Rwanda Energy Group

REG

RETICULATION STANDARD OF ELECTRICITY TRANSMISSION NETWORK

PLANNING

CONSTRUCTION

MAINTENANCE

Version 1

2020

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LIST OF ABBREVIATIONS

AC:	Alternating current
AAAC:	All Aluminium Alloy Conductors
ACI:	American Concrete Institute
ACS:	Aluminium Clad Steel
ACSR:	Aluminium Conductor Steel Reinforced
A/D:	Analog to Digital
BCU:	Bay control unit
BS:	British Standard
BS EN:	British Standard European Norm
°C:	Centigrade
CB:	Circuit breaker
CIGRE:	International Council on Large Electric Systems
CT:	Current transformer
CVT:	Capacitive voltage transformer
DC:	Direct current
DS:	Disconnect switch
EAS:	East African Standard
EHV:	Extra High Voltage
EMI:	Electromagnetic interference
EDCL:	Energy Development Corporation Limited
EUCL:	Energy Utility Corporation Limited
FAT:	Factory Acceptance Test
HV:	High Voltage
Hz:	System frequency (Hertz)
ICNIRP:	International Commission on Non-Ionizing Radiation Protection
IEC:	International Electro-technical Commission
IEEE:	Institute of Electrical and Electronic Engineers
IP:	Ingress Protection
ISO:	International Organization for Standardization
kA:	Kilo amperes

kV:	Kilo volt
kVA:	Kilo volt amperes
LAN:	Local area network
LV:	Low Voltage
MCB:	Miniature circuit breaker
MVA:	megavolt-ampere
MVAr:	megavar (1,000,000 vars), the unit for Reactive Power
MVArh:	megavar hour
MW:	megawatt (1,000,000 watts), the unit for Active Power
MWh:	Megawatt hour
NEMA:	National Electrical Supplier's Association
OLTC:	On load tap changer
OHGW:	Overhead Ground Wire
ONAF:	Oil natural Air Forced
ONAN:	Oil natural Air Natural
OPGW:	Optical Ground Wire
OSHAS:	Occupational Health and Safety Assessment Series
REG:	Rwanda Energy Group
RFI:	Radio frequency interference
RS:	Rwanda Standard
RSB:	Rwanda Standards Board
RTU:	Remote Terminal Unit
rms:	Root mean square
SCADA:	Supervisory Control and Data Acquisition
SLD:	Single line diagram
UPS:	Uninterrupted power supply
VT:	Voltage transformer

NORMATIVE REFERENCES

The IEC standards are given as reference for construction or for the quality of material. In addition to the previous, reference is also made to ACI, ACSE, ANSI, ASTM, BSEN, CIGRE, ICEA, IEEE and ITU & RSB standards.

In case of any conflict with the referred standards and codes, the following order of priority shall be observed:

a) R U R A : Guidelines, Codes and Regulations
b) RS, EAS and IEC standards
c) REG Procedure Manual
d) REG Health and Safety operating procedure
b) ACI, ACSE, ANSI, ASTM, BSEN, CIGRE, ICEA, IEEE, ITU and RSB standards
c) ISO 9001 and ISO 45001:2018
f) Transmission Master Plan for Rwanda

The last edition of the reference Standards shall be applied, unless something to the contrary is noted, in connection with the General Technical Requirements. Where only one standard under the set is listed the complete series under the set is applicable.

None other equivalent standard is acceptable. Any standard that is superseded should be updated in this manual at least once a year.

INTRODUCTION

The purpose of this document is to create a guideline for planning, design, construction, and operation maintenance of transmission network to be used by REG in-house construction teams as well as external consultants and contractors in REG. It addresses the standardization of the transmission network works and related equipment. The aim is to use harmonized and economic equipment with dynamic technology and standards. The standardization of transmission network construction will also reduce the amount of different spare parts to be kept for operation and maintenance.

Towers/poles, conductors, hardware and materials meeting other internationally accepted standards, which ensure an equal or higher quality would be accepted after approval of the responsible engineer.

Scope

This standard cover design, planning, construction and maintenance of transmission network. It does not cover switching control, relay protection, coordination with telecommunication lines.

The Document is divided into 3 Parts and Annexes:

Transmission Network Planning and Design

Transmission Network Construction Standards

Transmission Network Maintenance Standards

Annexes:

Annex 1: Network Planning and Development Forms

Annex 2: Transmission Network Maintenance Forms

PART 1: TRANSMISSION NETWORK PLANNING AND DESIGN

1.1. PLANNING PHILOSOPHY AND GENERAL GUIDELINES

a) Transmission Network in Rwanda shall meet N-1 contingency criterion.

b) All new transmission lines shall be designed to allow for two operating circuits.

c) A 110kV intermediate voltage must be used for distribution transformation (15 & 30kV). This separates the distribution network far enough from the international/interconnected transmission network.

d) Substations must be designed and positioned in accordance with the requirements of the REG Transmission and Distribution Master Plan.

e) Power cable and protection &control cables shall not be in the same trench.

f) New transmission lines shall be designed with reliability level 2 as illustrated in ***table 1***.

Table 1: Transmission lines reliability levels Ref IEC 60826

Reliability levels in years	**years**
1	50
2	150
3	500

g) The rated rupturing capacity of the circuit breaker in any sub-station shall not be less than 125% of the maximum fault level at that sub-station. (The 25% margin is intended to take care of the increase in short circuit levels as the system grows). The standard rated breaking current capacity of switchgear at different voltage levels are as illustrated in ***table 2***:

Table 2: Breaking HV current capacity, ref IEEE Std C37.04™-2018

Voltage level (kV)	**Breaking current (kA)**	**Time (s)**
220	50	3
110	40	3
15 and 30	31.5	3
(* The rupturing capacity shall be updated according to the network growth)		

h) The capacity at any single substation at different voltage levels shall not normally exceed as illustrated in ***table 3***:

Table 3: Capacity of substation in MVA according to voltage levels

Voltage level(kV)	Capacity (MVA)
220	320
110	150

i) Size and number of interconnected transformers in substation shall be planned in such a way that the outage of any single unit would not normally overload the remaining interconnected transformers.

j) Reactive power compensation devices shall be installed as far as possible in the high voltage network with a view to meet the reactive power requirement of actual load close to the load points. The method for the reactive power compensation to be adopted shall be confirmed by the design study.

k) All substations shall be equipped with the following:

- Earthing isolators
- Communication infrastructure to facilitate control and command
- Disturbance Fault Recorder
- Smart metering system at all incoming and outgoing feeders.

l) The protection of transmission lines shall be done with single pole auto reclose operable breakers.

m) A bypass with double bus-bar selection shall be used where justified in cases such as maintenance, test, continuity of service etc...

1.2. LOAD FORECAST

Load forecast is important in the update of the transmission network master plan and shall be based on load growth, which may occur in the following ways:

a) Extension of existing networks

b) New network construction

c) Addition of Bulk loads

1.3. ELECTRICAL TRANSMISSION NETWORK DESIGN

1.3.1. Basic design data

1.3.1.1. Electrical Characteristics

The electrical characteristics of the transmission network shall be as stated below:

- Nominal Voltages: 220 or 110kV
- Frequency: 50Hz
- The frequency and high voltage variation at any point on the network shall be ±5% of the nominal voltage and ±1% of the nominal frequency.
    - Power frequency withstand 220kV: 460 kV
    - Power frequency withstand 110kV: 230 kV
    - Rated lightning impulse withstand voltage 220 kV: 1050kV
    - Rated lightning impulse withstand voltage 110 kV: 550kV (according to IEC 60071)
    - Pollution: I (according to IEC 60815)
    - Cree-page distances shall be applicable to insulators, bushings, etc.
    - The voltage shall be in accordance with IEC standards (IEC 60038). The following factors shall determine the choice of voltage:
        - Magnitude of the power to be transmitted
        - Length of the line

1.3.1.2. Mechanical Characteristics

Mechanical design characteristics of the transmission network shall be as stated below:

- Wind Velocity: 45m/s
- Dynamic wind pressure: 720N/m²
- Maximum Sustained Wind speed: 29m/s
- Tower Design Safety factor: 2.5
- Air Temperatures:
    - Maximum outdoor temperature: +40°C
    - Minimum outdoor temperature: + 5°C
    - Maximum daily average temperature: +30°C
    - Annual average temperature: +20°C
- Rainfall: Annual average rainfall: 1,500mm

- Solar Radiation: Maximum solar radiation: 5,200 W/m²
- Air Humidity: Maximum at +35°C: 95%

1.3.2. Transmission line design

1.3.2.1. Tower

Towers shall be self-supporting with a broad base of hot deep galvanized steel lattice type with body and hillside extensions. The following types of tower shall be designed for REG projects:

Table 4: Standard classes of the type of towers

Designation		**Position**	**Angle of Deviation or Line Entry**	**Type of Insulator**
110kV	**220kV**			
ST	A	Suspension Towers	178 o~180o	Suspension
LST	B	Long Span Towers	170 o~180o	Tension
LAT		Light Angle Towers	165 o~180o	Tension
MAT	C	Medium Angle Towers	150 o~180o	Tension
HAT		Heavy Angle Towers	120 o~180o	Tension
ET	D	Dead-end Towers	90o	Tension

1.3.2.1.1. Tower Design

Design of the towers shall be done using appropriate soft wares such as PLS –Tower. The mechanical and structural design shall ensure that the line performance will comply with all relevant National and international standards. The design shall ensure that premature failure of components does not occur from fatigue stresses, abrasion, corrosion, or other serviceability conditions in operational line.

Design of structures and footing shall meet the requirements to ensure that the line is suitable for its intended purpose and to ensure acceptable levels of safety for construction, maintenance and operation.

Appropriate security level shall be determined considering the importance of line, impact on REG network reliability, its location, climate condition, public safety and design working life in consultation with REG.

1.3.2.1.1.1. Design Conditions

a) Assumed Normal-Loading Condition:

The assumed maximum simultaneous working loading on towers shall be as follows:

i. **Vertical loads:**

- Tower structures: actual weights of tower structures including accessories
- Power conductors: Weight of conductors of specified weight span with accessories
- Overhead optical fibre earth wire: weight of specified weight span with accessories
- Erection Loads: such loads as workers' weights on tower members, reaction of temporarily backstays during stringing operation, etc.

ii. **Horizontal Angle Effect**

Horizontal angle effect is a horizontal component of maximum working tension conductors and earth wire due to the specified horizontal angle deviation.

iii. **Transverse loads i.e.** Wind loads, horizontal angle deviation effects

iv. **Longitudinal loads i.e**. Wind loads, erection loads, maximum working tensions of power conductors and overhead earth wire for their termination for Type-T tower.

b) Assumed Broken-Wire Condition:

Under this condition, the power conductor or an earth wire is assumed broken at their maximum working tensions, in addition to the loads under the normal condition. In the case of Type-S tower, the pull will be assumed to be reduced to 70% of the specified maximum working tensions.

c) Factor of Safety:

The following factors of safety for tower structures shall be applied in the design:

- 2.5 for the maximum load under the normal loading condition.
- 1.5 for the maximum load under the broken-wire condition. Those factors of safety shall be proved under tower loading tests on the proto-type towers in the manufacturer's testing station, and there should be no failure or permanent distortion during the tests when 100% loading is sustained for five minutes.

(d) Height of Towers

Height of towers shall be determined using the following formula: $H = Gc + Sg + Li + Hc + Hg$

Where,

H = Total height of tower.

Gc =Necessary ground clearance of power conductors above ground or other objectives. Sg = Maximum conductor sag

Li = Length of a suspension insulator set, but nil for a tension type tower. Hc = Vertical spacing of upper conductor cross -arm spacing

Hg = Vertical spacing between upper conductor cross-arm and overhead earth wire.

(e) Basic, wind, uplift and weight spans

Basic span is the horizontal distance between centers of adjacent supports on the level ground from which the height of standard towers is derived with the specified conductor clearances to ground in still air at maximum temperature.

Wind span is equivalent to half the sum of adjacent horizontal span lengths supported on any one tower.

Uplift weight refers to the weights of conductors and overhead earth wire supported upwards at any one tower for reinforcing strength of cross arms.

Weight span is the horizontal distance between the lowest points of the conductors, on the two spans adjacent to the tower.

