NATIONAL TRANSMISSION AND DESPATCH COMPANY (NTDC)

SPECIFICATION P- : 2009

STATIC VAR COMPENSATORS

Prepared by
DESIGN DEPARTMENT (NTDC)

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STATIC VAR COMPENSATORS

1. FOREWORD

1.1 This specification has been prepared by Design Department, Services Division, NTDC.

1.2 This is a turnkey specification for a Contractor to connect a complete Static VAR Compensator (SVC) system to a substation. The specification does not include all the necessary terms & conditions of the contract.

1.3 The specification is subject to revision as and when required.

2. INTRODUCTION & PURPOSE

2.1 **Background**

2.1.1 The reactive power demand from the Company' system is escalating drastically but the sources to cope with such a huge reactive power requirement are limited especially during disturbances/contingencies.

2.1.2 The reactive power demand is maximum during summer due to air-conditioning and refrigeration loads. When system faces voltage dip due to any fault followed by trip of a 500kV circuit, the voltage recovery gets very slow resulting in voltage collapse. In order to meet the reactive power demand for steady state conditions, there is an ongoing program of installation of shunt capacitor banks at 11 kV, 66 kV and 132 kV levels by all the Distribution Companies (DISCOs) in their respective areas. However, these capacitor banks do not contribute much in voltage recovery under dynamic conditions when motor load is dominant in the system during summer. The motor stalling phenomena causes to draw huge reactive current which leads the voltage to drop down further and this vicious cycle causes the system to face voltage-instability leading to wide spread voltage-collapse and blackout. This phenomenon was studied by carrying out the transient voltage stability studies using dynamic load models and the results indicated that installation of SVC would be a remedy to overcome this problem.

2.2 **SVC Project Description**

2.2.1 For SVC site and system descriptions, please refer to Annexure-A.

2.2.2 The design of SVC shall meet the operational and system dynamic requirements specified in his specification using any configuration of Thyristor Controlled Reactors (TCR), Thyristor Switched Capacitors (TSC), fixed capacitors (FC) and harmonic filter circuits. The full dynamic range shall consist of thyristor controlled reactors and/or thyristor switched capacitors except FC. Temporary overload of specific components shall also be considered. The harmonic filter requirements have to be fulfilled over the whole reactive power range for harmonic emission from the grid as well as SVC system.

2.2.3 Each bidder shall provide a detailed design of the SVC being offered, showing all the equipments in the Contractor's scope of supply, control & protection schemes, cooling system arrangement, reliability and availability calculations etc.

2.2.4 The bidder shall declare safety hazards including hazardous materials associated with equipments being supplied and the design shall include suitable protection measures complying with the international standards.

3. REFERENCE STANDARDS

3.1 **Documentation, Language & Units**

3.1.1 All documents, drawings, instructions, manuals, technical information and test certificates shall use SI units and shall be in English.

3.2 **Standards/Specifications**

3.2.1 All work connected with the supply of the SVC system shall be in accordance with the requirements of appropriate latest International/Company standards and regulations such as IEC & IEEE. Where no International/Company standard exists, the SVC system shall comply with recognised standards and design practices. If the requirements of this specification conflict with any of the reference standards or practices, the Company's specification(s) shall prevail in particular to those items/requirements. The bidder shall state and furnish a list of all standards used for the specific type of equipment/material with the bid.

3.2.2 For the major SVC components, the latest version of the following standards in particular shall apply:

General

ISO 1000	Metric Standards
ISO 9001	Quality Assurance
ISO 1459, 1461	Hot-dip Galvanisation
IEC 60060	High Voltage Testing Techniques
IEC 60071	Insulation Co-ordination
IEEE 1031	IEEE Guide for the Functional Specification of Transmission Static Var Compensators

Thyristors

IEC 60146	Semiconductor Converters
IEC 60147	Essential Ratings and x-tics of Semiconductor Devices and General Principles of Measuring Methods
IEC 60747-1	Semiconductor Devices - Discrete Devices - Part 1: General
IEC 60747-2	Semiconductor Devices - Discrete Devices - Part 2: Rectifier Diodes
IEC 60747-6	Semiconductor Devices - Discrete Devices - Part 6: Thyristors
IEC 61954	Testing of Thyristor Valves for Static VAR Compensators
IEEE 1303	Guide for Static VAR Compensation Field Tests

Capacitors

IEC 61070-11, IEC/TR 600871-1;-4	Shunt Power Capacitors

Transformers

IEC 60076, P-46	Transformers

Reactors

IEC 60289	Reactors

Arrestors

IEC 60099, P-181	Surge Arrestors

Circuit Breakers

IEC 62271-100, P-193	Circuit breakers

Disconnectors

IIEC 62271-102, P-128	Disconnectors and Earthing Switches

Insulators & Bushings

IEC 60137	Bushings above 1000V
IEC 60168	Insulators of Ceramic or Glass
IEC 60815	Guide for Selection of Insulators in respect of Polluted Conditions

Instrument Transformers

IEC 60044-1, P-90	Current Transformers
IEC 60044-2, P-129	Voltage Transformers

Switch gear & Control gear

IEC 60694	Common clauses for HV Switchgear and Control gears
IEC 62271	High-voltage switchgear & control gear

Harmonics & Filter Banks

IEEE 519	Guide for Harmonic Control and Reactive Compensation of Static Power Converters
IEC PAS 62001	Specification and Design Evaluation of AC Filters for HVDC Systems

Measurements

IEC 60688	Transducer for Electrical measurements

Optical fibre

IEC 60794	Optical fibre cables

Relays

IEC 60255	Electrical Protective Relays

EMC

IEC 61000-4-2,3,4,5	Control System EMC (immunity)

3.2.3 The above stated list does not claim to be complete. Some additional standards are also referred under specific clauses. Additionally, all general laws and regulations have to be followed regarding Health and Safety.

