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## 0.1 Circulation List

| COPY NO. | COPY HOLDER |
|---|---|
| 1 | Research & Development Manager |
| 2 | Procurement Manager |
| 3 | Stores & Stock Control Manager |
| 4 | Technical Services Manager |
| 5 | Assistant Manager Technical Audit |

## 0.2 Amendment Record

| Rev No. | Date (YYYY-MM-DD) | Description of Change | Prepared by (Name & Signature) | Approved by (Name & Signature) |
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## FOREWORD

This specification has been prepared by the Research and Development and Technical Service Departments of The Kenya Power and Lighting Company Limited (KPLC) and it lays down requirements for 11kV Voltage Regulators. It is intended for use by KPLC in purchasing the equipment.

It shall be the responsibility of the manufacturer to ensure adequacy of the design and good engineering practice in the manufacture of the voltage regulators for KPLC. The manufacturer shall submit information which confirms satisfactory service experience with products which fall within the scope of this specification.

## 1. SCOPE

1.1 This specification is for oil-immersed, air-cooled step voltage regulators for 11kV distribution system operated at 50 Hz.

1.2 This specification covers step voltage regulators of the following voltage ratios and ratings:

a) 11000/11000±10% volts single-phase step voltage regulator rated 110 KVA. Load current: 100 Amps.

b) 11000/11000±10% volts single-phase step voltage regulator rated 220 KVA. Load current: 200 Amps.

## 2. REFERENCES

The following documents were referred to during the preparation of this specification; in case of conflict, the requirements of this specification shall take precedence.

IEEE Std C57.15: IEEE Standard Requirements, Terminology, and Test Code for Step-Voltage Regulators.

IEC 60076: Power Transformers.

IEC 60296: Specification for unused mineral insulating oil for transformers and switchgear.

IEC 60354: Loading guide for oil – immersed power transformers.

BS 381C: Specification for colours for identification, coding and special purposes.

## 3. TERMS AND DEFINITIONS

For the purpose of this specification the definitions given in the reference standards shall apply.

## 4. REQUIREMENTS

### 4.1 SERVICE CONDITIONS

4.1.1 Climatic Conditions

The voltage regulators shall be suitable for continuous operation outdoors in tropical areas at altitudes of up to 2200m above sea level, humidity of up to 90%, average ambient temperature of +30°C with a minimum of -1°C and a maximum of +40°C, heavy saline conditions along the coast and isokeraunic levels of up to 180 thunderstorm days per year.

4.1.2 System Conditions

4.1.2.1 The voltage regulators will be connected between line to line (delta configuration) or line and earth (star configuration) in a 3-phase system with the neutral point solidly earthed.

4.1.2.2 The overhead system is of unearthed construction i.e. without aerial earth wire. The system nominal voltage is 11000 Volts with system highest voltage of 12000 Volts and a frequency of 50Hz. Both primary and secondary systems are 3-phase 3-wires.

### 4.2 DESIGN AND CONSTRUCTION

4.2.1 The regulators furnished under this specification shall be designed, manufactured, and tested in accordance with IEEE Std C57.15, latest revision thereof. That Standard shall form part of this specification.

4.2.2 The Regulators shall be designed to be connected to a 11kV 3 phase system in a closed delta or open delta formation. It should also be possible to connect the Regulators in star (Y) formation.

4.2.3 The design shall have internal voltage tap settings that allow star connections. The internal tappings shall be clearly marked and shall apply to both primary and secondary windings of the transformer such that the control voltage does not change for all applications.

4.2.4 Drawings and documentation for each size of voltage regulator offered shall be submitted, clearly detailing important dimensions, regulator connections, clearances, accessories, fittings and any special features of offered design. The connections shall include the following:

a) Two regulators 3-phase 3-wire circuit (open-delta connection)
b) Three regulators 3-phase 3-wire circuit (closed-delta connection)
c) Three regulators 3-phase 4-wire circuit (star connection)

## 4.3 INTERNAL FEATURES CONSTRUCTION

4.3.1 The step-type voltage regulators shall be of outdoor, single-phase, oil-immersed construction.

4.3.2 The cooling shall be ONAN. Forced air (FA) ratings are not acceptable.

4.3.3 Loading shall be as per IEC 60354.

4.3.4 The regulators shall be supplied complete with new oil as per IEC 60296 (class 1 un-inhibited).

4.3.5 The manufacturer shall provide the chemical composition and properties of the oil and replacement cycle.

4.3.6 The voltage regulators shall be completely self-contained and provide ±10% regulation in thirty-two (32) steps of approximately ⅝ percent each.