These are clearly illustrated in ***figure 1*** and the requirement for each type of tower presented in ***table 5***

Table 5: Corresponding Basic, Wind, Uplift and Weight Span for different types of towers

Type of Tower	S(LT & LST)	L(LAT)	M(MAT)	H/HS(HAT)	T(ET)
Basic Span(m) normal working condition	350	350	350	350	350
Wind span(m) broken wire condition	260	260	260	260	260
Weight Span (m)-Normal working condition	700	1200	1200	1200	1200
Weight Span (m)-Broken wire condition (m)	500	900	900	900	900
Uplift weight for cross arms	-	300	300	300	300

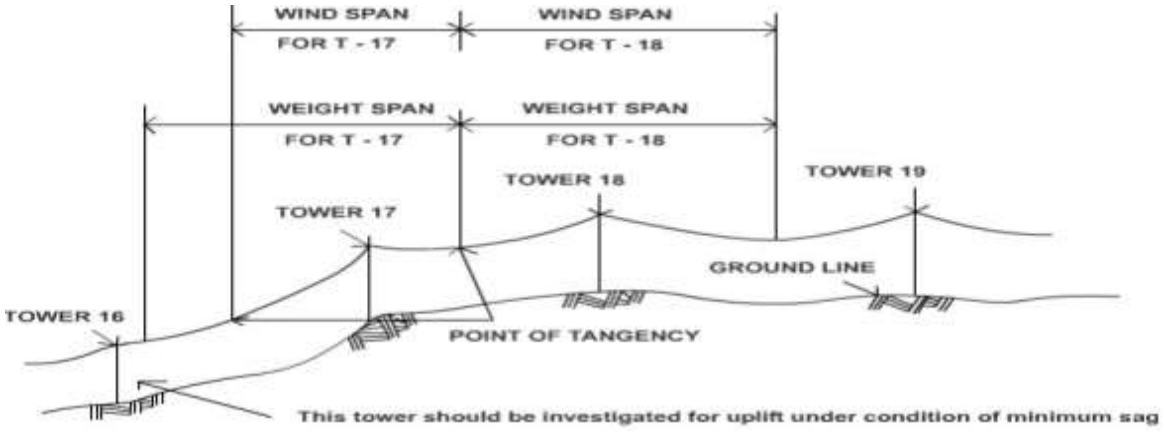

Figure 1: Illustration of Basic, Wind, Uplift and Weight Span

1.3.2.1.2. Structure configuration

The configuration of a transmission line tower shall depend on the following factors:

a) Voltage level;

b) Design span;

c) The minimum clearances to be maintained between conductors, and between conductor and tower, from consideration of the dynamic behavior of conductors and lightning protection of the line.

d) The type of tower

The typical tower configurations having single and double circuits are illustrated below:

Typical configurations of conductors of overhead lines on towers (Single circuit)

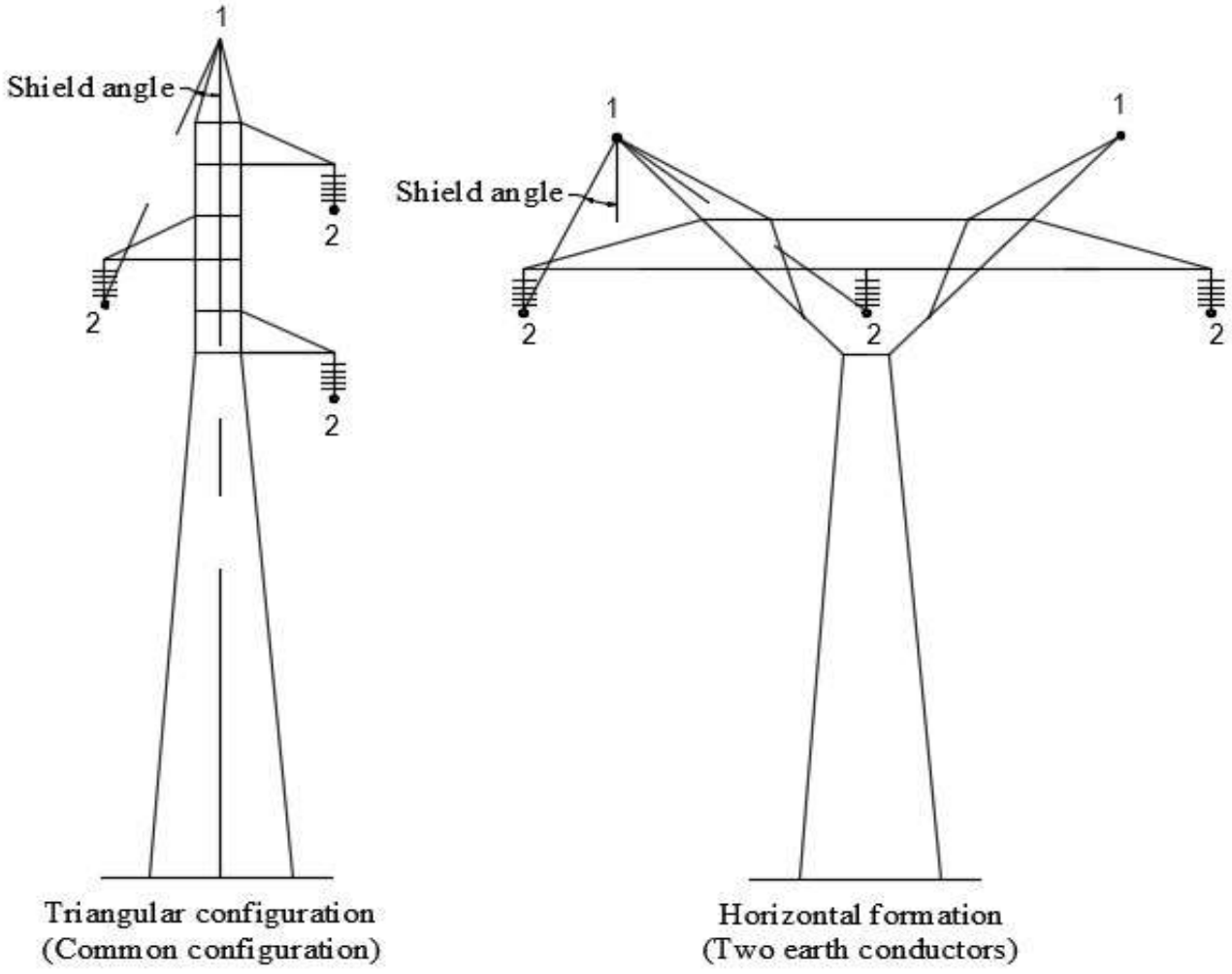

Figure 2: Typical configurations of conductors of overhead lines on towers (Single Circuit)

Typical configurations of conductors of overhead lines on towers (Double circuit)

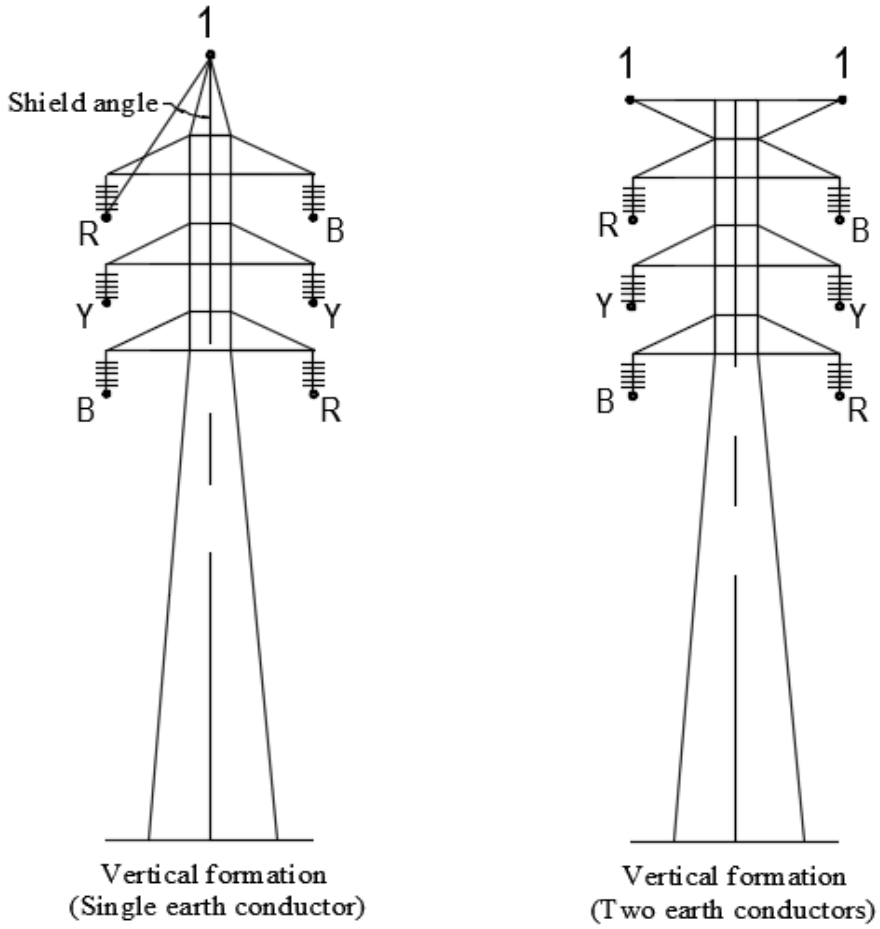

Figure 3: Typical configurations of conductors of overhead lines on towers (Double circuit)

1.3.2.2. Conductors

For transmission lines, power conductors to be used shall be ACSR (Aluminum Conductors Steel Reinforced). The sag and tensile for conductor and earth wire shall be established based on the site conditions.

1.3.3.2.1. Transpositions

Phase conductors are transposed on long transmission lines to balance the mutual impedances and reduce the load current unbalance. Unbalanced phase currents result in zero and negative sequence currents that increase power losses. In a fully transposed line, each phase is changed so that it occupies each geometric position for an equal length of the line. In this document, transposition shall refer to the rolling of the phase conductors.

Table 6: Sequence of transposition

Route length	Number of transpositions	Number of different phasing sections
< 50 Km	Nil	1
50 to 100 Km	1	2
> 100 Km	2	3

1.3.3.2.2. Optical Ground Wire (OPGW)

Transmission lines shall typically utilize OPGW as shield wire and communication path. The standard OPGW for lines shall be OPGW 97 and OPGW 44 (Ref IEEE 1138 and IEC 60794-4). The OPGW shall be grounded at each tower through jumper assemblies and approved clamps to be used for connections.

1.3.3.2.3. Tension of conductor

The tension in the conductor is normally expected to be less than 50% of its ultimate tensile strength. It depends of the diameter of the conductor, length of the conductor between supports, material of conductor, sag in conductor, wind pressure and temperature.

For major river crossings, tension limits, vibration, protection measures and actual ambient conditions (wind, temperature, and exposure) shall be verified for the specific site. In addition, the sag of the overhead steel ground wire at 25°C unloaded shall not exceed 90% of the active conductor sag. For the optical ground wire (OPGW), the sagging at 25°C shall correspond to the sagging of the overhead steel ground wire.

1.3.3.2.4 Ground and phase clearances

The following minimum vertical clearances shall be maintained at a maximum conductor temperature of 75ºC at the final state without wind.

Table 7: Minimum Vertical Clearances

	Minimum vertical clearances(m)
Roads	9.0
Pedestrian road and low vegetable terrain	8.0
Overhead lines	5.0
Telecommunications lines	4.6

The phase-to-phase distance (dm) should not be less than:

$$d_m \geq 0.9\sqrt{(F+L)}+C$$

Where:

F = Sag of Conductor (m) at maximum temperature (75^{o}C)

L = Length of the insulator string (m), L = 0 for tension string C = Constant for 220 kV = 1.5 m Special requirements in connection with crossing may be ordered by the client. Where construction of other types is met, the clearances shall be reviewed and approved.

1.3.3.2.5. Conductor- shield wire spacing

The minimum vertical distance between the phase conductor and the shield wire at the tower shall not be less than 3.0 m for both 110kV and 220 kV lines. To limit the probability of flashover, the minimal spacing between conductor and shield wire at the tower must be increased. An empirical formula for aluminum conductor line shall be referred to: spacing = (√S + V/150) m. Where S is sag in m and V is line voltage in kV.

1.3.3.2.6. Shielding angle

Given a high keraunic level for the region, the shielding angle to the outside phases will be limited to 10°.

Table 8: Line clearances ref: BS: 162 and IEC 60076-3

Horizontal Right-of-Way (m)			
Voltage Levels	110 kV	220 kV	400 kV
Easement width(m)	25	30	50
Minimum vertical clearance			
Voltage (kV)		Phase to earth (mm)	Phase to phase (mm)
110		863.6	990.6
220		1778	2057.4
Minimum working clearance			
Outdoor Switchyard			
Voltage (kV)		To ground (m)	Between section (m)
110		4.600	3.500
220		5.500	4.500

Minimum ground clearance (m)	
Voltage in kV	To ground
110	6.10
220	7.00

Minimum vertical clearance between lines crossing each other (in meter)			
System Voltage	110 kV	220 kV	400 kV
110 kV	3.05	4.58	5.49
220 kV	4.58	4.58	5.49
400 kV	5.49	5.49	5.49

Minimum height above railway (m)	
Voltage	Broad Meter & Narrow Gauges
Above 66kV up to 110 kV	14.60
Above 110 kV up to 220 kV	15.40
Above 220 kV up to 400 kV	17.90
Above 400 kV up to 500 kV	19.30

Various Basic insulation level and Air clearances to be provided			
Voltage kV	110kV	220 kV	400 kV
BIL(basic insulation level in kV)	550	1050	1425
P-E (Phase –Earth in cm)	115	240	350
P-P(phase –phase in cm)	135	210	410
P-G (phase –ground in m)	4.6	5.5	8.0
Section Clearance(m)	3.5	4.3	6.5

1.3.3.2.7. Aeolian Vibration

Where a conductor, earth wire or OPGW is strung, vibration dampers shall be installed to limit fatigue. Typical minimum requirements for a single conductor shall be as follows:

Table 9: Typical minimum requirements for a single conductor

Span length	**Suspension towers**	**Strain towers**
365 m or less	2 dampers per span conductor	2 dampers per span conductor
365 m to 670 m	2 dampers per span conductor	4 dampers per span conductor
670 m and above	4 dampers per span conductor	6 dampers per span conductor

1.4. SUBSTATION

1.4.1. Criteria for site selection of substation

a) Soil type and conditions
b) Topography
c) Environmental impact assessment shall include but not limited to the following: waste management, oil spillage, soil or ground water contamination due to oil leakages from transformers and other oil-filled equipment, obstruction of traffic and destruction of existing roads, environmental pollution, and electromagnetic fields.
d) Site access
e) Incoming/outgoing line access
f) Size of substation with factor and considerations such as:

- Load growth
- System reliability and stability
- Load transfer in emergency case
- Electricity master plan

1.4.2. Substation Design Considerations

Typical line bay shall have appropriate disconnector, surge arrestor, voltage transformer, current transformer, circuit breaker, and the second disconnector to the bus bar.