3.3 **Definitions**

3.3.1 For the purposes of this specification, the following technical terms and definitions shall apply. IEC 60050 & IEEE International Electro technical Vocabulary shall be referred for terms not defined in this clause.

i) Control range:

The total inductive plus capacitive range of reactive current or megavar variation of the static VAR compensator (SVC) at the point of connection during normal voltage (±5% of the nominal value) and contingency voltage (±10 % of the nominal value) range.

a) Lagging operation:

Inductive megaVARs absorption of the static VAR compensator (SVC).

b) Leading operation:

Capacitive megavars generation of the static var compensator (SVC).

ii) Point of common coupling (PCC):

The busbar from which other loads sensitive to voltage may be connected as well as the static var compensator (SVC) and any disturbing load it is required to compensate.

iii) Point of connection:

For a static var compensator (SVC) with a dedicated transformer, the high-voltage (HV) bus to which the whole system is connected.

iv) Reference voltage:

The point on the voltage/current (V/I) characteristic where the static var compensator (SVC) is at zero output (i.e., where no vars are absorbed from, or supplied to, the transmission system at the point of connection).

v) Response time:

The duration from a step change in control signal input until the static var compensator (SVC) output reaches 90% of required output, before any overshoot.

vi) Settling time:

The duration from a step change in control signal input until the SVC output settles to within ±5% of the required output.

vii) Slope:

The ratio of the voltage change to the current change over the full (inductive plus capacitive) linearly controlled range of the static var compensator (SVC) at nominal voltage, expressed as a percentage.

viii) Static var compensator (SVC):

A shunt-connected static var generator or absorber whose output is adjusted to exchange capacitive or inductive current to maintain or control specific parameters of the electrical power system.

ix) Thyristor-controlled reactor (TCR):
A shunt-connected thyristor-controlled inductor whose effective reactance is varied in a continuous manner by partial conduction of the thyristor valve.

x) Thyristor-switched capacitor (TSC):
A shunt-connected thyristor-switched capacitor whose effective reactance is varied in a step-wise manner by full or zero-conduction operation of the thyristor valve.

xi) Voltage/current (V/I) characteristic:
The relationship between the current of the static var compensator (SVC) and the voltage at its point of connection.

3.4 **Acronyms & Abbreviations**

BIL	Basic Insulation Level
EMI	Electromagnetic Interference
ETT	Electrically Triggered Thyristors
PCC	Point of Common Coupling
RI	Radio Interference
SVC	Static var Compensator
SWC	Surge Withstand Capability
TIF	Telephone Influence Factor
TNA	Transient Network Analyzers
TSC	Thyristor-Switched Capacitor
TVI	Television Interference
V/I	Voltage/Current
CT	Current Transformer
PT	Potential Transformer
HMI	Human Machine Interface
DFR	Digital Fault Recorder
DSM	Dynamic System Monitor
VQR	Voltage Quality Recorder
SOE	Sequence of Event Recorder

4. ENVIRONMENTAL DATA

4.1 **Ambient Conditions**

4.1.1 The SVC shall be designed to meet all ratings and performance requirements specified in this document while operating in the following environmental conditions:

Maximum temperature (under the Sun)	55°C
Maximum mean over any 24 hours	45°C
Mean temperature in any year	30°C
Minimum temperature	-10°C

4.2 **Relative Humidity**

4.2.1 The relative humidity may range up to 100%. The maximum values of the ambient temperature and humidity, however, do not occur simultaneously. During monsoons high humidity may persist for many days at a time with temperature ranging from 30°C to 40°C.

4.3 **Altitude**

4.3.1 Installations may be upto 1000 m above sea level.

4.4 **Atmospheric Conditions**

4.4.1 It may be assumed that the air is not, normally, heavily polluted by dust, smoke, aggressive gases, vapors or salt spray. However, at certain times of the year severe dust storms may be experienced.

4.4.2 Certain areas are subject to heavily polluted atmosphere and insulation or bushings for installation in such areas shall have an extended creepage distance from line to earthed parts.

5. SCOPE OF WORK

5.1 **General Requirements**

5.1.1 The Contractor shall be responsible for all the specified studies, design, engineering, furnishing of all equipments, delivery, civil works, erection, installation, testing, commissioning and field verification of the complete SVC system. The Contractor may also be required to provide all information for independent design verification and system modelling.

5.1.2 The Contractor shall be responsible for design, construction, site improvements and determining the final dimensions based on detailed design study.

5.1.3 All equipment shall be designed as needed to meet the requirements in this specification. Any equipment and/or function of the SVC not specifically mentioned herein shall be designed as required by the overall design of the SVC system in order to ensure the satisfactory operation of the system even after installation and operation of SVC.