4.3.7 The regulators shall be designed such that they can be partially or completely untanked for inspection and maintenance without disconnecting any internal electrical or mechanical connections.

4.3.8 The tap-changing mechanism shall be motor-driven, quick-break slow-make type, and shall be completely oil-immersed.

4.3.9 The regulator shall be automatically controlled responding to changes in the system voltage to initiate the desired tap change.

4.3.10 The regulator shall be of a sealed-tank construction to permit operation at oil and winding hot spot temperature of 55°C and 65°C rise respectively without increasing the oxidation rate of the oil.

4.3.11 The inside of the tank shall be coated with oil resisting varnish or paint so that oil cannot come into contact with tank or metal at any point.

4.3.12 The regulator winding shall include thermally upgraded insulation to permit operation of the regulator up to 65°C rise without loss of life to the insulating system.

4.3.13 At 65°C rise, the regulator shall provide 12% extra current capacity over the base current rating.

4.3.14 A suitably patterned, epoxy-coated insulation paper shall be used in the winding. Prior to assembly of the core and winding assembly, the winding shall be baked with sufficient mechanical pressure exerted on the winding to assure a complete bonding of the insulation to improve its short-circuit current withstand capabilities as specified by IEEE Std C57.15.

4.3.15 The windings shall be of high conductivity electrolytic copper capable of sustaining short circuit forces on the regulator.

4.3.16 An appropriately rated current transformer shall be provided and be capable of handling the burden from the metering and control functions.

4.3.17 The series windings shall have Load bonus feature which shall allow extra current flow above the rated for reduced regulation limits (the upper limit being ±10%). The manufacturer shall provide a table showing the load bonus versus regulation limits settings.

## 4.4 EXTERNAL FEATURES CONSTRUCTION

4.4.1 The tank shall be round, sealed and constructed of mild steel plates fabricated by pressing or rolling.

4.4.2 The complete regulator shall be painted to protect against corrosion, and the final colour of the exterior surface shall be Dark Admiralty Grey colour No. 632 as per BS 381C with a coating of not less than 80 microns

4.4.3 Three bushing designated S (source), L (load), and SL shall be marked (permanently) on the regulator cover adjacent to the bushings. The S, L, and SL bushings must be interchangeable with each other.

4.4.3 Each bushing shall include clamp-type terminal suitable for current rating of the regulator.

4.4.4 All regulators shall be provided with an external metal oxide varistor (MOV) bypass arrester connected across the series winding.

4.4.5 An external oil sight gauge shall be provided which indicates oil level.

4.4.6 An external dial-type position indicator with drag hand and load bonus adjustment shall indicate the tap changer position. The position indicator shall be mounted above the oil level and slanted downward at a 45-degree angle for ease of reading when the regulator is pole mounted.

4.4.7 Mounting bosses shall be provided for the installation of lightning arresters adjacent to the source (S), load (L), and source-load (SL) bushings. The bosses shall be fully welded around their circumference. Spot welding is not acceptable.

4.4.8 Three number surge arrestors of rated voltage 12kV; 10KA discharge class 2 shall be connected to the S, L and S-L bushings.

4.4.9 All regulators shall NOT have a drain valve and upper filter press connection. These shall be sealed.

4.4.10 A hand hole with cover shall be provided on top of the regulator for inspection purposes and for access to terminals used for reconnection of regulators for lower-voltage operation.

4.4.11 The regulators shall be provided with a base suitable for securing them to a pad or elevating structure. All regulators must be capable of being secured to elevating structures.

4.4.12 Each regulator shall be provided with two laser-etched nameplates, one mounted on the control enclosure and the other mounted on the regulator tank. The nameplate shall include technical details of the regulator, manufacturer's name, type reference and serial numbers with a 6mm (0.25") minimum height.

4.4.13 In addition, each regulator shall be complete with the following parts/accessories:

a) Load bonus position indicator;
b) Lifting lug for complete unit;
c) Control cabinet;
d) Ground pad;
e) Minimum oil gauge;
f) Pressure Relief;
g) Lifting eyes for cover and internal assembly;
h) Steel channel base.