Typical transformer bay shall have the following equipment: disconnector, voltage transformer, surge arrestor, current transformer, Circuit breaker, post insulators where necessary and HV/MV bushing of the transformer from which MV underground cables supply indoor MV switchgears. A feeder adaptation unit (FAU) is required where all LV terminals are collected for supplying all LV circuits for command, protection and communication from the control room and from the outdoor switchyard.

1.4.2.1. Power Transformer

a) Power transformers in transmission substations shall be rated at minimum 20MVA.
b) Transmission transformer connections shall be done to ensure redundancy.
c) Power transformers shall be designed according to IEC 600273, 60296, 60529, 60076, IEEE C57.12.90 and IEEE C 57.21.
d) For 220kV voltage transformation shall always be via 110kV.i.e. no voltage transformation shall be done from high voltage 220kV to distribution voltages of 30kV or 15kV.

e) The transformer base shall be rail based.

f) The transformer oil should be manufactured in accordance with IEC 60296 standard. It shall be pure hydrocarbon mineral oil, without any additive, gas proof, clean and sufficient free from moisture and other foreign materials likely to impair its property, with excellent oxidation stability, high dielectric properties, low temperature properties.

g) The oil-collecting pit for each transformer shall have a capacity for 120 % oil of the transformer. A water/oil evacuating system using a pump shall be installed for the oil/rain water collecting pit.

h) OLTC shall always be installed at the primary side of the transformer.

i) The neutral points shall be brought out by suitable means and shall be grounded as per requirements of the Substation design

1.4.2.2. Substation Conductors & Cables

The conductor used in substation shall be either AAAC or ACSR

1.4.2.3. Bus bar

a) All switching substation bus-bars shall be made of aluminium tubes (minimum thickness & diameter 10mm, 120mm) while T-OFF substation shall be made of either aluminium tubes or conductor, based on short-circuit current calculation.

b) Double bus-bars shall be used during installation of new substations and configuration shall be done to ensure redundancy

1.4.2.4. Voltage transformer (VT)

a) The voltage transformers for HV shall be capacitor outdoor type (CVT), single phase, oil filled, self- cooled, having shaded porcelain bushing, suitable for operation under the service conditions with protection from the sun, rain and dust, Ref: IEC 60044-5.

b) The VT shall be capable to withstand line discharge effect and the ferro-resonance effect.

c) Secondary voltages shall be of 110V or 100V

d) The VT burden shall be above 20VA

e) The VT shall be provided with class A, constructed in manner to ensure high accuracy at both normal and over voltages.

f) The VT secondary terminals shall be brought out through MCB of suitable rating in a weatherproof terminal complying with IP65.

g) The nameplate indicating all technical characteristics shall be fixed on the accessible level of the VT.

h) The voltage transformers shall be of the metal-enclosed, gas or oil insulated type. The grounded surfaces shall be completely safe to touch during operation.

1.4.2.5. Current transformer (CT)

a) Current Transformers (CTs) for 220KV, 110 kV shall comply with IEC 60044-1, 60137 and 60815.

b) The CTs shall be designed for both metering and protection.

c) The CTs shall be rated at 120% of the rated primary current. d) Secondary currents of the CT shall be 1A or 5A.

d) Knee voltages shall be as below:

Table 10: Knee voltage limits

Voltage, kV	**Knee Voltage, V**
220	>1200
110	>600
30	>300
15	>300

e) Current burdens shall be as below:

Table 11: Current burden Limits

Voltage, kV	**Burden, VA**
220	>25
110	>25
30	15-20
15	15-20

f) Resistance of the load shall not be greater than 2.5Ω

g) Accuracy class for protection shall be 5P or 10P

h) CTs' bushings shall be of the outdoor type designed corresponding to IEC 60137 and to IEC 60815

1.4.2.6. Circuit Breaker

a) Spring mechanism shall have the capability to be charged either manually or electrically;
b) Tripping coil must be double;
c) Control operation (manual and remote);
d) The circuit breaker shall be SF6 gas insulated;

1.4.2.7. Lightning (Surge) Arrestors

a) The lightning arrester shall be designed in accordance with IEC 62271-1 and IEC 60099-4
b) The lightning arrestors shall be provided with discharges number counter.

1.4.2.8. Disconnector and Earthing Switches

All disconnector and earthing switches shall comply with IEC 62271-102

1.4.2.9. Earthing System

a) The substation earthing system shall be designed in accordance to IEEE 80-2000 Guide for Safety in AC Substation Grounding, ENA EG1-2006 Substation Earthing Guide, IEC standards.
b) All earthing system (earthing rod & tape) shall be made of annealed copper
c) The main earth grid shall be in form of earthing mat, with individual earthing equipment connected to this mat.
d) The earth resistance shall be as low as possible and shall not exceed the following limits.

Table 12: Earthing system limits

No	Particulars	Permissible values
1	Power Plant Stations	0.5 Ω
2	HV/MV Substations	1.0 Ω
3	MV/MV Stations	2.0 Ω

1.4.2.10. Protection system

a) All protection devices and philosophy shall comply with international standards and prior reviews by REG protection engineers;

b) All new protection system shall be compatible with the existing REG protection protocol

c) Protection relays shall only be from manufacturers approved by REG;

1.4.2.11. Remote Terminal Unit (RTU)

a) All new RTUs shall be compatible with the existing REG communication protocol

b) R T U shall only be from manufacturers approved by REG.

1.4.2.12. Disturbance Fault Recorders

All substations and power plants shall be equipped with Disturbance Fault Recorders (DFRs).

1.4.2.13. Metering system

a) Smart metering system shall be installed at all incoming and outgoing feeders.

b) Accuracy class for metering shall be 0.2

PART 2: TRANSMISSION NETWORK CONSTRUCTION

2.1. CONSTRUCTION OF TRANSMISSION LINE

2.1.1. Prerequisites:

The following Approved design documents shall be required prior to construction:

a) Feasibility study
b) Soil investigations
c) L i n e profile
d) Line routes
e) Foundation designs (all types)
f) Engineering drawings for all support structures, conductors and accessories
g) Stringing charts

2.1.2. Overhead line construction process

2.1.3. Tower foundation

a) Dimensions, shoring, strutting, dewatering, shuttering, stub setting (or tower footing), backfilling, assembly and check shall conform to the civil engineering design approved by REG.

b) All 220 kV towers foundations shall be constructed with full concrete; but for 110 kV both concrete and grillage foundation may be applicable referring to civil engineering design in accordance with EN 50341-1 and IEC 60826.

c) The following tolerances shall be applicable in case of position of foundation as a whole with reference to tower position as spotted on the survey chart:

Table 13: Requirements for tower foundation

Type of tower	Out of Alignment	From centre of route	From trans centre line
Suspension or intermediate	0.50	±25mm	±250mm
Section or tension (Set at bi-section of deviation angle)	0.50	±25mm	±25mm

2.1.4. Tower erection

a) Towers shall be erected according to engineering drawings from manufacturer and the approved line profile.

b) Towers shall be erected after the concrete is at least 28 days old.

c) Straining of the members shall not be permitted for bringing them into position. Before starting erection of an upper section, the lower section shall be completely braced and all bolts fitted in accordance with approved drawings.

d) All plan diagonals relevant to a section of tower shall be placed in position' before assembly of upper section is taken up.

e) All bolts shall have their nuts facing outside the tower for horizontal or nearly horizontal bolt connections and downwards for vertical bolt connections. Bolts, nuts and washers shall be of the same quality and standards as steel tower structure parts.

f) The cross-arm shall be assembled on ground and the top cross-arm shall be lifted first, followed by the middle and bottom cross-arms. The tips shall be fully tightened before lifting them into position. Such bolts which are not accessible for tightening by ordinary tommy spanners, may be tightened with the help of box or ratchet ring spanners.

g) All nuts shall be tightened properly using correct size spanners. Before tightening, it will be seen that filler washers and plates are placed in relevant gaps between members. Bolts of proper size and length are inserted, and one spring washer has been inserted under each nut. In case of step bolts, spring washer shall be placed under the outer nut.

h) The bolts and nuts in all joints up to 5m height above tower base shall be made in such a way to avoid theft (anti-theft bolt).

i) The following accessories shall be part of the tower: number plate, danger notice plate, helicopter patrol plate, phase plates, circuit plates, anti-climbing fittings, bird guards and step bolts above anti-climbing fittings.

j) Except where otherwise specified all ferrous parts shall be galvanized. Galvanizing of the members and accessories of the tower shall conform to ISO 752 and ISO 10684:2004.

2.1.5. Insulator, accessories and fittings

a) The insulator strings shall be fixed on the towers just prior to the strings of conductors.

b) Damaged or repaired insulators, accessories and fittings shall not be used in installation.

c) Before hoisting, all insulators shall be cleaned in a manner that may not spoil or injure or scratch.

d) Security clips shall be in position for the insulators before hoisting.

e) Arcing horns or guard rings, if required, shall be placed along the line on suspension, and facing upwards on tension insulator string assemblies, the poke arrangements shall be horizontal for tension, and longitudinal for suspension strings.

f) All fittings for insulators shall be malleable or cast iron hot-dipped galvanized.

g) Strength of insulators shall be such that the safety factor when the insulators are supporting the maximum working load is not less than 2.5.

h) All insulator units will be composed of top and bottom arcing rings to equalize the voltage distribution over the insulator.

2.1.6. Conductor stringing

Conductor stringing shall be carried out using appropriate stringing machines and tools. The maximum tolerance in final still air sag at maximum temperature shall be ± 4 percent of such sag, in any span as obtained from the sag tension chart. The sag of any conductor in a span shall not depart from the mean sag of all conductors in the same span by more than 3 percent.

2.1.6.1. Tensioning and sagging of Conductors

The tension insulator sets, complete with clamped conductors shall be hoisted at the ends remote from the tensioning points. The running blocks at the tensioning end shall be fitted on the cross-arms with sacking wrapped under the slings. The mid-span tension joints shall be placed to ensure the following:

a) No joint shall be placed within 15m of the conductor support;
b) There shall be no joints in important crossing span.
c) There shall be not more than one joint per conductor in a span.
d) The tensioning and sagging shall be done in accordance with the approved stringing charts prepared from the data and relevant specifications of the line. Tensioning and sagging operations shall be carried out in calm weather when rapid changes in temperature are not likely to occur.

2.1.6.2. Clipping-in

a) Clamping the conductors in position, armoring at supports, placing the dampers and spacers, etc, shall be done in accordance to the manufacturer instruction manual.
b) The jumpers at the section and angle towers shall be formed to a curved shape to ensure minimum clearance requirements. Pilot suspension insulator strings with or without dead weights shall be used where necessary to restrict jumper swing. Fasteners on all fittings and accessories shall be secured in position; the security clip also properly opened and sprung into position.
c) Repairs to conductors shall be carried out during the running out operations, with either repair sleeves or jointing sleeves.

2.1.7. Conductor spacing and clearances

The conductor spacing and clearances shall be in accordance to the approved string tension chart;

2.1.7.1. Live metal-structure clearances

Air gap between earthed tower steelwork and line conductors or live metal string components are as follows:

a) Net clearance of 2.910 m for insulator or jumper swing, without wind at every day temperature (25°C).
b) Net clearance of 1.600 m for insulator or jumper swing corresponding to a wind (wind pressure of 450 Pa) speed of 60% of the maximum wind at every day temperature (25°C).

c) Net clearance of 0.890 m for insulator or jumper swing corresponding to the maximum wind speed (wind pressure of 760 Pa) at every day temperature (25°C). (Precise Source and preferably IEC and consider different voltage levels)

2.1.8. Aircraft warning devices

Due to the activity of aircraft in the vicinity of certain parts of the transmission line, it shall be necessary to mount warning spheres on earth wires at some locations with the following features:

a) Aircraft warning spheres shall be capable of being clamped securely to overhead earth wire.
b) The sphere itself shall be of plastic or fiber glass construction of at least 0.5m in diameter and colored as required by local regulations.