5.2 Equipment/Material

5.2.1 The Contractor's scope of works also includes but not limited to the followings. For additional/special requirements, refer Annexure - D.

i) All engineering, fabrication, supply, installation, testing and commissioning of the SVC components, their assemblies and accessories.

ii) 132 kV/MV transformer, ONAN/ONAF cooling, 3 single-phase units, oil immersed, outdoor type with HV & MV insulated bushings, control & auxiliary cubicles and all other allied accessories. One single-phase unit shall be supplied as spare in addition.

iii) Complete TCR & TSC units including thyristor valves for reactive power control with their protection, control, monitoring and cooling system.

iv) Harmonic filters as required by the specified harmonic performance levels.

v) All transformer bay equipment on the primary side of the step-down transformer including circuit breakers, disconnect switches, instrument transformers, surge arrestors, a motor-driven earthing switch, etc.

vi) All bus work on secondary side of the transformer including tubular bus bars, steel support structures, insulators, circuit breakers, disconnectors, earth switches, surge arresters, connectors, joints, fittings etc.

vii) Bushings to the SVC valve building.

viii) SVC MV Auxiliary transformer.

ix) Control and Protection equipment of the SVC, including measurement, monitoring, indication etc.

x) SVC MV Surge capacitors and SVC Control HMI.

xi) MV Current and Voltage transformers.

xii) Separate SVC auxiliary supplies (AC and DC) complete with automatic changeover, cable laying, protection, batteries and battery chargers with charger coupler arrangement.

xiii) Ring main unit (RMU) arrangement for the AC supplies shall be applied to ensure uninterruptible supply.

xiv) Surge protection and overhead lightning protection of the SVC yard and supporting structure.

xv) SVC yard lighting.

xvi) All equipment's support structures, foundations and trenches.

xvii) SVC control and power cabling.

xviii) Three each, 132kV air insulated Surge Arresters mounted in close proximity to the SVC HV transformer bushings.

xix) Three each, MV Transformer mounted Surge Arresters.

xx) Complete SVC buildings including thyrister valve hall, control/relay/protection rooms as per design requirements and according to Company standards with foundation, plumbing, lighting, fire protection and electrical outlets as well as facilities for ambient temperature & humidity control.

xxi) The Contractor shall design and construct a room for the storage of the recommended spare parts and one maintenance room for the local repair/maintenance of the SVC equipment/parts.

xxii) All delivered equipment shall be adequately protected and anti-corrosive in nature.

xxiii) Any other equipment and engineering required for the proper functioning, operation and maintenance of the SVC.

xxiv) Single Line and Layout Drawings of the substation where SVC is to be installed, are presented in Annexure-C.

5.3 Services

5.3.1 The following services shall be part of the Contractor's scope of work:

i) Site civil works including site preparation.

ii) SVC yard and associated substation civil work i.e. sub-soil investigation, site development, clearing, grading, access roads, site fences, gates, surface treatment, drainage, drainage materials, filling, footings, foundations, trenches, ducts, site security during construction etc as per site requirements.

iii) Delivery, receiving and handling at the site of all materials and equipment under scope of work.

iv) Supply and installation of interconnecting cables or fibre optics from the SVC equipment to the SVC control building and to the substation control building.

v) Assembly, erection and installation of all equipment on site. Wiring and connection of all equipment, apparatus, components, and equipment frames, racks and switchboard panels, etc.

vi) Supervision and performance of field verification, final checkout, start up and commissioning tests of all SVC apparatus and controls connected to the grid including all interfaces, and verification of proper operation and functioning of the same.

vii) Training of the Company's personnel, which will enable them to operate and maintain the SVC and modify its control parameters if so required.

viii) Arrangement of testing facilities and witnessing of routine/type tests, trainings etc. to the Company engineers, as required.

ix) Any other services and engineering required for the proper functioning of the SVC.

5.4 Interfaces

5.4.1 <u>Connection to the Substation</u>

5.4.1.1 The existing 132 kV outdoor switchgear in double bus single breaker configuration shall be expanded by a complete 132 kV bay for making interconnection to the SVC.

5.4.1.2 The SVC shall be connected to the specified bus bar at the substation through a coupling transformer and outdoor bay. The bay shall comprise of circuit breakers, disconnectors, earthing switches, arresters, current and voltage transformers etc. as per SVC overall operation and design requirements.

5.4.1.3 132kV tubular bus bar arrangement and its connections from the SVC 132 kV bay in the existing 132kV switchyard to the SVC transformer air insulated outdoor bushing.

5.4.2 <u>Earthing, Grounding Mat</u>

5.4.2.1 The grounding mat is to be connected to the existing grounding system in the substation. The Contractor shall perform earth measurements and care shall be taken when providing new grounding system that it shall not form closed loops to ensure that induced current from the TCRs is not circulated in the grounding loops.

5.4.3 SCADA & Communication Systems Interfacing

5.4.3.1 Interface to the Company's communication and SCADA system shall be provided including RTUs in SVC control room, substation control room etc. and all necessary cables for interfacing. The interfaces shall match with the existing RTUs. The SVC shall also be remotely controlled through SCADA interface by the Company's control centre.