## 4.5 RATINGS

**4.5.1** The ratings for the regulator shall be as shown in the table for service conditions as per IEEE Std C57.15. The manufacturer however shall apply appropriate de-rating factors to suit the service conditions mentioned in clause 4.1. The corrected values shall be entered in appendix A.

| | |
|---|---|
| Cooling Medium | Oil |
| Number of phases | 1 |
| Maximum System Voltage | 12kV |
| Frequency | 50 Hz |
| Rated current for 110KVA regulator | 100Amps |
| Rated current for 220KVA regulator | 200Amps |
| Rated short time current | 21kA |
| Duration of short circuit | 3seconds |
| Impulse withstand voltage (BIL) | 95kV |
| One minute power frequency withstand voltage | 38kV |

4.5.2 The regulator shall be capable of carrying its full normal rated current plus 12% boost continuously under the tropical conditions stated, and at any tappings without the temperature rise in the hottest region exceeding 55° C and 65° C in oil and winding respectively.

4.5.3 The minimum external electrical clearances and minimum creepage distance of the bushing shall be as indicated below:

| | | |
|---|---|---|
| Nominal System Voltage between Phases | | 11kV |
| Maximum system voltage | | 12kV |
| Minimum clearances between phase to earth | mm | 300 |
| Minimum clearances between phases | mm | 250 |
| Creepage distance | mm | 300 |

## 4.6 REGULATOR CONTROL BOX

4.6.1 The regulator control panel shall be mounted in a weather-resistant enclosure capable of being padlocked. The control enclosure shall have an external welded ground boss.

4.6.2 The control panel shall be hinge-mounted and designed for easy replacement. The front panel assembly shall be constructed to provide direct control interchange-ability without removal of the control enclosure. Visible means shall be provided to de-energize the control and short the current transformer prior to control testing or removal.

4.6.3 All leads in the control enclosure shall be either color coded or labeled for easy identification.

4.6.4 All printed circuit boards shall have fungi and moisture protection.

4.6.5 A ratio correction transformer shall be provided inside the enclosure for easy access to fine voltage adjustment. Ratio correction taps and the corresponding system voltage shall be clearly identified on the nameplates.

4.6.6 **The control panel** shall have a temperature range of -40°C to +85° C and include the following features:

a) A three-position voltage source switch, labeled INTERNAL-OFF-EXTERNAL, which allows the regulator to be operated from an internal potential source, operated from an external source, or de-energized;

b) A three-position, AUTO/REMOTE-OFF-MANUAL switch that allows automatic or manual operation of the regulator. Supervisory motor control shall be permitted only when the switch is on the AUTO/REMOTE position;

c) A spring-loaded three-position manual RAISE-OFF-LOWER toggle switch, which shall only be active when the control switch is in the MANUAL position;

d) A position indicator drag hand reset switch;

e) A neutral position-indicating lamp that is actuated via the tap changer to provide neutral indication;

f) An operations counter that counts every tap change;

g) Separate motor and panel fuses that are replaceable from the front panel. Fuse size shall be clearly marked at each fuse. One set of spare fuses shall be included in the control enclosure;

h) A means shall be provided to indicate whether the voltage is inside or outside the set voltage band;

i) Voltmeter test terminals shall be supplied which connect to the secondary of the load side (L bushing) of the regulator;

j) External voltage source terminals shall be supplied to allow tap changer and control operation from an external 120-Vac source. An interlocking means shall be provided to prevent energizing the high-voltage bushings from the external source.

4.6.7 The voltage regulator shall be microprocessor based and have provisions for programming of the following parameters:

a) Set voltage shall be adjustable from 100.0 to 135.0 volts with a maximum increment of 0.5;

b) Set voltage bandwidth shall be adjustable from 1.0 to 6.0 volts with a maximum increment of 0.1 volt;

c) Time delay shall be adjustable from 5 seconds to 180 seconds with a maximum of 5 second increments;

d) Line drop compensation resistance and reactance settings that are adjustable from -24.0 to 24.0 volts in increments of 0.2 volts maximum. A means shall be provided to set the polarity.

4.6.8 The voltage regulator control shall include the following features:

a.) A digital metering package of Class 1 accuracy which shall provide the following information:

1. Instantaneous values of load voltage, compensated voltage, current, power factor, kVA load, kW load, kvar load, voltage harmonics, and current harmonics. Voltage and current harmonics shall include, at a minimum, total harmonic distortion;

2. Maximum demand values of load voltage, compensated voltage, current, kVA load, kW load, and kvar load. For each of these values, the present value, highest value since last reset, and lowest value since last reset shall be provided. Highest and lowest values shall be time and date tagged. Power factor at maximum and minimum kVA load shall be provided. Metering values must be available for both forward and reverse power flow conditions.

b.) A tap position indication capability, which tracks the movement of the tap changer motor, shall provide the present tap position and the highest and lowest positions since last reset. The highest and lowest values shall be date and time tagged.

c. A voltage limiting capability which prevents the regulator from making additional tap changes once the regulator output voltage meets a programmed upper- or lower-limit setting. If the source voltage should change, causing the regulator output voltage to exceed either limit, the control shall automatically run the regulator so as to keep the voltage within the limit settings.

d. A 9-pin data port shall be provided on the front panel for the temporary connection of a personal computer or a hand held reader.