2.1.9. Towers earthing

a) All high voltage towers shall be permanently and efficiently earthed. Each grounding shall be constructed in such a way that isolation from the tower and concrete foundation is possible to allow earthing inspection during line service life.
b) Continuous overhead shield wire (OHSW) shall be provided and securely fastened to each tower
c) All structures shall be provided with means for connecting earthing devices at or around nominal ground level, on each leg and for connecting earth wire bonds to each top cross-arm or earth wire peak.
d) Maximum individual earthing resistance of a tower shall be not greater than 10Ω
e) All switchyard equipment shall be earthed with a value not greater than 1Ω.
f) The tower inside the substation or outside the boundary of the substation at a distance less than 100m must be connected to the earthing system of the substation, these towers must be earthed with a value not greater than 1Ω.
g) All 220kV and 110kV towers located within a distance of 1200m from center point of substation must be earthed with a value not more than 5Ω.
h) The earthing test shall be carried out before the OHSW connected;
i) The use of chemicals to reduce soil resistivity is prohibited;
j) The earthing tests shall be conducted preferably in dry season.

2.2. CONSTRUCTION OF SUBSTATION

2.2.1. Pre-requisites

The following approved design documents and assessment reports shall be required prior to construction;

a) Feasibility Study
b) Environmental Impact Assessment Report (Oil and SF6 Gas Handling, Erosion & Sediment Control)
c) Topographic survey report
d) Soil investigation report
e) Substation layout (Civil works and electrical installation)
f) Electrical Equipment drawings and installation guides
g) Operational Health and Safety Implementation plan)
h) Resettlement Action plan

The substation construction works shall be carried out in accordance to the national safety legal framework, IEC61850, REG Policy & Safety Operating procedures and RS ISO 45001: 2018 Operational Health & Safety. Residue works, inspection and commissioning of line.

2.2.2. Substation Construction process

2.2.3. Civil works

All civil works shall be carried out according to the approved drawings and civil materials. The required drawings shall be the following:

a) Structural drawing (dimensions, weight, etc.);
b) Substation layouts;
c) Equipment arrangement;
d) Foundations of equipment in the outdoor switchyard;
e) Power cable trenches;
f) Protection and control cable trenches;
g) Water drainage inside and outside the substation
h) Access roads to substation equipment
i) Boundary fence and entrance gates
j) Electrical control building

2.2.4. Installation of substation primary equipment

2.2.4.1. Pre-requisite

The following approved design documents shall be required prior to installation:

a) Outdoor Electrical Single Line Diagram
b) Switchyard General Arrangement
c) Equipment test reports
d) Equipment installation and instruction manuals

All substation equipment shall be installed according to approved design documents and specific equipment installation manuals from manufacturers.

2.2.4.2. Disconnector and Earthing Switches

a) All disconnector and earthing switches shall be installed as indicated on the Switchyard General Arrangement.
b) All moving parts shall be lubricated for smooth operation.
c) The mechanical and electrical mechanisms shall be interlocked in manner to avoid closing grounding blades when the main switch is in service

2.2.4.3. Lightning (Surge) Arrestors

a) The lightning Arrestors shall be installed according to IEC-99-4 and to the approved design;

b) The lightning arrestors are installed with discharges number counter;

c) In cases where, surge arrestors are supplied in more than one section, these sections must be joined together to form one unit before being erected onto the support structure.

2.2.4.4. Voltage Transformer (VT)

a) The V.T. secondary terminals shall be brought out through miniature circuit breakers (MCB) of suitable rating in a weatherproof terminal complying with IP65.

b) The nameplate indicating all technical characteristics shall be fixed on the accessible level of the VT. The level of quantity of insulating oil shall be visible and accessible.

2.2.4.5. Current Transformers (CT)

a) The type of construction and insulation shall comply with IEC 60185/ 1966 and IEC 60186/ 1969;

b) CT terminal boxes shall be properly sealed to prevent any dust, rain water and insects;

c) All terminals of CT shall be well tightened and unused CT secondary terminals are to be properly shorted to avoid development of abnormal voltage and subsequent failure of CTs in case they are left open.

2.2.4.6. Circuit Breaker

The drive mechanism for the three-position switch shall be for both, manual and motor operation. This motor mechanism shall be commanded with 110 V DC.

2.2.4.7 Bus bar

The bus bar gantries shall be erected as for a double bus bar system.

2.2.4.8 Conductors in switchyard

a) Landing spans (clearance), strung bus-bars and overhead earth wires must be installed in accordance with the Substation General Arrangement and Section Drawings, plus the relevant Standard Assembly Drawing(s). The conductors must be strung to the correct sags and/or tensions as specified on the appropriate drawing.

b) The conductor must not be driven over or walked on by pedestrians. Every precaution must be taken to ensure that the conductors when erected are left without any scratches, cuts, protruding strands, bird caging, rough welds, deposits of grease or dirt, deformation or adhesions.

2.2.4.9. Power Transformer

a) The transformer shall wear a plate in accordance with IEC 60076, at an accessible level.
b) The oil level in the conservator shall not be below the level of the H.V. bushing caps.
c) The oil level shall have adequate capacity with highest and lowest visible oil level;
d) The neutral points shall be brought out by suitable means and shall be grounded as per requirements of the Substation design.

2.2.5. Control Building

The control building to be constructed shall contain all auxiliaries. The scope of civil works shall comprise but not limited to the following approved specific designs:

a) Foundations of equipment in the outdoor switchyard
b) Boundaries fence and entrance gates
c) Site installations
d) Electrical control room
e) Electrical switchgear rooms: The 30/15 kV switchgear room shall be constructed such as to have space for at least 2 additional feeders for each bus bar side.
f) Electrical auxiliary rooms (such a s A C /DC supply, battery, control, relays, SCADA and telecommunication rooms etc…), offices and utilities
g) Small power and lighting installation including outdoor substation and security lighting system;
h) Ventilation system;
i) Cable laying between the station building and the outdoor switchyard; MV underground cables from power transformer to the switchgears shall be copper, single-core with a minimum cross section of 95mm^2 Cu.
j) Earthing grid for the substation
k) Piping for water supply, sanitary works, sewer and rainwater drainage systems and connections.

l) Safety fence around the outdoor switchyard.

m) Surrounding pavements and gravelling of all areas inside the plot limits/adjacent roads. The substation contractor is bound to coordinate the electrical and the civil work for achieving an homogeneous and uniform design. The electrical and civil works shall be approved by the project manager before execution as per the contract.

n) Firefighting system

2.2.6. Substation earthing

a) The substation earthing system must be constructed and commissioned in accordance to the approved design as referred to IEEE 80-2000 Guide for Safety in AC Substation Grounding, ENA EG1-2006 Substation Earthing Guide and IEC standards.

b) Earth grid conductor crimp connections, including lugs must be well compressed.

c) To prevent the transfer of dangerous voltages outside the substation (switchyard), al l conducting services leaving the earth grid area (metallic pipes, fences, control, protection and communication cables, MV panel etc.) must be earthed independently.

PART 3: MAINTENANCE OF TRANSMISSION NETWORK

3.1. Pre-requisite

The following approved design documents shall be required to guide in the maintenance activities of the transmission network:

a) Manufacturer instruction/service manual

b) Commissioning test reports

c) As built drawings

d) Maintenance plan

e) Health & Safety procedure manual

3.2. Maintenance of transmission line

Maintenance works on the transmission lines shall either be carried out on planned/routine basis to check for the operability of the line or as corrective measures after an inspection or unexpected failure.

3.2.1. Preventive/ planned maintenance

Planned transmission line inspection shall be carried out at least once in every 6 months. This shall be carried out in accordance to REG procedure manuals and REG operating safety procedures. An approved transmission line quality check list ***Annex 2***, should be used and shall include but not limited to the activities in the standard transmission maintenance program, ***Table 14***.

The transmission line checklist as in ***Annex 2*** shall consist mainly of the following:

a) Location, tower number, type of tower (angle, suspension);
b) Clearances of the line, to ground and in air, vertical and horizontal;
c) Availability of all tower parts and their conditions;
d) Earthing system;
e) Condition of foundations;
f) Availability and position of arcing horns;
g) Condition of conductors, jumpers, clamps, dampers, etc.

3.2.2. Fault/Curative Maintenance

Fault maintenance shall include intervention activities arising from unexpected in service line failure/trip. These activities shall be carried out in the shortest time possible as described in REG procedural manual and Safety operating procedures.

In events, that may require an outage, REG management shall approve it.

An approved transmission line quality checklist ***Annex 2*** should be used and shall include but not limited to the activities in the standard transmission maintenance program, ***Table 14.***

Table 14: Standard Transmission Line Maintenance Program

Transmission Line Maintenance Program				
Description	**Type of Inspection**		**Activities**	**Corrective Actions**
	Visual	Climbing Visit		
	Frequency			
	After 6 Months	2 years		
	Items to Inspect According to the Type of Inspection			
Identification				
Name of Transmission line	X	X	Record name of transmission Line	N/A
Tower Number	X	X	Record number of tower	N/A
Type of tower (Tension or Suspension)	X	X	Record type of tower	N/A
GPS Coordinate	X	X	Record GPS Coordinate	N/A
Footing				
Ground Line		X	Check back filling around Footings	Improve backfill
Corrosion	X	X	Check for rust or corrosion on footings	Apply zinc based paint
Diagonal Braces	X	X	Check for damaged or missing members	Replace missing members
Concrete	X	X	Eroded or cracked concrete Footings	Repair or replace concrete
Anchor Bolts & Nuts	X	X	Check for missing or loose Bolts	Tighten or replace bolts or nuts
Depth & Alignment	X	X	Check to see if tower plumb or if footings have shifted	Re-plumb or reset tower

Earthing				
Connections	X	X	Check all Earthing & ground connections	Tighten connections
Continuity	X	X	Check for continuity of earthing system	Repair
Right-of-Way				
Vegetation	X	X	Check amount & height of vegetation on right-of-way	Cut vegetation
Roads, Bridges, Culverts	X	X	Check conditions of access roads & roads on right-of-way	Repair
Structures (Metal)				
Bolts		X	Check for missing or loose Bolts	Replace or tighten
Step Pins		X	Check for loose or missing step pins	Replace or tighten
Protective Coating	X	X	Check for rust spots on steel	Brush & paint with zinc based paint
Bent or Missing Members	X	X	Check for bent or missing steel members on legs, cross-arms	Replace
Number & Danger Signs	X	X	Check for bent or missing Signs	Tighten or replace
Warning Markers	X	X	Check for loose or missing line markers	Tighten or replace
Conductors & Hardware				
Conductors				
Sag	X	X	Check for loose sag	Re-sag
Strands	X	X	Check for damaged or broken Strands	Install/ repair sleeves
Clearance	X	X	Check conductor clearance on low spans	Re-sag
Joints		X	Check sleeves for discoloration, spot-check with infra-red	Replace sleeves

Clamps		X	Check all clamps for signs of wear & looseness	Tighten or replace
Dampers	X	X	Check for loose or broken dampers	Repair or Replace
Dead-End Assemblies		X	Check for loose or missing bolts, nuts and cotter pins	Tighten or replace
Jumpers & Terminals		X	Check for loose or missing bolts, nuts and cotter pins	Tighten or replace
Grading Rings		X	Check for loose or missing bolts, nuts and cotter pins	Tighten or replace
Overhead Ground Wire & OPGW				
Sag	X	X	Check to see if OHGW or OPGW has slipped through clamp	Re-sag
Strands	X	X	Check for worn or broken strands	Install/ repair sleeve
Clamps		X	Check U-bolts & jumpers	Tighten or replace
Dead-End Assemblies		X	Check for loose or missing bolts, nuts and cotter pins	Tighten or replace
Vibration Dampers		X	Check for loose or missing vibration dampers	Tighten or replace
Fusion Boxes	X	X	Check the condition of the fusion box	Repair or replace

3.3. MAINTENANCE OF SUBSTATION

Preventive maintenance works shall be carried on each substation equipment following an approved working plan. These maintenance schedules shall be carried out by trained personnel with reference to the manufacturer guidance in the equipment service manual.

3.3.1 Maintenance of outdoor equipment in substation

Prior to specific preventive maintenance activities of different substation equipment, care shall be taken on the following external aspects:

3.3.1.1. External Cleaning

The insulators of the transformer bushings; circuit breaker; CT; VT; isolator shall be cleaned from dirt/dust deposition together with the cleaning of the other insulators in the substation. Frequency of this cleaning depends on the polluting atmosphere. For installations with higher atmospheric pollution, cleaning frequency may be increased and these may be suitably protected against pollution.

3.3.1.2. Rust Protection

All steel equipment support and enclosures such as marshalling kiosks, boxes parts of the operating mechanism are made of steel and are surface treated against rust. In spite of the good rust protection, minor corrosion will occur after some years, especially when these are standing in strong corrosive surroundings. The rust stains shall be sand papered away and new rust protection shall be painted or sprayed on. As rust protection, grease G or Tectyl 506 is recommended.

3.3.1.3. Lubrication

The lubricants recommended by equipment manufacturers shall primarily be used. The bearings of the breaker and operating mechanism of isolator are to be lubricated with grease (appropriate) although these normally do not need lubrication before the major overhauls.

Plain bearings in mechanism details such as arms, links and link gears are also to be lubricated with appropriate grease. These bearings shall be regularly lubricated with a few drops of appropriate oil. The teeth in the gear shall be lubricated with appropriate grease. Dryness of driving mechanism may lead to mal- operation and failure.