5.4.3.2 The 132 kV connection bay shall be included in the remote control system of substation.

5.4.3.3 Alarms shall be grouped locally in a rational way and be exchanged with the remote control centre.

5.4.3.4 The Contractor's responsibility includes the provision of potential free contacts at the SCADA terminal box at the site for exchanging the data but excludes the communication links.

5.4.4 Water supply, Sewage and Drainage

5.4.4.1 In the substation, the water supply has to be arranged by the Contractor. The connection for the SVC cooling system has to be investigated by the Contractor. The connection for the drainage of the SVC and the rainwater is also included in the Contractor's scope of work.

5.5 Documents

5.5.1 Supply of the following documentation shall be made by the successful bidder:

i) All drawings/data, instructions/service/trouble shooting manuals necessary to operate and maintain the SVC and associated equipments with complete drawings in triplicate. The drawings shall include the complete set of plans, elevations, sections, wiring, schematics, piping, etc. of the whole SVC system. The scope of spare parts and special tools must be co-ordinated with the requirements/guarantees of reliability and availability requirements mentioned in sub-clause 7.9.

5.6 Spare Parts & Special Tools

5.6.1 The bidder shall furnish recommended spare parts for the SVC system as well as all special tools needed for the maintenance/operation of the SVC. A detailed list of the spare parts/special tools including all necessary information regarding manufacture, supplier, equipment specification, calibration intervals, etc. shall be furnished with the bid. Refer to sub-clause 8.15 of this specification as well.

5.7 **Equipment, Material & Services Furnished by the Company**

5.7.1 A dedicated piece of land where the SVC system shall be installed.

5.7.2 Water, one or two (independent) auxiliary AC feeders (230/400V) for temporary use, as required for installation of the equipment and to facilitate reasonable working conditions for the Contractor's personnel.

5.7.3 Available as-built reference data and drawings for the Contractor's use for design and interconnection of the SVC system.

6. POWER SYSTEM CHARACTERISTICS

6.1 The power system AC characteristics at the point of connection prior to SVC installation are mentioned in Annexure - B. SVC operation is required within the specified parameter values and durations.

7. SVC CHARACTERISTICS

7.1 **Voltage & Reactive Output Ratings**

7.1.1 Continuous Ratings

7.1.1.1 The discussion under this clause is based on the V/I characteristics mentioned in clause 8 of IEEE Std 1031 and are indicated in Fig 1 below:

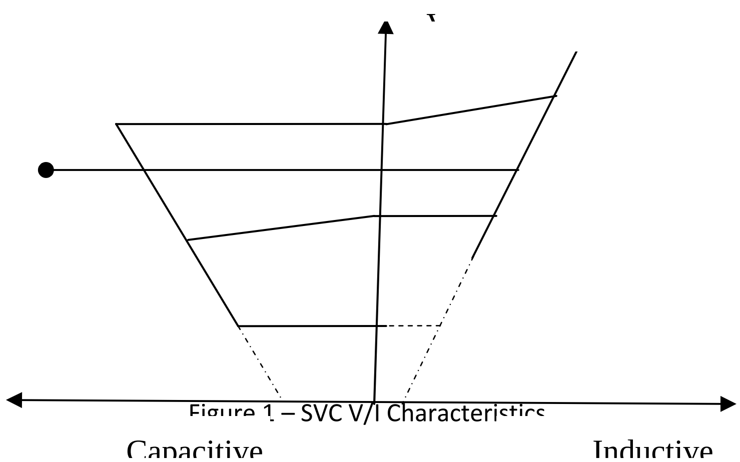


Figure 1 – SVC V/I Characteristics

7.1.1.1 The nominal continuous operating capacitive and inductive capability shall not be less than the values specified in Annexure-A at PCC. Component tolerances and frequency deviations shall be considered while designing SVC requirement for continuous rating.

7.1.1.2 The reactive power range specified in the preceding sub-clause is the minimum requirement at SVC HV bus after allowing for the combined effect of all component and control tolerances including that of the transformer. These tolerances shall be stated by the bidder in the bid and be guaranteed.

7.1.1.3 The SVC shall be capable of and continuously controllable over the voltage range from 0.9 p.u. to 1.1 p.u. of the primary voltage and full nominal reactive (inductive & capacitive) range specified in Annexure-A.

7.1.1.4 The nominal slope of the characteristic shall be adjustable in steps of not greater than 0.5% between 0 % and 3 % on 100 MVA base.

7.1.1.5 The SVC shall be capable of continuous operation for system frequencies specified in Annexure-B.

7.1.1.6 The nominal operating voltage for the low voltage side of step-down transformer is to be determined by the Contractor in order to optimize the SVC design.

7.1.1.7 The SVC configuration must ensure that under normal steady state operation, including operation with partial rating, the SVC output must not exhibit any over-voltages (due to switching of non-controlled reactive elements within the SVC) larger than 5 % of the operating voltage at minimum short circuit power.

7.1.2 Short-time Ratings

7.1.2.1 The SVC shall be capable of short-time overloads and over- voltage operation which may occur during system disturbances and contingencies.

7.1.2.2 The SVC shall continue to generate maximum capacitive reactive power during a temporary under-voltage down to a value and duration specified in Annexure-A (point C on Fig. 1). The SVC may be blocked if the under-voltage persists for more than the specified duration.