## 5. TESTS AND INSPECTION

5.1 The voltage regulator shall be inspected and tested in accordance with the requirements of this specification and IEEE Std C57.15. It shall be the responsibility of the manufacturer to perform or to have performed the tests specified.

5.2 Certified true copies of previous type/design test reports by the relevant International or National Testing/Standards Authority of the country of manufacture (or ISO/IEC 17025 accredited laboratory) shall be submitted with the offer for evaluation (all in English Language). A copy of the accreditation certificate for the laboratory shall also be submitted.

The test reports (for similar design) to be submitted shall include: Temperature Rise Tests (Thermal Tests), Lightning Impulse Tests and Short Circuit Tests.

5.3 Routine tests shall be witnessed by KPLC Engineers at the factory and reports submitted to KPLC for approval before shipment/delivery of the goods.

Routine tests shall include the following:

a) Resistance measurements of all windings
b) Ratio tests on all tap connections
c) Polarity test
d) No-load (excitation) loss at rated voltage and rated frequency
e) Excitation current at rated voltage and rated frequency
f) Impedance and load loss at rated current and rated frequency
g) Lightning impulse tests
h) Applied-voltage tests
i) Induced-voltage tests
j) Insulation power factor tests
k) Insulation resistance tests

## 6. MARKING AND LABELLING

6.1 In addition to marking required elsewhere in this specification, the voltage regulators shall be fitted with a permanent rating plate indicating the following:

a) The manufacturer's name or identification mark;
b) The type reference number and serial number;
c) The rated voltages;
d) The rated range;
e) The rated frequency;
f) The burden and accuracy class;
g) The highest system voltage (e.g. 12kV);
h) The insulation level;

6.2 All markings shall be by engraving.

## 7. SPARES AND ACCESSORIES

The following accessories and spares shall be provided:

a) Long length cable to allow remote placement of the regulator control. The cable shall be 7 meters long and shall be pre-connected at the factory.

b) A hand-held, battery-operated device Data Reader, which temporarily connects to the control, and reads and stores all metering and control set values. The device shall be able to store information from up to 20 regulator controls. The device shall be compatible with IBM®-PC, or compatible computers. A device-to-control cable shall be included.

c) A thermostatically-controlled heater assembly to reduce moisture in areas of high humidity. The heater assembly shall include an ON-OFF switch. In the ON position, a thermostat in the heater assembly shall activate the heater at approximately 30°C (85°F) and turn it off at approximately 40°C (100°F).

## 8. DOCUMENTATION

In addition to documents required elsewhere in this specification, a set of Three (3) Original Hard Cover Installation and Maintenance Manuals for the voltage regulators shall be supplied with the equipment.

**APPENDIX A**: Format for Clause-by-Clause Schedule

The tenderer shall fill the guaranteed values of the equipment offered for the service conditions stated in all the clauses under item 4.1 in the format given below: (It is to be noted that the tenderer shall extract all the clauses and fill in the format).

| | **REQUIREMENT** | **BIDDER'S GUARANTEED PARAMETER VALUE** | **DESCRIPTIVE RESPONSE & COMMENTS** |
|---|---|---|---|
| | **SERVICE CONDITIONS** | | |
| 4.1.1 | Altitude | | |
| | Temperatures | | |
| | Humidity | | |
| | Pollution | | |
| | Isokeraunic level | | |
| 4.2 | **DESIGN & CONSTRUCTION** | | |
| ***4.2.1*** | ***Applied standard*** | | |
| 4.2.2 | Connectivity | | |
| 4.2.3 | Internal tappings | | |
| ***4.2.4*** | ***Drawings & documentations*** | | |
| | **INTERNAL FEATURES** | | |
| ***4.3.1*** | ***Out door, oil-immersed, single phase*** | | |
| 4.3.2 | ONAN | | |
| 4.3.3 | Loading | | |
| ***4.3.4*** | *Oil furnished* | | |