3.3.1.4. Treatment of Contact Surfaces

The contacts of breaker / isolator / ground switch shall be treated according to the following instructions: Silvered contact surfaces:

- Silvered contact surfaces shall be cleaned, if necessary, with a soft cloth and appropriate solvent (Trichloroethane). Steel brushing or grinding is not allowed.
- Copper surface: Copper surfaces shall be clean and oxide free. If necessary, they shall be cleaned with cloth and solvent or steel brushing. After steel brushing, the surface shall be cleaned of loose particles and dust.

- Aluminum surface: Aluminum contact surfaces shall be cleaned with steel brush or emery cloth. After making the surface dry and free of dust by wiping with a dry cloth, a thin layer of Vaseline shall be applied. The joint shall be assembled within 15 minutes.

a) Moving Contact Surfaces

- **Silvered:** Cleaned if necessary, with soft cloth and appropriate solvent. No steel brushing.
- **Non-silver coated:** Cleaned as silvered surfaces, can be steel brushed. After steel brushing they shall be thoroughly cleaned of loose particles and dust
- **Lubrication:** Lubricant – grease is applied in a very thin layer on the surfaces of the male contact and the puffer cylinder. The superfluous grease is carefully removed.

3.3.2. Preventive maintenance activities of main substation equipment

Periodic testing and maintenance of each substation equipment shall be carried out according to manufacturer's maintenance instructions and REG procedure manual. Reference shall be made to the transformer test results performed in accordance with the relevant standards. Maintenance schedules for various equipment of HV Substation are given below:

The following letters used signify:

M-monthly**, QY**-quarterly**, HY**-half yearly**, Y**-yearly**, 2Y**-once in 2years**, 3Y**-once in three years**, 4Y**-ocne in 4 years, **SOS**-as and when required**.**

3.3.2.1. Transformers and Reactors

Table 15: Transformer and Reactor maintenance activities that require no shut down

	Activity	Frequency
1	Checking of bushing oil level	M
2	Checking of oil level in conservator	M
3	Checking of oil level in OLTC conservator	M
4	Checking of leaks	M
5	Checking condition of silica gel in breather	M
6	Checking condition of silica get in breather	M
7	Checking of oil level in oil seal of breather	M
8	Testing of oil for DGA and other oil parameters	HY
9	Vibration measurements (for Shunt Reactors only)	2Y

Table 16: Transformer and Reactor maintenance activities that require shut down

	Activity	Frequency
1	BDV, ppm of OlTC Diverter Switch compartment oil (Less frequently if operations are not more	Y
2	External cleaning of radiators	Y
3	Cleaning of all bushing (if required)	Y
4	Checking of auto starting of cooler pumps and fans	Y
5	Marshalling boxes of transformer/reactor and OLTC (i) Cleaning of marshalling boxes of transformer/reactor and OLTC (ii) (ii) Tightening of terminations (iii) Checking of contactors, space heaters, illumination, etc.	Y Y Y Y
6	Maintenance of OLTC driving mechanism	Y
7	Checking of all remote indications (WTI and Tap position indicator) and top up oil in pockets, if required	Y
8	Electrical checking/testing of pressure relief device, Buchholz really, OLTC surge relay/checking of alarm/trip and checking /replacement of the gaskets of the terminal box	Y
9	Checking/testing of Buchholz relay by oil draining	Y
10	Frequency response analysis	SOS
11	Tan measurement for bushings	Y
12	Recovery voltage measurement	SOS
13	IR measurement of winding (Polarization Index and D.A.Ratio)	2Y
14	Tan measurement of Windings	2Y
15	Checking and cleaning of diverter contacts	2Y
16	Checking and calibration of OTI, WTI	2Y
17	Measurement of windings resistance at all tap positions	4Y
18	Filtration/degassing of main tank oil	SOS
19	Testing of bushing CTs	SOS
20	Filtration/replacement of oil of OLTC	SOS
21	Measurement of windings ratio/Transformers turns ratio test	SOS
22	Checking of earthing connections	Y

Insulation resistance measurement, tan δ of winding/busing, winding resistance at all taps to be carried out once before expiry of warranty and then to be continued as per schedule. Vibration measurement for reactor to be carried out initially after 3 months and 6 months after commissioning and then to be continued as per schedule.

3.3.2.2. Circuit Breakers

Table 17: Maintenance checks for Circuit breaker operation

	Activity	Frequency
1	CB operating timings (Main, PIR, Aux.)	Y
2	Static contact resistance measurement	Y
3	Dynamic contact resistance (DCRM), contact travel, contact speed, contact wipe, arcing contact length	Y
4	Checking of pole discrepancy relay	Y
5	Functional checks, duty cycle operation including rapid re-closing (O-o.3s- CO)	Y
6	Checking of all operation lock=outs including SF6 density monitor	Y
7	Checking of all interlocks	Y
8	Checking of pressure settings	Y
9	Cleaning of breaker interrupter, support insulators and grading capacitors	Y
10	Check alarm points in control house	Y
	Measurement/testin	
1	Checking of close/trip coil currents	Y
2	Checking of healthiness of operation counter	Y
3	Capacitance and tan δ measurement of grading capacitors	Y
4	Motion testing (speed test)	Y
	Control	
1	Checking of tightness of all cable terminations in MB	Y
2	Checking of door sealing gaskets and replacement, if necessary	Y
3	Repainting of metallic surfaces	SOS
4	Checking of space heater (before monsoon)	Y
	SF6 Circuit	
1	Checking of oil leaks from grading capacitors	M
2	SF6 gas leakage test	SOS
3	Dew point measurement of SF6 gas	Y
4	Checking tightness of foundation bolts	Y
	Air Blast Circuit	
1	Checking of oil leak from grading capacitors	M
2	Checking of air compressor for oil level, oil quality, air filter	QY
3	Maintenance of air dryers	HY
4	Functional checking of auto starting of air compressors and dryers	Y
5	Checking of air pressure drop during duty cycle operation	Y
6	Dew point measurement of operating air at the outlet of air dryer	Y
7	Checking of tightness of foundation bolts	Y
8	Air (pressure leakage check)	SOS
9	Overhauling of compressors	SOS

Minimum Oil Circuit		
1	Checking of oil leak from grading capacitors	M
2	Checking for oil leakage/oil level and N2 pressure (if applicable)	M
	Testing of oil for BDV	After 15 fault trips or yearly
4	Maintenance of breather and change of silica get	SOS
Vacuum Circuit		
1	Cleaning of control cubicle and checking for loose connections	QY
2	Checking of ON/OFF indicators, spring charge indicator and checking manual and electrical operation	HY
3	Checking vacuum of interrupter by application of high voltage disengaging with operating mechanism	Y
4	Checking erosion of contacts by erosion mark on operating rod	Y
5	measurement of gap specified n closed position of contacts (wherever provide)	
6	Checking tightness of foundation bolts	Y
7	Replacement of vacuum interrupter	SOS
Hydraulic Operating		
1	Checking of oil level and replenishment/topping up, if necessary	M
2	Checking of oil leaks	M
3	Checking of oil pressure drop during duty cycle operation check	Y
4	Checking of auto-starting/stopping of oil pump, pressure switch	Y
5	Checking of healthiness of accumulator by checking the pressure when building up pressure from zero -	Y
6	Checking of operation of safety value	Y
Pneumatic Operating Mechanism		
1	Checking of air compressor for oil level, oil quality, air filter, V-belt	QY
2	Maintenance of air dryer, if provided	HY
3	Functional checking of auto-starting of air compressors and dryers	Y
4	Checking of air pressure drop during duty cycle operation	Y
5	Overhauling of compressors	SOS
Spring Operated		
1	Oil leakages from close and open dashpots, replace the same if observed	Y
2	Greasing/lubrication of gears and various latches in the operating	Y
3	Checking of play of gaps in catch gears	Y
4	Maintenance of spring charging motors, cleaning of carbon brushes contactors	Y
5	Replacement of oil in dashpot	SOS

3.3.2.3. Current Transformers

Table 18: Maintenance checks for Current Transformer Operation

	Activity	Frequency
1	Visual inspection of CT for oil leakage and crack in insulator, etc.	M
2	Thermovision scanning of CT	Y
3	Checking of oil leakage in terminal box	Y
4	Checking of primary connection strips, if provided externally	Y
5	N2 pressure checking	2Y
6	Measurement of Tan δ and capacitance	2Y*
7	I R measurement (DAR)	2Y
8	Checking of primary connection strips, if provided internally	SOS
9	Measurement of CT secondary resistance	SOS
10	Magnetization characteristics	SOS
11	CT ratio test	SOS
12	DGA and testing of other parameters of oil	SOS
13	Checking of burden on the secondary winding	SOS

* To be repeated before one year from commissioning and then a per schedule

3.3.2.4. Marshalling Box

Table 19: Maintenance checks for the Marshalling Box

	Activity	Frequency
1	Checking of oil leakage in terminal box	M
2	Checking of healthiness of gaskets	Y
3	Checking of space heater and illumination	Y
4	Checking the tightness of all connections including earthing of PF terminal	Y
5	Cleaning of marshalling box and junction box	Y

3.3.2.5. Voltage (Capacitive) Transformers (VT)

Table 20: Maintenance checks for the Voltage Transformer

	Activity	Frequency
1	Checking of oil leaks	M
2	Measurement of voltage at Control room panel	HY
3	Visual checking of earthing HF point (in case it is not being used for PLCC)	Y
4	Checking for any breakage or cracks in cementing joint	Y
5	Cleaning of CVT capacitor stacks and tightness of terminal connections	Y
6	Theromovision Scanning of Capacitor stacks	Y
7	Capacitance and Tan δ measurement	3Y*
8	Testing of EMU tank oil for BDV (if oil found discolored)	SOS
9	Checking for rust and painting	

To be repeated before 1 year from commissioning and then as per schedule. This test is not possible to be conducted at site if isolation of neutral of intermediate PT is not possible at site.

3.3.2.6. Disconnector/Isolators and Earth Switches

Table 21: Maintenance checks for Disconnector/Isolators and Earth Switches

	Activity	Frequency
	Main Contact	
1	Cleaning and lubrication of main contacts, pins and bearings	Y
2	Checking of tightness of bolts, nuts and pins, etc.	Y
3	Cleaning of support insulators and checking of insulator cracks, if any	Y
4	Checking of interlocks	Y
5	Checking of earth connection of structure	Y
6	Operation check of isolators	Y
7	Checking of alignment	Y
8	Main contact resistance measurement	Y

Operating Mechanism		
1	Checking and lubrication of linkages including transmission gears	Y
2	Checking and tightening of stopper bolts	Y
3	Cleaning of auxiliary switch contacts and greasing with silicon grease	Y
4	Lubrication of operating mechanism hinges, lock joints on levers, Bearings	Y
5	Checking of all mounting bolts for tightness	Y
6	Checking of healthiness of door gaskets	Y
7	Checking of earth connection of MOM box	Y
8	Checking of tightness of electrical connections	Y
9	Checking of space heaters and illumination	Y
Earth Switch		
1	Checking and alignment of earthing blades	Y
2	Cleaning of contacts and lubrication	Y
3	Operation of earthing switch	Y
4	Checking of aluminum/copper flexible connectors	Y
5	Checking of earth connections of earth switch, structure and MOM box	Y
6	Checking of tightness of bolts, nuts and pins etc. and lubrication of pins and Bearings	Y
7	Contact resistance measurement	2Y

3.3.2.7. Lightning (Surge) Arresters

Table 22: Maintenance checks for the Lightening (Surge) Arresters

	Activity	Frequency
1	Checking of leakage current (Third harmonic resistive current)	Y
2	Testing of counters and leakage current meters	Y
3	Cleaning of insulator	Y
4	Checking of earth connections between surge arrester, surge monitor and earth	Y
5	Measurement of capacitance, Tan δ and IR of each stack	SOS
6	Check for status of surge monitors	SOS

3.3.2.8. Bar, jumpers, connectors, clamps, switchyard illumination, etc.

Table 23: Maintenance checks for the Bar, jumpers, connectors, clamps, switchyard illumination

	Activity	Frequency
1	Measurement of station earth resistance	Y
2	Cleaning of insulators	Y
3	Checking of insulators for cracks	Y
4	Thermovision scanning of all conductor joints, terminal connectors/clamps	Y
5	Checking of earthing connection of all structures	Y
5	Removal of hot spots	SOS
6	De-weeding of switchyard	SOS
7	Repainting, rust removal of all structures, equipment's, etc.	SOS
8	Checking of switchyard lighting	SOS

3.3.2.9. Capacitors

Table 24: Maintenance checks for the Capacitors

	Activity	Frequency
1	Checking of leakage of oil	M
2	Unbalance in capacitors by checking open delta voltage	M
3	Physical checks, Tightness	Y
4	IR value	Y
5	Leakage current measurement	Y
6	Cleaning of insulators/bushings and tightening of connections	Y
7	Capacitance measurement of capacitor cells	Y
8	Checking of Protection relays for adopted setting	Y
9	Checking tightness of earth connection and foundation bolts	Y