7.1.2.3 The SVC shall continue to absorb reactive power during a temporary over -voltage in a controlled manner up to a value and duration specified in Annexure-A (point D on Figure 1). This is the minimum requirement and the Contractor shall determine the maximum overload and over- voltage requirements based on the network data. The SVC shall be rated and designed to withstand these over-voltages.

7.1.2.4 The compensator transformer and all bus equipment such as filter branches, thyristor-controlled reactor (TCR) branches, thyristor-switched capacitor (TSC) branches, capacitor bank branches, and reactor bank branches whether at high-voltage or medium-voltage shall be rated to withstand the specified continuous and short-time operation and be protected against voltage and current stresses that exceed these conditions. All components of the SVC, such as the filter and capacitor bank branches shall not trip during the overload period. The control and protection of the SVC shall not trip the equipment during transient over-voltages caused by network contingencies like fault clearances.

7.1.2.5 The SVC reactive output current shall not be limited while within the specified range setting and operating modes. The SVC controller shall be capable of controlling (switching and blocking) the TCR's, TSC's and switching the external devices such as bus reactors and capacitors at any time during the transient disturbance.

7.1.2.6 The SVC shall be designed to be able to operate at the temporary frequencies deviations specified in Annexure-B.

7.1.2.7 The SVC shall not increase the voltage unbalance at the SVC HV terminals by more than 0.1 % due to component, measurement, control system and thyristor firing unbalance tolerances when the voltage balancing control is out of operation or not required.

7.1.2.8 The components of the SVC shall be designed for operation consistent with the V-I characteristic defined in the presence of power frequency surges and dips at the SVC HV bus corresponding to the overload cycles specified. The SVC shall not be tripped or prevented from operation during these network conditions. The duration between consecutive overload cycles will not be less than 60 minutes.

7.1.2.9 The SVC shall be able to operate in degraded modes with respect to any of the TCR/TSC being out of service and/or any single filter branch being out of service and any combination thereof. The reactive power output of the SVC will be adjusted to the allowable range. SVC is required to operate in degraded mode when at least 50% of the specified capacity (inductive or capacitive) is not available. The bidders are required to describe the degraded modes of their system with the bid.

7.2 Control Objectives

7.2.1 Control of phase voltage based on

i) Individual phase voltages
ii) Positive and negative sequence voltages

7.2.2 Control of three-phase average or positive sequence of the fundamental voltage in steady state, during and after faults, over the full slope range is required. The SVC voltage controller shall be optimized to rapidly control the HV voltage to prevent large induction load stalling and the associated delayed voltage recovery phenomenon during and after single phase, phase to phase and three phase faults on the Company's system.

7.2.3 Control of voltage with superimposed reactive power control. The controller returns SVC output slowly to a preset steady-state value, so that its megavar capacity to support voltage is held in reserve for disturbed conditions.

7.2.4 Voltage control with superimposed damping control based on active power, speed, or frequency measurements to damp oscillations or to enhance the power transfer capability.

7.2.5 The SVC shall not trip during the dead time of 350 ms during automatic reclosing operations.

7.2.6 The SVC shall have provision to control at least three shunt capacitors and/or shunt reactors located on remote/SVC substations.

7.2.7 The SVC shall not trip during the under-voltage conditions and the controller shall:

i) Prevent harmonic instability due to network resonances
ii) Not limit the dynamic performance of the SVC
iii) Not limit the voltage and reactive power control range

7.2.8 The control system must function such that under normal operation including operation with partial rating, the SVC output must not exhibit any over-voltages (due to switching of non-controlled reactive elements within the SVC) larger than 5% of the operating voltage at minimum short circuit power.

7.2.9 The control system shall co-ordinate the operation of the SVC to regulate the primary voltage and the reactive power consumption. Operation logics for the breakers, disconnectors and earth-switches in the SVC shall also be incorporated in the control system. The control shall be fully computerised and programmable and have sufficient scope and flexibility to permit re-programming to accommodate future changes in the power system.

7.2.10 A comprehensive control strategy would be devised for voltage control, reactive power control, over-voltage/under-voltage strategies and restoration of output to pre-disturbance level through slow-susceptance control or any other strategy.

7.2.11 The performance of OLTC on 220kV/132kV transformer for steady state voltage regulation shall also be brought under this controller.

7.3 Control System Description

7.3.1 The Controller for the SVC system shall be housed in a newly built SVC control room. The control system shall be HMI based integrated with the SVC protection system having the following minimum features:

i) As a minimum, a digital programmable controller shall be supplied to control the SVC completely. Programmable means numerically accessible to the Company to change or modify the control parameters of the SVC.

ii) The controller shall have diagnostic and self-checking features for both itself, and for valves, gate firing & drive circuits, interface hardware/software and transducers. The controller shall be re-programmable.

iii) It shall have excess capacity to allow future program upgrades to satisfy the changing requirements of the power systems or future extensions to the SVC. The re-programmability shall include:

a) Ability to control up to 3 shunt devices (reactors or capacitors)

b) Ability to control the SVC with an additional signal for stability or system damping i.e. Power Oscillation Damping (POD).

iv) The SVC controller shall have programmable filtering and dynamic compensation for input signals to ensure proper dynamic performance. The control system shall be insensitive for all harmonics. It shall be programmable for all parameters.

v) The accuracy of voltage shall be within ± 0.005 p.u. of the reference voltage. The accuracy of linearity of the slope delivered by the SVC shall be ± 1 % of the slope setting of current, expressed as a percentage of nominal current at maximum output.