| | | | |
|---|---|---|---|
| ***4.3.5*** | *Composition of oil* | | |
| ***4.3.6*** | ***Regulation steps*** | | |
| ***4.3.7*** | ***Easy of untanking*** | | |
| 4.3.8 | Core construction | | |
| 4.3.9 | Maximum flux density | | |
| ***4.3.10*** | ***Tap changing mechanism*** | | |
| 4.3.11 | Divertor switch type | | |
| ***4.3.12*** | ***Sealed tank construction*** | | |
| ***4.3.13*** | ***Pressure release device*** | | |
| 4.3.14 | Outside Painting | | |
| 4.3.15 | Inside painting | | |
| ***4.3.16*** | ***Insulation class*** | | |
| ***4.3.17*** | ***Extra current at 65°C temp rise*** | | |
| 4.3.18 | Short circuit withstand as per IEEE Std C57.15 | | |
| | Winding Material: Shunt | | |
| | Winding Material: Series | | |
| | Insulation Class | | |
| ***4.3.19*** | ***High conductivity electrolytic copper windings*** | | |
| ***4.3.20*** | ***Sensing Current transformer*** | | |
| ***4.3.21*** | ***Load bonus feature*** | | |
| | **EXTERNAL FEATURES** | | |
| 4.4.1 | Tank construction | | |
| ***4.4.2*** | ***Bushings details*** | | |
| ***4.4.3*** | ***Clamp diameters*** | | |
| ***4.4.4*** | ***By pass MOV*** | | |
| 4.4.5 | Oil sight gauge | | |
| 4.4.6 | Dial type position indicator | | |
| 4.4.7 | Mounting bosses for arresters | | |
| *4.4.8* | *Surge arresters ratings* | | |
| 4.4.9 | Drain valves blocked | | |
| 4.4.10 | Hand hole | | |
| 4.4.11 | Base type | | |
| 4.4.13 | Nameplate | | |

| | | | |
|---|---|---|---|
| | **RATINGS** | | |
| ***4.5.1*** | ***Altitude at which tests are conducted & adjustments for clause under 4.1*** | | |
| | ***Cooling medium*** | | |
| | ***No. of phases*** | | |
| | ***Range of Regulation*** | | |
| | ***Steps*** | | |
| | ***Rated voltage*** | | |
| | ***Frequency*** | | |
| | ***Rated current for 330KVA*** | | |
| | ***Rated current for 660KVA*** | | |
| | ***Rated short circuit withstand*** | | |
| | ***Duration of short circuit*** | | |
| | ***Impulse withstand voltage*** | | |
| | ***Power frequency 1 minute withstand*** | | |
| ***4.5.2*** | ***Temperature rise oil/winding*** | | |
| ***4.5.3*** | ***Clearance phase - earth*** | | |
| | ***Clearance phase - phase*** | | |
| | ***Creepage distance*** | | |
| | Losses at 25% | | |
| | Losses at 50% | | |
| | Losses at 75% | | |
| | Losses at 100% | | |
| | **REGULATOR CONTROL BOX** | | |
| ***4.6.1*** | ***Weather resistant*** | | |
| ***4.6.2*** | ***Construction*** | | |
| 4.6.3 | Coding of leads | | |
| 4.6.4 | Printed circuit board features | | |
| ***4.6.5*** | ***Ratio correction transformer*** | | |
| ***4.6.6*** | ***Temperature range*** | | |
| | ***List contents of box (a to k and others)*** | | |
| ***4.6.7*** | ***Microprocessor based*** | | |

| | | | |
|---|---|---|---|
| | ***voltage regulator*** | | |
| | ***List features of voltage regulator (a to d and others)*** | | |
| 4.6.8 | ***Instantaneous and maximum demand metering (list measurands)*** | | |
| | Tap position tracking | | |
| | Voltage regulating action | | |
| | Load shedding | | |
| | Reverse flow detection | | |
| | Voltage instability sensing | | |
| | Terminals | | |
| **5** | **TESTS AND INSPECTION** | | |
| | **5.1** | | |
| | **5.2** | | |
| | **5.3** | | |
| | ***Full load losses*** | | |
| | ***No load losses*** | | |
| | | | |
| **6** | **MARKING** | | |
| | | | |
| **7** | **ACCESSORIES & SPARES** | | |
| | ***Connection cable*** | | |
| | ***Data reader*** | | |
| | ***Heaters*** | | |
| **8** | **DOCUMENTATION** | | |
| | *List technical brochures, drawings, technical data & manuals attached* | | |

**NB:-** This schedule does not in any way substitute for detailed information required elsewhere in the specification.

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**Manufacturer's Name, Signature, Stamp and Date**