3.3.2.10. Protection System

Table 25: Maintenance checks for the protection system

	Activity	Frequency
General Checks		
1	Testing of Dr/EL with time synchronization and unit	M
2	Calibration of tariff energy meters	-
3	Checking of voltage (in service) for relays	Y
4	Checking of DC logic circuits for trip and annunciations including timers by	Y
5	Calibration of panel meters (Indicating/recording instruments along with transducers)	SOS
Distance Protection		
1	Reach check for all 4/5 Zones*	Y
2	Times measurement	Y
3	Power swing blocking check	Y
4	Switch on the fault (SOTF) check	Y
5	Level detectors of pps.	Y
6	Fuse failure check	Y
7	Polarization check	Y
8	Negative phase sequence (NPS) detector check	Y
9	VT fuse failure check	Y
Common Tests For Distance And Unit Protections		
1	Trip contacts check	Y
2	Annunciation check	Y
3	Check for carrier send	Y
4	Auxiliary relays healthiness	Y
5	Over voltage relays	Y
6	Local breaker back-up	Y
7	STUB protection check	Y
8	Fault locator initiation check	Y
9	DR. EL initiation check	Y
10	Auto recluse check	Y
11	DC logic	Y
12	Reactor back up impedance	Y
13	Carrier send for remote trip	Y
14	Auxiliary relays (Buchholz, PRD, etc)	Y
15	Reactor differential protection	Y
16	REF protection	Y
17	DC logic	Y
18	Over fluxing relay	Y
19	Over load	Y
20	Directional over current	Y
21	LBB	Y

22	Auxiliary relays (Buchholz, PRV, etc.)	Y
23	Fuse failure check	Y
24	Transformer differential protection.	Y
25	Restricted earth fault	Y
Bus Bar Protection (to be done whenever the protection AC circuits are disturbed like addition of new feeder)		
1	Primary injection test	SOS
2	Protection stability and sensitivity checks	SOS
3	Relay and DC logic check	Y
Differential Relays		
1	Pick up current at the fixed/selected setting	Y
2	Operation of high set element/instantaneous unit at the fixed/selected setting	Y
3	Operation of the relay at the selected restraint bias setting.	Y
4	Checking of 2nd harmonic current restraint feature	Y
5	Operation of alarm and trip contacts.	Y
6	Through current stability checks on the existing load.	Y
Under Voltage Relay		
1	Starting and pick up of the relay as per plug setting	Y
2	Relay operating time as per relay characteristic	Y
3	Operation of alarm and trip contacts	Y
4	Verification of input voltage on relay terminals	Y
Over Voltage Relay		
1. Starting and pick up of the relay as per plug setting		Y
2. Relay operating time as per relay characteristic		Y
3.peration of high set element/instantaneous unit at voltage setting, if applicable		Y
4. Operation of alarm and trip contacts		Y
5. Verification of input voltage on relay terminals		Y
Neutral Displacement Relay		
1. Starting and pick up of the relay as per plug setting		Y
2. Relay operating time as per relay characteristic		Y
3. Operation of alarm and trip contacts		Y
4.Verification of continuity of input circuit (for RVT/NCT secondary circuit in case of capacitor banks, under shutdown).		
5. Verification of open delta voltage input by by-passing PT secondary supply one phase at a time (in case of 3 nos. single phase PT's).		Y
Over current and Earth Fault Relay		
1.Starting and pick up of the relay as per plug setting		Y
2. Relay operating time as per relay characteristic		Y
3. Operation of high set element/instantaneous unit at current setting, if applicable		Y
4. Operation of alarm and trip contacts		Y
5. Verification of input currents		Y
6. Verification of directional feature, if applicable.		Y

Under Frequency Relay		
1	Pick up value of the relay at its settings by slowly decreasing the frequency from	Y
2	Drop off value of the relay at its settings by slowly increasing the frequency from	Y
3	Verification of df/dt feature of the relay, if applicable	Y
4	Operation of alarm and trip contacts	Y
5	Verification of input voltae on relay terminals	Y
Over Fluxing Relay		
1	Operating of over flux alarm as per relay setting by varying the voltage and	Y
2	Operating of over flux trip features as applicable for the following;	Y
	(i) IDMT characteristic	
	(ii) Instantaneous element	
	(iii) Fixed time setting	
3	Operation of alarm and trip contacts	Y
4	Verification of input voltage on relay terminals	Y
Local breaker back up protection, restricted earth fault (REF) and other instantaneous		
1	Pick up value of the relay at the selected setting	Y
2	Operating time of the relay	Y
3	Operation of alarm and trip contacts	Y
4	Verification of input currents	Y
5	Through current stability checks on the existing load in case of REF/circulating	Y
Fuse Failure Relays		
1	(i) Remove main fuse of each phase voltage input to the distance protection	Y
	(ii) Checking that the "VT Fuse Fail Alarm" is received.	Y
	(iii) Checking that the distance protection does not operate	Y

***** Includes Z_1, Z_2, Z_3 and Z_3 (reverse) or Z_4 and Z_5 (reverse)

Note: The above schedule for Distance relay is generic in nature and the manufacturer's maintenance instruction shall be referred to for any particular make of relay testing.

3.3.2.11. Gas Insulated Switchgear (GIS)

Maintenance of GIS shall be done as recommended by the manufacturer's manual. Maintenance shall be carried out by skilled and authorized persons only. The following main points shall be taken account while carrying out maintenance of GIS: Equipment to be maintained should be de-energized/de-gassed, isolated and earthed on all sides of the work zone. Necessary tools and tackle such as slings, platforms, electrical equipment and tools shall be kept ready and shall be in good condition before commencement of the maintenance.

Regular inspections, Routine scheduled maintenance and overhaul maintenance as specified by the manufacturers' manual.

Monitoring of pressure and quality of SF6 shall comply with IEC 62271-203/2003 guidelines. The leakage rate from any single compartment of GIS to atmosphere and between compartments shall not exceed 0.5% per year for the service life of the equipment.

3.3.2.12. Batteries and DC Distribution System

Mandatory tests shall include but not limited to; Battery capacity testing, continuity test of all circuits, dielectric test of all wiring, polarity tests of auxiliary transformers, battery capacity specific gravity, cell strap connection resistance, internal cell resistance, voltage readings. Additionally, cell containers are to be kept always clean to avoid surface leakage, all connections are to be checked for tightness. The following quality checks shall be periodically carried out.

Table 26: Maintenance checks for the batteries and DC Distribution System

	Activity	**Frequency**
1	Visual inspection of electrolyte levels and battery jars	M
2	Measurement of Specific gravity and voltage of cell	M
3	Checking electrolyte level and topping up with DM water, if required	M
4	Checking of Emergency DC lighting to control Room	M
5	Checking of any earth fault (If E/F relay not provided)	QY
6	Checking of electrical connections of charger panel and DCDB panels for tightness and cleanliness	Y
7	Checking of electrical connections for batteries and application of petroleum jelly on cell terminal, if required	Y
8	Checking control cards of charger and measurement of test point voltage values	Y
9	Battery impedance testing (Optional)	Y
10	Testing of DC E/F and under voltage relays	Y
11	Discharge test of battery set	Y
12	Record battery voltage & current	M

ANNEX 1

TRANSMISSION NETWORK DEVELOPMENT FORMS

- PROJECT DESIGN REPORT
- SITE HANDOVER REPORT
- TESTING AND COMMISSIONING REPORT FOR TRANSMISSION LINE
- GIS AS-BUILT DATA
- AS BUILT FOR ELECTRICITY TRANSMISSION LINE
- PROVISIONAL HANDOVER OF TRANSMISSION LINE
- FINAL HANDOVER OF TRANSMISSION LINE
- TESTING AND COMMISSIONING REPORT FOR HV SUBSTATION
- PROVISIONAL HANDOVER REPORT FOR HV SUBSTATION
- FINAL HANDOVER REPORT FOR HV SUBSTATION
- TYPICAL SINGLE LINE DIAGRAM OF HV/MV SUBSTATION

PROJECT DESIGN REPORT			
Name of Project			
Cost Estimate (budget)			
Project implementer/Contractor			
Project Investigation Information			
Name of the planned HV line or substation			
Voltage Level of HV line			
Length of the HV line			
Type of support structures for HV Line			
Name of Substation Supply			
Capacity of power to be evacuated (MW) by the HV line			
Proposed conductor type and Size/(mm^2) of HV line			
Main Substation Transformer Capacity (MVA)			
Transformation voltage (…./….kV)			
Area of the land available for Substation construction (m^2)			
Nature of the soil			
Planned number of outgoing feeders from substation			
Planned carrying Capacity of outgoing feeders (MVA)			
Planned conductor sizes for outgoing feeders (mm^2)			
Load flow studies performed	Yes/No	Name of the person who did load flow:	
Simulated voltage at load end (kV)			
Simulated voltage at substation while loading			
Is this Project in line with the Master plan guidelines for network development?	Yes/No		
Additional requirements or conditions for technical approval			
Name of Design Engineer	Position	Signature and Date	
FOR APPROVAL			
Is this Project technically approved? If no, please highlight what needs to be done prior to approval with	Yes/No	Required additional details:	
Name	Position	Signature and date	

SITE HAND OVER REPORT		
Description of the area site		
Name of Project		
Contract Reference		
Name of Implementer / Contractor		
Expected date of Completion		
Brief description of the works (project scope)		
Is contractor's site mobilization and quality plans in place?	Yes/No	
Has expropriation been done?	Yes/No	Status of expropriation:
Was environmental impact assessment done?	Yes/No	
Are Land title/construction permits available?	Yes/No	
Was a safety briefing done by REG?	Yes/No	
Are there potential safety risks identified on site? Name those:	**Potential risk**	**Mitigation measures**
Was REG switching procedures explained to the Implementer / Contractor?	Yes/No	
Parties declare that information provided in this site hand over certificate is true and correct and provide sufficient information for the purposes of site hand over		

SIGNATURES

For REG

NAMES	POSITION	SIGNATURE AND DATE

For Contractor

NAMES	POSITION	SIGNATURE AND DATE

TESTING AND COMMISSIONING REPORT FOR HIGH VOLTAGE LINE	
PROJECT BASIC DATA	
Project Name	
Contract Reference	
Name of Contractor / Implementer	
Tower structure, height and number	
Length of the line (km):	
Conductor type and size:	
VISUAL CHECKS	
Condition of tower foundation (Tower footing, erosion protection…)	
Status of tower members (No member missing, straight, …)	
Status of insulators (damaged, inappropriate)	
Tower accessories available (Number, Phase, danger, circuit plates…)	
Status of bolts and nuts (Tightening, punched…)	
Tower member galvanizing	
Clearance (Vertical and Horizontal)	
Right of way	
TESTS BEFORE CONNECTION OR ENERGIZING	
Earthing resistance in Ohms	
Earthing resistance at towers near the substation at a distance less than 100m (Value in Ω≤ 1Ω)	
Earthing resistance at towers at a distance less than 1200m from the substation (Value in Ω≤ 5Ω)	
Earthing resistance at towers at a distance more than 1200m from the substation (Value in Ω≤ 10Ω)	
Insulation in Mega/GigaΩ: Resistive line ≥ 1 GΩ; Capacitive or Inductive line ≥ 1 MΩ/KV	
Phase 1 - Phase 2:	
Phase 1 - Phase 3:	
Phase 2 – Phase 3:	
Phase 1 – Shield wire (OPGW) / Ground:	
Phase 2 - Shield wire (OPGW) / Ground:	
Phase 3 - Shield wire (OPGW) / Ground:	

CONTRACTOR/IMPLEMENTER		
Name	**Position**	**Signature and Date**
REG REPRESENTATIVES		

GIS AS-BUILT DATA

To keep the REG GIS Database update, all Contractors and all Departments who touch on the Network must submit as-built data after completion of project in addition to all other required documents. These data should be reported to the Unit in charge of Geographical Information System (GIS). The following projection should be respected as it is the one used in the REG ArcGIS system:

- Coordinate system: GCS_ITRF_2005 or GCS WGS 1984 (as indicated in the contract)
- Projection: Transverse Mercator
- Datum: D_ITRF_2005 or WGS 1984 (as indicated in the contract)
- False Easting: 500,000.0000
- False Northing: 5,000,000.0000
- Central Meridian: 30.0000
- Scale Factor: 0.9999
- Latitude of origin: 0.0000
- Units: Meter

AS-built Data for Electricity Transmission Line

The as-built Data for Electricity Transmission lines shall be provided with the following:

- As-built maps and drawings accompanied with their Shape files compatible with the recent Arc GIS and engineering software in use
- Excel sheets indicating the towers schedules including but not limited to the information of tables below:

Towers schedule for HV line

Conductor type and size: ACSR/ACCR…….mm2										**Max Load: …… kN**								
Towers Number	**GPS Coordinates**	**Span (m)**	**Length of Conductor**	**Type**						**Suspension 178-180^0**	**Tension 170-180^0**	**Tension 170-180^0**	**Tension 165-180^0**	**Tension 150-180^0**	**Tension 120-180^0**	**Tension 90^0**		**Observations**
				Types of Towers														
																		Starting and end Point
1																		
2																		
Total																		

PROVISIONAL HAND-OVER FOR HIGH VOLTAGE LINE											
PROJECT BASIC DATA											
Project implementer/Contractor											
Project location (Districts)											
Name of Substation Supply											
Voltage level (kV)											
Maximum current carrying capacity (MVA)											
Length of the HV line (km)											
Type and Size of conductor (s)											
Warranty/guarantee/Defect Liability period , start & end date											
Pylon/Tower structures Height and number	Type & H										
	Number										
Number of Circuits											
Type of OPGW wire installed (Number & size)											
Was As-built drawings with all GIS information submitted?											

