

The shunt capacitor bank shall be protected against phase and ground faults and excessive currents associated with voltage disturbances and harmonics.

4. **Overvoltage protection**

The shunt capacitor bank shall be protected against overvoltages.

XV. TESTS

This section gives the test requirements for capacitor units and it is in accordance with IEC-60871.

1. **Routine Tests**

a. Capacitance measurement

The capacitance shall be measured at 0.9 to 1.1 times the rated voltage, using a method that excludes errors due to harmonics.

b. Measurement of the tangent of the loss angle (tan δ) of the capacitor

The tan δ shall be measured at 0.9 to 1.1 times rated voltage at 20 ^{o} C using a method that excludes errors due to harmonics.

c. Voltage test between terminals

The capacitor shall be subject for 10 sec to either an A.C. test with sinusoidal voltage of $Ut = 2\ U_N$ where U_N = rated voltage of the capacitor or to D.C. test with a test voltage of $Ut = 4\ U_N$.

d. A.C voltage test between terminals and container

Time duration of the test = 10 s
Test voltage = $2.5 \times U_N \times n$
Where : U_N = rated voltage of the capacitor
n = number of units in series relative to the electrical potential to which the containers are connected.

e. Test of internal discharge device

f. Sealing test

g. Discharge test on internal fuses

According to IEC 60871-4.

2. **Type tests**

a. Thermal stability test

b. Measurement of the tangent of the loss angle (tan δ) of the capacitor at elevated temperature

Tan δ shall be measured at the end of the thermal stability test and with the thermal stability voltage.

c. AC Voltage test between terminals and container

Test duration = 1 minute
Test voltage = $2.5 \times U_N \times n$
The tests are with artificial rain.

d. Lightning impulse voltage test between terminals and container

Impulse test voltage : 75 KV Crest

- Fifteen impulses of positive polarity
- Fifteen impulses of negative polarity
- wave 1.2/50 μs to 5/50 μs

e. Short – circuit discharge test

f. Disconnecting test on internal fuses

According to IEC 60871-4.

NOTE : Official test reports for the above type test can be submitted along with the offer if available. IPTO maintains the right to accept them or not.

XVI. MARKINGS

A. Markings on the Capacitor Unit

The following information shall be given on the plate of each capacitor unit.

1. Manufacturer
2. Identification number and manufacturing year.
3. Rated output Q_N in kilovars.
4. Rated Voltage U_N in kilovolts.
5. Rated frequency f_N in Hz.
6. Temperature category.
7. Discharge device – The rated ohmic value shall be indicated.

B. Markings on the Bank

The following information shall be given on a plate. This plate shall be suitable for being mounted on the bank's steel structure and on a location visible from ground level.

1. Manufacturer.
2. Total rated output Q_N in megavars.
3. Rated Voltage U_N in kilovolts.
4. Insulation level (power – frequency voltage/lightning impulse withstand Voltage).
5. Connection symbol (Y_N).
6. Minimum time required between disconnection and reclosure of the bank.
7. Time to discharge to 75 V.

XVII. ECONOMIC COMPARISON OF OFFERS AND POWER LOSSES

The economic comparison of the offers shall be based on the capacitor bank total initial cost. The total initial cost will be computed by the purchaser, who will consider the Seller C & F price, as amended after the evaluation of the proposed terms of payment.

The guaranteed losses will not be greater than 0.17W/KVar ($\tan\delta \leq 0.17X10^{-3}$) at rated voltage and frequency and at 20 ^{o}C. If during rutine testing, the measured losses of a number of capacitor units exceed the above mentioned loss limit, taking into account the allowable tolerance of +10%, a time extension up to 8 hours for new loss measurements of the certain capacitors units will be provided. During that time period the under testing units will be on voltage continuously. If during the measurements process at the end of the above time period, the measured values of losses are still greater than the required ones, then the manufacturer is obliged to perform a thermal stability type test and the new values of losses used for comparison reasons will come up from the application of the following method:

A thermal stability type test will be executed on a sample of capacitor units, according to ISO-2891, for general inspection level 1, acceptance quality limit following table 2A (normal inspection) and for zero number of pieces not following the power loss limit required by the specification. The correction coefficient, which will come up from the above type test, will be used for the correction of the measured power losses at the routine tests and it will be the mean value of the ratios of the measured losses, of the samples.

$$\frac{P_{loss,init} - P_{loss,stabil}}{P_{loss,init}} \quad (I)$$

where

$P_{loss,init}$: intial power losses before the thermal stability test

$P_{loss,stabil}$: power losses after the thermal stability test.

During the power loss measurement at the routing tests, the measured losses shall be corrected using the above coefficient (I) and will be compared with the limit of losses required in the specification.

If even after the above proceeding, a number of capacitor units are still not in compliance with the limit of 0.17W/KVar (+10% tolerance), then the specific capacitor units will be rejected and replaced by new ones complying with the above specified limits.

XVIII. DATA TO BE SUBMITTED BY BIDDERS

1. Bidders must provide all information requested in "ATTACHMENT A" of this hereby technical description. Failure on the bidder's part to comply with this request will be taken as sufficient reason for rejection of the offer.

2. A three – phase electrical diagram of the bank.

3. Technical pamphlets and brochures which will help the evaluation process.

4. Drawings showing the outline dimensions of

   a. The bank itself including the support structure.
   b. The capacitor units.
   c. The CTs.
   d. Support insulators.

5. Data for the support structure, internal fuses, discharge devices, CTs, insulators and capacitor elements.

6. Any official test reports for the required type tests and any seismic test reports.

7. A study can be submitted if no seismic test reports are available.

8. The time required to elapse between deenergization and energization of the capacitor bank.

XIX. DATA TO BE SUBMITTED BY THE SUCCESSFUL BIDDER

After the signing of the contract, the successful bidder shall furnish three (3) sets of drawings for approval, prior to the capacitor bank construction.
These drawings shall include the following:

1. Capacitor bank detailed outline dimensions. Capacitor bank along with its support structure.
   This shall include top and side view of the bank mounted on its support structure (frame).