7.4 Major Control Functions

7.4.1 There shall be two major control strategies for the output control of the SVC:

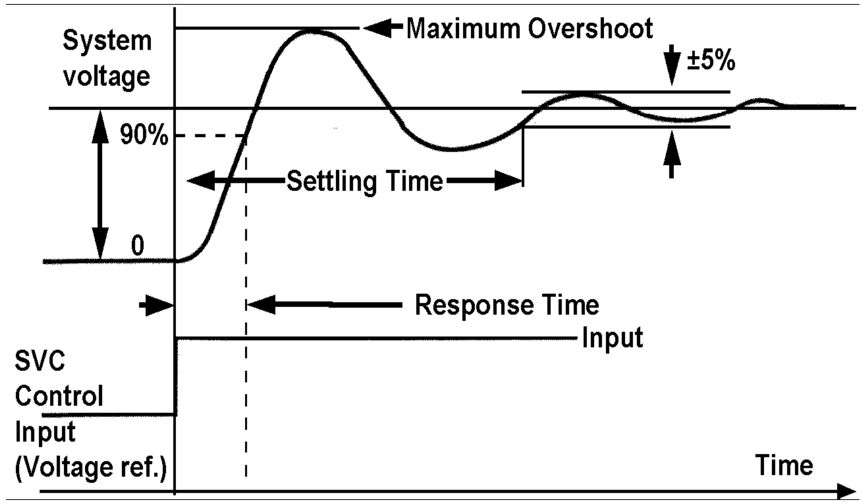
7.4.1.1 <u>Voltage Control Mode (VCM)</u>

7.4.1.1.1 In this mode, the control system shall perform a three phase voltage regulation based on a voltage error and using a slope correction for stationary output control. The error shall be determined by the difference between a set voltage reference and the positive sequence voltage response from the primary side of the step-down transformer. The voltage reference and slope shall be controllable in the interval specified in sub-clause 7.1

7.4.1.1.2 Measurement and signal conversion of the voltage error shall not exceed 0.3%.

7.4.1.1.3 When in voltage control mode, the SVC shall meet the following requirements on speed of response time to a step change:

i) The change of measured system voltage shall reach 90% of desired total change in less than 40 ms of the initially control signal of voltage reference with a maximum overshoot of 10 %. The settling time of the HV bus bar voltage to reach within 5% of the final value shall be less than 200 msec. During this change, the SVC output shall not reach its limits. The response is required when the system 3-phase fault MVA is at the minimum value mentioned in Annexure-B. (Refer Figure 2 below)



7.4.1.2 Fixed Susceptance Mode (FSM) OR Constant Q-Mode

7.4.1.2.1 In this mode, the susceptance of the SVC shall be manually controllable by direct operator action. The operator shall set the susceptance reference and the MVAR output is then given by the product of the value of this reference and the square of the primary voltage. The susceptance reference shall be continuously variable within an interval that corresponds to the output interval specified in sub-clause 7.1.

7.4.1.2.2 In this mode a system voltage limiting controller is active and prevents over-/under voltages by limiting the reactive output of the SVC.

7.4.2 It shall be possible to change between the two strategies above without any transients in the reactive output from the SVC. Changeover of the control facility from one mode of operation to the other in both directions shall not subject the system to any bumps.

7.4.3 In Fixed Susceptance Mode (FSM) operation the controller is blocked and the switchover facility accepts the manual susceptance set point. Bumpless changeover from FSM operation to VCM operation is ensured by automatic set point correction and with an update function of the controller to the actual susceptance value at the changeover instant.

7.4.4 In VCM operation, the output of the manual susceptance set point is blocked and the switchover facility accepts the output of the PI-controller.

7.4.5 On changeover from VCM operation to FSM operation the last susceptance output of the controller is stored by the manual susceptance set point setter. After switchover, the manual susceptance set point can be adjusted to the required value by the operator.

7.5 Supplementary Control Functions

7.5.1 Slow Reactive Power Regulator Function

7.5.1.1 When the SVC is in voltage control mode it shall be possible to activate a slow susceptance regulator (slow-Q regulator). This is normal operation mode. When this regulator is activated the stationary output from the SVC is controlled to a specific susceptance as long as the difference between the line voltage and the voltage reference stays within a certain band. If the difference is larger than the band the stationary output from the SVC will automatically follow the slope in order to keep the voltage at a certain level (VCM).

7.5.1.2 The transient response from the SVC will still follow the slope even when the susceptance regulator is activated.

7.5.1.3 The susceptance reference shall be continuously variable within an interval that corresponds to the output interval specified in sub-clause 7.1 and the size of the band in the interval 0-10%.

7.5.1.4 changeover/activation & deactivation of the slow susceptance regulator from one mode of operation to the other in both directions shall be possible without transients in the output in the reactive output from the SVC. Hunting between the controls modes has to be avoided.

7.5.2 Gain Supervision

7.5.2.1 A gain supervisor which shall be a function for supervision of the stability of the closed loop voltage control, shall be included.

7.5.2.2 The function of the supervisor is that when the supervision of the gain in the voltage regulator detects oscillations in the susceptance reference, the gain shall gradually be reduced until stability is reached.