SNAGS TO BE CORRECTED		
No	**Description**	**Measures to be Taken**
1		
2		
3		
4		
5…		

CONTRACTOR/IMPLEMENTER		
Name	**Position**	**Signature and Date**

REG REPRESENTATIVE		
Name	**Position**	**Signature and Date**

FINAL HAND-OVER OF HIGH VOLTAGE LINE	
PROJECT BASIC DATA	
Project implementer/Contractor	
Project location	
Name of Substation Supply	
Voltage level (kV)	
Maximum current carrying capacity (MVA)	
Length of the HV line (km)	
Size of conductor (s)	
Project has been successfully completed and all snags raised have been cleared	Yes /No
All As Built documents have been submitted (drawings, As built, GIS data,…)?	Yes /No
Warranty/guarantee/Project liability period ,start & end date	
Comments and Other useful information	

CONTRACTOR/IMPLEMENTER		
Name	**Position**	**Signature and Date**

REG REPRESENTATIVE		
Name	**Position**	**Signature and Date**

TESTING AND COMMISSIONING REPORT FOR HV SUBSTATION

1. Visual inspection

Pos	Status	Observations (ok/Not ok)
1	Inspect physical and mechanical condition of both equipment and enclosures	
2	Check for cleanliness of all equipment	
3	Inspect for proper labeling of all equipment	
4	Compare equipment nameplate data with drawings and specifications	
5	Verify that all grounding and shorting connections provide contact	
6	Verify tightness of accessible bolted electrical connections	
7	Verify that oil is at correct level in the bushings, conservator tank, thermometer pockets, diverter switch tank etc.	
8	Verify for proper setting of the arcing horn of the transformer	

2. Circuits Testing

	Circuit	Observations (ok/Not ok)
1	AC supply	
2	DC supply	
3	Battery charger Performance	
4	Rectifier Supervision, Events and Alarms	
5	Battery record during the battery charge and discharge	
6	Main substation equipment	
	Lightning arrestor,	
	Voltage transformer,	
	Current transformer,	
	Disconnector,	
	Earthing disconnector	
	Circuit breaker,	
	Power transformer	

3. Measurement (Test) of main substation equipment:

Pos	equipment	Test		A/NA
1	Lightning arrestor	Insulation withstand and resistance		
		Residual voltage		
		Internal partial discharge		
		Pressure relief if applicable		
		Checking for counter and leakage current		
		Operating duty		
		Capacitance and tan Delta		
2	Voltage transformer	Insulation Resistance		
		Turns Ratio on all tap positions		
		Burden at transformer terminals		
		Dielectric withstand on primary windings secondary connected to ground		
		Power Factor or Dissipation - Factor		
3	Current transformer	Insulation Resistance		
		Ratio verification		
		Polarity test on each Current transformer		
		Power Factor or Dissipation - Factor		
		Excitation test on transformers used for relaying applications		
		Burdens of Current transformer		
		Knee point voltage test		
		Dielectric withstand tests on the primary winding with the secondary grounded		
4	Disconnector	HV Testing		
		Measure Insulation resistance		
		Measure Earth switch Earth connection resistance		
		Auxiliary and control circuit voltage withstand		
		Measure Contact resistance		
5	Circuit breaker	Operating mechanisms		
		Control and Signaling circuit		
		Insulation resistance:	Phase to earth	
			Phases-phases	
			Across contacts when open	
		Purity and dew point of SF6 at rated pressure of the breaker at atmospheric temperature		
		Local/remote breaker operations		
		Operation of counter and all mechanical indications		
		Operation of pole discrepancy relay		
		Check for capacitor tripping device		
		Capacitance and tan ϕ of voltage grading capacitors		
		Short circuit trip		
		Checking of all Non-return valves/ Safety valves		

6	Transformer	Transformer ratio	
		Transformer insulation resistance (cores, windings and oil)	
		Magnetizing and magnetic balance test	
		Polarity and Vector group	
		Impedance and zero sequence impedance	
		Short circuit current, load losses and impedance at all taps	
		On load tap changer	
		Insulation resistance and polarization index	
		Capacitance and tan ϕ of winding	
		Oil and Winding temperatures sensors	
		Operation status of DGA, BDV, MOG, Buchholz relay and OLTC Oil	
		Fan and accessories	
		MCB and marshalling kiosk	

A/NA: Acceptable /Non Acceptable

4. Final inspection and release for energizing

	Activity	YES/NO
1	All works completed (if any)	
2	All temporary connections removed (if any)	
3	All terminals tightly fastened	
Remarks:		
READY FOR ENERGIZING NOTE		YES/NO
Substation equipment has successfully passed SAT and is ready for energizing		
APPROVAL		

	Name	Position	Signature & date
Tested by			
Witnessed by:			
Authorized by			

PROVISIONAL HAND OVER REPORT FOR HV SUBSTATION

1.1 GENERAL		
Project identification		
Project implementer/contractor:		
Financier		
Project Start Date		
Project End Date		
Warranty/guarantee period start and end date(date/month/year)		
Project cost(Amount in Rwf)	Contract amount	
	Expropriation cost	
	Payment to property valour	
	Cost for supervision firm	
	Other expenses incurred (including taxes, FAT)	
	Contract amount	
	Expropriation cost	
	Total cost	
Project technical details provided		**Yes /NO**
Copy of contract documents		
BoQ as build with serial numbers, manufacturer and country of origin		
Single Line and Schematic diagrams (Attached);		
Factory Test reports (FAT);		
AS built documentation;		
Operation and Maintenance manuals;		
Test and Commissioning reports;		
List of tools and spare parts provided as stated in BoQ (with serial numbers, cost details and country of origin)		
Snag list;		
Expropriation files with proof of payment;		
Land title under REG names;		
GIS as built data (shape files)		
Copy of contract documents		

1.2. Line Bay				
HV Feeder name				
Conductor used for feeders and number of conductors per circuit				
Continuous (75°) rating of the feeders (A)				
Emergency (90°) rating (A)				
HV Surge arrestors	Manufacturer			
	Type/Class/ rating (kA)			
	Manufacture date for each	Phase A	Phase B	Phase C
	Serial Number			
HV line Isolator	Manufacturer			
	Type/Rating (A)			
	Earthing Switch installed			
	Manufacture date			
	Serial Number			
HV Busbar Isolators	Manufacturer			
	Type/Rating (A)			
	Earthing Switch installed			
	Manufacture date			
	Serial Number			
HV Line Breaker	Manufacturer			
	Reclosing capability (Y/N)			
	Reclosing 1p or 3p			
	Type/rating			
	Manufacture date			
	Serial Number			
HV VT	Manufacturer			
	Class/Power			
	Ratios			
	Manufacture Date			
	Serial Number			
110kV CT	Manufacturer			
	Class/Power			
	Ratios			
	Manufacture Date			
	Serial Number			
1.3. Transformer Bay				
Surge arrestors	Manufacturer			
	Type/Class/ rating (kA)			
	Manufacture date for each	Phase A	Phase B	Phase C
	Serial Number			

Busbar Isolators	Manufacturer			
	Type/Rating (A)			
	Earthing Switch installed			
	Manufacture date			
	Serial Number			
Circuit Breaker	Manufacturer			
	Type/rating			
	Reclosing capability (Y/N)			
	Reclosing 1p or 3p			
	Manufacture date			
	Serial Number			
Current Transformer	Manufacturer			
	Class/Power			
	Ratios			
	Manufacture Date			
	Serial Number			

1.4. HV Indoor feeder control panel	
Manufacturer	
Commissioning Date	
Bay Control Unit Manufacturer	
Type of metering installed	
Type of feeder protection installed	
Is the feeder connected to SCADA?	
RTU Manufacturer	

1.5. Transformer control panel	
Manufacturer	
Commissioning Date	
Bay Control Unit Manufacturer	
Type of metering installed	
Type of protection installed	
Is the feeder connected to SCADA?	

1.6. Power Transformer …/…….kV ……MVA	
Transformer name and location (*if applicable*)	
Manufacturer	
Manufacturing Date	
Commissioning Date	
Serial Number	
Guarantee period and start date	

Primary/Secondary voltages	
Transformer size (MVA)	
Cooling System (ONAN/ONAF/OFAF)	
Vector Group	
Tap Changer Manufacturer	
Tap Changer Manufacturing date	
Tap Changer Serial number	
Number of Taps (tap changer taps)	
Tap positions available (%)	
Is Testing & Commissioning data attached? (yes or no)	
1.7. Earthing Transformer (if applicable)	
Transformer name and location (*if applicable*)	
Type (Aux/Earthing/NEC/R)	
Manufacturer	
Manufacturing Date	
Commissioning Date	
Serial Number	
Guarantee period and start date	
Primary/Secondary voltages	
Transformer size (kVA)	
Size of main LV Breaker (A)	
Current setting of LV Breaker (A)	
Configuration (pole mounted/ concrete base/ cabin, etc.)	
Cooling System (ONAN/ONAF/OFAF)	
Vector Group	
Number of Taps	
Tap positions available (%)	

1.8. MV PANELS – Transformer incomer panel	
Name of Substation	
Contractor used for construction	
Manufacturer	
Feeder name	
Serial Number	
Commissioning Date	
Guarantee period and start date	
Panel Voltage	
VT Equipped (Y/N)	
VT Serial number	
Single or double busbar	
Busbar rating (kA)	
Breaker insulation medium	
Breaker rating (kA)	
Bay Control Unit make	
SCADA controlled	
Is Testing & Commissioning data attached?	
1.9. MV FEEDER PANELS	
Name of Substation	
Number of feeder Panels	
Feeder name 1 and serial no.	
Feeder name 2 and serial no.	
Feeder name 3 and serial no.	
Feeder name 4 and serial no.	
Contractor used for construction	
Manufacturer	
Commissioning Date	
Guarantee period and start date	
Panel Voltage	
VT Equipped (Y/N)	
VT Serial number	
Single or double busbar	
Bus-bar rating (kA)	
Breaker insulation medium	

Breaker rating (kA)	
Bay Control Unit make	
SCADA controlled?	
Is Testing & Commissioning data attached?	
1.10. BATTERIES AND DC SYSTEM 110V	
Contractor used for construction	
Substation Name	
Manufacturer of Battery Charger	
Commissioning Date	
DC Output Voltage	110V
Warranty/guarantee period and start date:	
Number of battery cells installed	
Voltage per cell	
Capacity of each cell (Ah)	
Is Testing & Commissioning data attached?	
1.11. BATTERIES AND DC SYSTEM 48V	
Contractor used for construction	
Substation Name	
Manufacturer of Battery Charger	
Commissioning Date	
DC Output Voltage	48V
Warranty/guarantee period and start date:	
Number of battery cells installed	
Voltage per cell	
Capacity of each cell (Ah)	
Is Testing & Commissioning data attached?	
1.12. BUILDING CIVIL WORKS	
Project implementer/contractor:	
Substation Name	
Warranty/guarantee period and start date:	
Building Size (m^2)	

Roof structure	
Outside walls coverage	
Inside walls coverage	
Air conditioner installed?	
How many rooms? Please name (*by function*)	
How many incoming MV panels?	
How Many Bus Couplers	
How many Feeder panels	
Batteries and charger installed (Y/N)	
Auxiliary transformer installed (kVA)	
RTU and SCADA comms. installed (Y/N)	
LV DB installed (Y/N)	
1.13. Equipment Submitted	
First aid and safety equipment	
Relay Test Equipment	
SF6 gas service mobile unit	
Laptop with software for relays	
Gas leakage detector	
Tools and spares for 110kV and 30kV equipment	
1.14. Documentation Submitted	
Is Testing & Commissioning data submitted?	
Complete Equipment nameplate data submitted?	
As built drawings and schematic diagrams submitted (if applicable or else only list those provided)	
GIS as build data	
Layout maps provided	
Copies of expropriation files	
Contract (s) Contractor (main), Consultant (if applicable), Contract for any other directly or indirectly outsourced services,	

Project has been completed	Yes /No
Snags raised	
Warranty/guarantee/Liability period, start & end date	
All As Built documents have been submitted (drawings, As built and GIS information…)	Yes /No
Comments and Other useful information:	

RECEPTION	**NAMES**	**POSITION**	**SIGNATURE AND DATE**
For REG			
For Contractor/Implementer			

FINAL HAND OVER REPORT FOR HV SUBSTATION

PROJECT BASIC DATA	
Project Name	
Contract Identification	
Project implementer/Contractor	
Project location	
Name of Substation	
Voltage level (kV)	
Maximum power capacity (MVA)	
Project has been successfully completed and all snags raised have been cleared	Yes /No
Warranty/guarantee/Project Liability period, start & end date	
All As Built documents have been submitted (drawings, As built and GIS information…)?	Yes /No
Comments and Other useful information	