2. Detailed drawing indicating the capacitor bank points of connections to the other station equipment.

3. Three (3) phase electrical diagram of the bank.

4. Wiring and outline drawings for the CTs for the unbalance protection and terminal markings of the unbalance CTs.

XX. PACKING

1. The capacitor units shall be packed inside robust wooden boxes.

2. The support structures (frame) shall be delivered in such a manner as to be easily identified per capacitor bank. In other words all sections of the support structure must bear proper labels or markings.

3. All bus work and connecting materials shall be packed inside robust wooden boxes and be easily identified per capacitor bank.

4. The CTs shall be packed inside robust wooden boxes, three per box.

5. All post insulators shall also be packed inside robust wooden boxes easily identifiable per capacitor bank.

6. All the above mentioned wooden boxes will be of pallet type, closed, of at least 20 mm thickness and they will be protected internally by an insulating material (eg. nylon)

XXI. SPARE PARTS

Supply of one capacitor unit per shunt capacitor bank (26,7 MVar) will be included in the offer

" ATTACHMENT A"
155 KV, 26.7 MVAR SHUNT CAPACITOR BANK
AND
ITS ASSOCIATED 123KV CURRENT TRANSFORMERS

Data to be provided by bidders.
Failure to comply will constitute sufficient reason for rejection of the offer.

A. Capacitor Elements

1. Type of elements and ohmic value : ……
2. How are the elements protected? : ……

B. Capacitor Units

1. Number of bushings : ……
2. Temperature category : ……
3. Rated Voltage : ……
4. Rated Frequency : ……
5. Rated Power : ……..
6. Lightning impulse withstand voltage : ……
7. Power frequency withstand voltage : ……..
8. Material of terminals : ……..
9. Creepage of bushings : ……
10. Type dielectric fluid. Toxic fluids are not allowed. : ……..
11. Is discharge device included which shall reduce the voltage to 75 V within 10 minutes? : ……
12. Type of material of the outer housing of the bushings : ……
13. Color of the porcelain housing : ……
14. Insulation level between terminals : ……
15. AC withstand voltage between terminals and container : ……

C. Capacitor Bank

1. Rated Power : ……..
2. Rated Voltage : ……..
3. Rated frequency : ……
4. Maximum Voltage : …….
5. Lightning impulse withstand Voltage : …….
6. Power frequency withstand Voltage : …….
7. Connection : ……
8. Is the bank composed of units of the same size ? : ……
9. Total creepage distance of the bank (sum of creepage distance) : …….
10. Phase arrangement of the capacitor units in the star-grounded bank : ……..
11. Number of units groups in series per branch of the H bridge : ……..
12. Installation : …….
13. Insulation between frames (racks) : ……..
14. Creepage distance between frames : ……

D. Other Information

1. Are the requirements of paragraph X-1 met? : ……
2. Maximum permissible current of the capacitor units. : …….
3. Switching overvoltage withstand (Indicate also duration and times per year) : …….
4. Transient overcurrent withstand : ……

5. Capacitance Tolerances (if any) : ……...

6. Indicate the maximum permissible continuous current of each internal fuse. : ……

7. Are the internal fuses capable of carrying the short-circuit fault currents external to the units ? : ……

8. Current produced by the loss of two (2) capacitor elements : ……

9. Current produced by the loss of four (4) capacitor elements. : ……..

10. Is a support structure (frame) provided? : ……..

11. Kind of metal used for the support structure. : …….....

12. Is the base of the lowest support insulators on the support structure 2.3 meters above ground level ? : ……

13. Is the requirement of paragraph XII-4 met? : …….....

14. Are the bus and connecting components for assembling the bank provided ? : ……..

E. <u>Current transformers for unbalance detection</u>

1. Are three (3) single phase CTs provided? : ……..

2. Rated voltage : ……..

3. BIL : ……

4. Accuracy class : ……

5. Rated output : ……

6. Ratio : ……

7. Type of housing : ……

8. Creepage distance of housing : ……

9. Current flowing when two (2) capacitors

elements are lost. : ……..

10. Current flowing when four (4) capacitor elements are lost. : …….

11. Location of active part. : ……

12. Installation : ……

13. Temperature category : ……...

14. Rated short-time thermal current : ……...

15. Rated dynamic current : ……

16. Power frequency withstand voltage of primary winding : ……

17. Power frequency withstand voltage of secondary winding : ……

18. Static loading withstand : ……

19. Type of bellows : ……

20. Type of oil : …….

21. Description of primary terminals : ……..

22. Partial discharge level : ……..

23. Type of secondary terminals : …….

24. Dielectric dissipation factor : ……..

25. Chopped impulse voltage withstand : ……..

26. Rated lightning impulse withstand voltage of primary winding : ……..

27. Accessories : ……..

……..

……..

……..

F. Support (frame) Insulators

1. Total number of support insulators : ……..
2. Material of the support insulators : ……..
3. Creepage distance of each support insulator : ……..
4. Color of the support insulators : ……..

G. Tests

1. Can the offered capacitors be tested in accordance with the requirements of paragraph XV-1 and XV-2 ? : ……

H. Markings

1. Will the markings be in accordance with the requirements of paragraph XVI ? : ……

I. Elapse time

1. The elapse time required between deenergization and energization of the capacitor bank. : ……

J. Guaranteed Capacitor losses

1. Capacitor losses in W/KVAR : ……

K. Deviations

1. List deviations, if any. : ……