7.5.2.3 The reduction of the gain shall only be in the open loop gain of the voltage regulator. The closed loop gain shall remain the same. Normally, it is an increase in the transmission system contribution to the closed loop gain that results in the instability. The reduction in the voltage regulator gain shall only balance the external increase.

7.5.2.4 The reduction of the gain shall be able to be reset to nominal value by means of commands from the operator interface. A relative gain factor shall also be able to be changed from a gain optimizer.

7.5.3 Gain Optimisation

7.5.3.1 To adjust the gain in the closed voltage control loop for varying short-circuit power conditions, a special optimisation function shall be included. The action of the Gain Optimiser must not produce large changes in the SVC output. By adjusting the gain, fast voltage response shall be obtained with stable SVC output at the short circuit power interval specified in Annexure-B.

7.5.4 TCR Direct Current Control

7.5.4.1 Second harmonic interaction, e.g. between the TCR and the step-down transformer, can take the transformer into saturation. This condition shall be barred by a control function which eliminates DC currents in the TCR.

7.5.5 Under and Over-voltage Strategies

7.5.5.1 At under or over-voltage conditions for the primary voltage, special control strategies shall be activated that overrides the normal control modes presented above.

7.5.5.1.1 Under-voltage Strategies

i) Usually, if the voltage is low the output from the SVC will be capacitive. If the voltage in all three phases goes below a certain value (0.3 pu), a special under-voltage strategy shall be activated that blocks the firing pulses to the TSC valves and controls the SVC output to a settable reference. As soon as the voltage in one of the phases goes higher than a certain value (0.3 pu) the under-voltage strategy is de-activated and the normal control will be in operation.

7.5.5.1.2 Over-voltage Strategies

i) The TCR valves shall be controllable up to 1.3 pu primary voltage. If the voltage increases above this limit continuous firing pulses shall be given to the TCR valve and the firing pulses to the TSCs may be blocked when the voltage exceeds 1.3 pu. The continuous firing of the TCR valves is retained until the voltage is again below 1.3 pu when the normal control takes over. The settings for an over-voltage trip have to be co-ordinated with the existing over-voltage protection of the grid.

7.5.6 Protection

7.5.6.1 The control and protection of the SVC shall not trip the equipment during transient over-voltages and by network contingencies like fault clearances.

7.5.6.2 The thyristors, TSCs & TCRs shall be protected against transient stresses like overvoltage & overcurrent during system contingencies - the details of which shall be furnished in the bid.

7.5.6.3 There shall be a (phase-wise operating) supervision of the correlation between the triggering pulses to the thyristor valves and the measured valve currents.

7.5.6.4 For further details, please refer sub-clause 8.13.

7.6 Harmonic Performance

7.6.1 The SVC system shall be designed to avoid resonance condition between its shunt capacitor banks, shunt reactors, filter branches, and the ac system. In addition to that it shall limit the harmonic distortion imposed on the connected transmission system.

7.6.2 Filter Performance

7.6.2.1 The SVC contribution to the harmonic distortion levels at the SVC connection point to the transmission system shall not exceed the limits described in Annexure-B according to IEC and/or IEEE, under worst case of:

i) The continuous range of system and environmental conditions stated in this specification.
ii) Variation in tolerance of total filter capacitance, including permissible fuse failures.
iii) Variation in tolerance for SVC parameters such as transformer winding unbalances valve firing variations and unequal reactor and capacitor reactance between phases.

7.6.3 Filter Component Rating

7.6.3.1 The harmonic filter components including SVC components shall be rated to carry the harmonic currents generated by the background harmonic distortion of the system and the harmonic currents produced by SVC itself. The rated voltage of capacitors shall not be less than the arithmetic sum of the normal continuous power frequency voltage and the largest of the individual harmonic voltages.

7.7 Audible Noise

7.7.1 The Contractor shall design and construct the SVC to limit the audible noise interior and exterior to the facilities.

7.7.2 The level of the audible noise inside the SVC building shall not exceed 80 dB (A) in areas where personnel are permitted during SVC operation. Audible sound shall be further limited not to exceed 50 dB (A) in the control room.

7.7.3 The Contractor shall also be responsible for establishing existing audible noise levels prior to the construction of the facilities and for preparation of a report. The final report shall record audible noise levels prior to and after construction to verify the compliance with the specified requirements. Post-commissioning audible test be carried out to ensure requirements of noise level limits.

7.8 **Description & Evaluation of Losses**

7.8.1 The bidder shall provide a summarized loss evaluation of the total proposed SVC system. The summarized losses shall include losses on all SVC components up to the main bus connection and shall, in particular, include the followings:

i) Main Step-down transformer including harmonics
   a) Core losses
   b) Copper losses at upper rating including fan consumption (converted to 75°C)

ii) Auxiliary transformer (s)
   a) Core losses
   b) Copper losses at upper rating including consumption (converted to 75°C)

iii) Thyristor valves and associated equipment
   a) Thyristors, diode, voltage damping & grading losses etc.
   b) Auxiliary power for controls and cooling system etc.

iv) Reactor banks

v) AC Filters
   a) Fundamental frequency Losses
   b) Harmonic losses

vi) Shunt Capacitor Banks (Filter, TSCs, shunt)

vii) Control and protection equipment

viii) Station Service Equipment

ix) Miscellaneous (details shall be provided by the bidder)

x) SVC auxiliary equipment

xi) Heating, cooling and air conditioning for all equipment, enclosures and outdoor cabinets

7.8.2 Losses in switchgear, bus bars, cables, clamps, connectors, etc., are excluded. The applicable tolerance, if any, shall be stated clearly for all the equipments.