CONTRACTOR/IMPLEMENTER		
Name	**Position**	**Signature and Date**

REG REPRESENTATIVE		
Name	**Position**	**Signature and Date**

ANNEX 2

CHECKLISTS FOR NETWORK TRANSMISSION MAINTENANCE

1. INSPECTION CHECKLIST FOR MAIN HV SUBSTATION EQUIPMENT
2. INSPECTION CHECKLIST FOR HV TRANSMISSION LINE

1. INSPECTION CHECKLIST FOR MAIN HV SUBSTATION EQUIPMENT

a) External checklist of substation

No	Activity	Observations
1	External Cleaning	
2	Rust Protection	
3	Lubrication	
4	Treatment of Contact Surfaces	
5	Moving Contact Surfaces	

b) Checklist for Transformers and Reactor

	Activity	Observations
1	Checking of bushing oil level	
2	Checking of oil level in conservator	
3	Checking of oil level in OLTC conservator	
4	Checking of any leaks	
5	Checking condition of silica gel in breather	
6	Checking of oil level in oil seal of breather	
7	Testing of oil for DGA and other oil parameters	
8	Vibration measurements (for Shunt Reactors only)	
9	BDV, ppm of OlTC Diverter Switch compartment oil (Less frequently if operations are not more	
10	External cleaning of radiators	
11	Cleaning of all bushing	
12	Checking of auto starting of cooler pumps and fans	
13	Marshalling boxes of transformer/reactor and OLTC (i) Cleaning of marshalling boxes of transformer/reactor and OLTC (ii) Tightening of terminations (iii) Checking of contactors, space heaters, illumination, etc.	
14	Maintenance of OLTC driving mechanism	
15	Checking of all remote indications (WTI and Tap position indicator) and top	
16	Electrical checking/testing of pressure relief device, Buchholz really, OLTC surge relay/checking of alarm/trip and checking /replacement of the gaskets of the terminal box	
17	Checking/testing of Buchholz relay by oil draining	
18	Measurement of windings resistance at all tap positions	

19	Filtration/degassing of main tank oil	
20	Filtration/replacement of oil of OLTC	
21	Measurement of Transformers turns ratio test	
22	Checking of earthing connections	
23	Vibration & acoustic testing	

c) Checklist for Circuit breakers

	Activity	**Observations**
1	CB operating timings (Main, PIR, Aux.)	
2	Static contact resistance measurement	
3	Dynamic contact resistance (DCRM), contact travel, contact speed, contact	
	wipe, arcing contact length	
4	Checking of pole discrepancy relay	
5	Functional checks, duty cycle operation including rapid re-closing (O-o.3s-CO)	
6	Checking of all operation lock=outs including SF6 density monitor	
7	Checking of all interlocks	
8	Checking of pressure settings	
9	Cleaning of breaker interrupter, support insulators and grading capacitors	
10	Check alarm points in control house	
11	Checking of close/trip coil currents	
12	Checking of healthiness of operation counter	
13	Checking of tightness of all cable terminations in MB	
14	Checking of door sealing gaskets and replacement, if necessary	
15	Checking of oil leaks from grading capacitors	
16	SF6 gas leakage test	
17	Dew point measurement of SF6 gas/ operating air at the outlet of air dryer	
18	Checking tightness of foundation bolts	
19	Checking of air compressor for oil level, oil quality, air filter, air pressure leakage check	
20	Functional checking of auto starting of air compressors and dryers	
21	Checking of air pressure drop during duty cycle operation	
22	Checking of oil leaks, level and replenishment/topping up, if necessary	
23	Checking erosion of contacts by erosion mark on operating rod or measurement of gap specified n closed position of contacts (wherever provided)	
24	Checking vacuum of interrupter by application of high voltage by disengaging with operating mechanism if necessary	
25	Checking of ON/OFF indicators, spring charge indicator and Checking manual and electrical operation	
26	Testing of oil for BDV	
27	Greasing/lubrication of gears and various latches in the operating mechanism	
28	Maintenance of spring charging motors, cleaning of carbon brushes and contactors	

d) Checklist for Current Transformer

	Activity	Observation
1	Visual inspection of CT for oil leakage and crack in insulator, etc.	
2	Checking the tightness of all connections including earthing of PF terminal	
3	Checking of cleaning of marshalling box and oil leakage in terminal box	
4	Checking of primary connection strips, if provided externally	
8	Checking of primary connection strips, if provided internally	
9	Measurement of CT secondary resistance	
11	CT ratio test	
12	DGA and testing of other parameters of oil	
13	Checking of burden on the secondary winding	

e) Checklist for voltage(capacitive) transformers(VT)

	Activity	Observations
1	Checking of oil leaks	
2	Measurement of voltage at Control room panel	
3	Visual checking of earthing HF point (in case it is not being used for PLCC)	
4	Checking for any breakage or cracks in cementing joint	
5	Cleaning of CVT capacitor stacks and tightness of terminal connections	
8	Testing of EMU tank oil for BDV (if oil found discolored)	

f) **Checklist for Disconnector/Isolators and Earth Switches Main Contact**

(i) Disconnector

	Activity	Observations
1	Cleaning and lubrication of main contacts with silicon grease, pins and b	
2	Checking of tightness of bolts, nuts and pins, stopper bolts, etc.	
3	Cleaning of support insulators and checking of insulator cracks, if any	
4	Checking of interlocks	
5	Checking of earth connection of structure	
6	Checking of isolators operating mechanism, blades, contacts, alignment	

(ii) Earth Switch

	Activity	Observations
1	Checking and alignment of earthing blades	
2	Cleaning of contacts and lubrication	
3	Operation of earthing switch	
4	Checking of aluminum/copper flexible connectors	
5	Checking of earth connections of earth switch, structure and MOM box	
6	Checking of tightness of bolts, nuts and pins etc. and lubrication of pins and bearings	
7	Contact resistance measurement	

g) Checklist for Lightning (Surge Arresters)

	Activity	Observations
1	Checking of leakage current (Third harmonic resistive current)	
2	Testing of counters and leakage current meters	
3	Cleaning of insulator	
4	Checking of earth connections between surge arrester, surge monitor and earth	
6	Check for status of surge monitors	

h) Check list for Bus Bar, jumpers, connectors, clamps, switchyard illumination, etc.

	Activity	Observations
1	Measurement of station earth resistance	
2	Cleaning of insulators	
3	Checking of insulators for cracks	
4	Thermovision scanning of all conductor joints, terminal connectors/clamps	
5	Checking of earthing connection of all structures	
5	Removal of hot spots	
6	De-weeding of switchyard	
7	Checking of switchyard lighting	

i) Checklist for Capacitors

	Activity	Observations
1	Checking of leakage of oil	
2	Unbalance in capacitors by checking open delta voltage	
3	Physical checks, Tightness	
4	IR value	
5	Leakage current measurement	
6	Cleaning of insulators/bushings and tightening of connections	
7	Capacitance measurement of capacitor cells	
8	Checking of Protection relays for adopted setting	
9	Checking tightness of earth connection and foundation bolts	

j) Checklist for Protection Systems

	Activity	Observations
1	Testing of Dr/EL with time synchronization and unit	
2	Calibration of tariff energy meters	
3	Checking of voltage (in service) for relays	
4	Checking of DC logic circuits for trip and annunciations including timers by simulation	
5	Calibration of panel meters (Indicating/recording instruments along with the transducers)	

(i) Distance Protection

	Activity	Observations
1	Reach check for all 4/5 Zones*	
2	Times measurement	
3	Power swing blocking check	
4	Switch on the fault (SOTF) check	
5	Level detectors of pps.	
6	Fuse failure check	
7	Polarization check	
8	Negative phase sequence (NPS) detector check	
9	VT fuse failure check	

(ii) Common Tests door distance and Unit Protections

	Activity	Observations
1	Trip contacts check	
2	Annunciation check	
3	Check for carrier send	
4	Auxiliary relays healthiness	
5	Over voltage relays	
6	Local breaker back-up	
7	STUB protection check	
8	Fault locator initiation check	
9	DR. EL initiation check	
10	Auto recluse check	
11	DC logic	
12	Reactor back up impedance	
13	Carrier send for remote trip	
14	Auxiliary relays (Buchholz, PRD, etc)	
15	Reactor differential protection	
16	REF protection	

17	DC logic	
18	Over fluxing relay	
19	Over load	
20	Directional over current	
21	LBB	
22	Auxiliary relays (Buchholz, PRV, etc.)	
23	Fuse failure check	
24	Transformer differential protection.	
25	Restricted earth fault	

(iii) Bus Bar Protection

	Activity	**Observations**
1	Primary injection test	
2	Protection stability and sensitivity checks	
3	Relay and DC logic check	

(To be done whenever the protection AC circuits are disturbed like addition of new feeder)

(iv) Differential Relays

	Activity	**Observations**
1	Pick up current at the fixed/selected setting	
2	Operation of high set element/instantaneous unit at the fixed/selected setting	
3	Operation of the relay at the selected restraint bias setting.	
4	Checking of 2nd harmonic current restraint feature	
5	Operation of alarm and trip contacts.	
6	Through current stability checks on the existing load.	

(v) under Voltage Relay

	Activity	**Observations**
1	Starting and pick up of the relay as per plug setting	
2	Relay operating time as per relay characteristic	
3	Operation of alarm and trip contacts	
4	Verification of input voltage on relay terminals	

(vi) Over Voltage Relay

	Activity	**Observations**
1	Starting and pick up of the relay as per plug setting	
2	Relay operating time as per relay characteristic	
3	Operation of high set element/instantaneous unit at voltage setting, if applicable	
4	Operation of alarm and trip contacts	
5	Verification of input voltage on relay terminals	

(vii) Neutral Displacement Relay

1	Starting and pick up of the relay as per plug setting	
2	Relay operating time as per relay characteristic	
3	Operation of alarm and trip contacts	
4	Verification of continuity of input circuit (for RVT/NCT secondary circuit in Case of capacitor banks, under shutdown).	
5	Verification of open delta voltage input by by-passing PT secondary supply One phase at a time (in case of 3 nos. single phase PT's).	

(viii)Over current And Earth Fault Relay

1	Starting and pick up of the relay as per plug setting	
2	Relay operating time as per relay characteristic	
3	Operation of high set element/instantaneous unit at current setting, if Applicable.	
4	Operation of alarm and trip contacts	
5	Verification of input currents	
6	Verification of directional feature, if applicable.	

ix) Under Frequency Relay

1	Pick up value of the relay at its settings by slowly decreasing the frequency from 50 Hz	
2	Drop off value of the relay at its settings by slowly increasing the frequency from pick up value	
3	Verification of df/dt feature of the relay, if applicable	
4	Operation of alarm and trip contacts	
5	Verification of input voltae on relay terminals	

(x) Over Fluxing Relay

	Activity	
1	Operating of over flux alarm as per relay setting by varying the voltage and frequency one at a time	
2	Operating of over flux trip features as applicable for the following; (i) IDMT characteristic (ii) Instantaneous element (iii) Fixed time setting	
3	Operation of alarm and trip contacts	
4	Verification of input voltage on relay terminals	

(xi) Local breaker back up protection, restricted earth fault (REF) and other Instantaneous current operated relays

1	Pick up value of the relay at the selected setting	
2	Operating time of the relay	
3	Operation of alarm and trip contacts	
4	Verification of input currents	
5	Through current stability checks on the existing load in case of REF/circulating current differential protection.	

k) **Checklist for batteries and dc distribution system**

	Activity	**Observations**
1	Visual inspection of electrolyte levels and battery jars	
2	Measurement of Specific gravity and voltage of cell	
3	Checking electrolyte level and topping up with DM water, if required	
4	Checking of Emergency DC lighting to control Room	
5	Checking of any earth fault (If E/F relay not provided)	
6	Checking of electrical connections of charger panel and DCDB panels for tightness and cleanliness	
7	Checking of electrical connections for batteries and application of petroleum jelly on cell terminal, if required	
8	Checking control cards of charger and measurement of test point voltage values	
9	Battery impedance testing (Optional)	
10	Testing of DC E/F and under voltage relays	
11	Discharge test of battery set	
12	Record battery voltage & current	

Checked by (Names, position and signature)

Verified by (Names, position and signature)

Comments

2. INSPECTION CHECKLIST FOR HV TRANSMISSION LINE

Checklist for normal and special line patrolling

Name of the line …… Date ……..……

	Activity	Observation on each tower							
		1	2	3	4	5	6	7	8….
Tower	Tower/Pole Foundation status								
	Tower/ Pole Straightness, bending								
	Fixing bolts & nuts								
	Missing tower member								
	Horizontal clearances								
	Vertical clearance								
	Obstacles (trees, dwellings, crossings, parallel lines etc.)								
	Cross check of specific items(viz. tree growth, clearances, condition of insulators, foundations etc.) reported by patrol men during normal patrolling at the location and action taken on these items								
	Tower footing resistance at the locations where disc flashover is reported 110 &220kV lines								
	Apparent defects (vandalized, bird nest, steel bar exposed, cross arms stolen, rusted, covered by creepers, loose of bolts….)								
Insulator	Status of Insulators and accessories (Broken or cracked, Missing disc, Not well-fitted, Not aligned, Burnt, etc.)								

conductor	Type and Size,		
	Apparent defects (Strands Broken, bird caging, etc.)		
	Number of Junctions		
	Conductor on insulator status (Not well fitted, Loosen)		
	Internal Clearances (Normal, Below normal)		
	Conductor to ground/external clearance(Normal, Below normal)		
	Right of way (Bush cleared, bush around lines, bush below lines,)		
	condition of conductor, earth wire, clamps and fittings, vibration dampers, spacers, armor grips etc. along the span		

Checked by (Names, position and signature)

Verified by (Names, position and signature)

Comments