7.8.3 The total system fundamental frequency losses excluding transformer no-load loss shall be calculated and submitted by the bidder with the bid assuming an outside temperature of 50 deg. C with bus voltage of 1.0 p.u., at maximum slope setting and at the following operating points:

i) Total system losses (excluding transformer no-load loss), P_1 (kW), at 100% inductive output at **10**% of the system total operating time, T_1.

ii) Total system losses (excluding transformer no-load loss), P_2 (kW), at 50% inductive output at **15**% of the system operating time, T_2.

iii) Total system losses (excluding transformer no-load loss), P_3 (kW), at 0 Mvar output at **10**% of the system operating time, T_3.

iv) Total system losses (excluding transformer no-load loss), P_4(kW), at 50% capacitive output at **45**% of the system operating time, T_4.

v) Total system losses (excluding transformer no-load loss), P_5(kW), at 100% capacitive output at **20**% of the system operating time, T_5.

7.8.4 In addition to above, the bidder shall submit a description of the calculation methodology for total system losses with break-up details. As-built SVC losses shall be based both on factory measurements and calculations and shall be furnished with the bid. The bidder shall also quote and submit, at the time of bidding, the guaranteed losses at maximum capacitive and maximum inductive MVAR output from the SVC and a graph of losses in kW against Mvar output for the entire output range of the SVC at nominal system reference voltage, frequency, slope settings at ambient temperature of 50°C, shall be submitted by the bidders. This shall include losses in all components, all hysteresis effects and any increased losses due to any thyristor switching and all auxiliary plant loads. The bidder shall describe the method that will be used to verify all guaranteed losses and summarize the comparison between guaranteed and as-built losses in a report.

7.8.5 For each operating point, losses are calculated for the parts of the SVC in operation or connected, weather conducting current or not. If more than one combination of SVC parts might operate at a given output, both values shall be given and separately summed with explanation.

7.8.6 Capitalization of Losses

7.8.6.1 The SVC system bid prices shall, as part of the bid evaluation process, be adjusted to take into account the present value of the total SVC system losses over a 25 year period in order to determine comparable prices between proposed systems. The tolerance in component losses, if any, shall clearly be stated in the bid by the bidder.

7.8.6.2 For transformers, the following rate shall be applicable for the capitalization of losses:

- Capital cost of no-load loss US$ **5200** per kW

The capitalized cost of no-load losses at 100% voltage and load losses at principal tap corresponding to 100% upper rated power at reference temperature of 75°C including corresponding consumption of fan motors shall be considered.

7.8.6.3 The losses will be verified/measured during SVC system factory testing in the presence of engineers and in case the measured values exceed the guaranteed values, a penalty at twice the rate of the capital cost stated above shall be payable by the Contractor in excess of guaranteed values.

7.8.6.4 The total cost for losses used in the evaluation will be calculated by the Company using the following formulas:

i) Total evaluated loss, $=[P_1 \times T_1 + P_2 \times T_2 + P_3 \times T_3 + P_4 \times T_4 + P_5 \times T_5]$

7.8.6.5 The total evaluated cost of the complete SVC system losses in USD is given by:

$$\text{Ceq} = \left(\sum P \times \text{Co}\right) \times \left[\frac{1-(1+i)^{-n}}{i}\right]$$

Where

Co = Cost per year per kW of losse

i = Interest Rate = 14%

Note: The operating life of the plant is considered as 25 years.

7.9 **SVC Availability and Reliability**

7.9.1 The SVC system is being installed to provide steady state and transient voltage support, in order to improve the stability margins of the transmission system to avoid voltage sags leading to voltage collapse under disturbed condition thus enhancing the reliability and quality of power delivery. The entire SVC system shall be designed for a life time of at least 30 years.

7.9.2 Definitions

i) **Forced outages** are outages caused by the SVC equipment which result in loss of the essential function of the SVC. These outages are initiated by protective devices.

ii) **Scheduled outages** are outages necessary for preventive maintenance to assure continued and reliable operation of the SVC.

iii) **Outage duration** is the elapsed time from the instant the SVC is out of service to the instant it is returned to service.

iv) **Forced outage rate (FOR)** is the number of forced outages per year.

v) **Forced outage unavailability (FOU)** is the unavailability caused by forced outages in percent per year.

vi) **Availability** is defined as 1-FOU in percent per year.

vii) The following shall be included in outage duration:

a) The time required to determine the cause of an outage or to determine which equipment or units of equipment must be repaired or replaced.

b) The time required to repair or replace the relevant equipment.

c) The time required by system operators/ technicians for disconnection and grounding of equipment in preparation for repair work and for removal of grounds and reconnection of equipment after repairs is complete.

7.9.3 Partial Outage

7.9.3.1 If partial SVC output is available, the duration of equivalent outage shall be calculated as the product of the derated condition duration and the proportion of the nominal output range (capacitive or inductive as applicable) which cannot be achieved during this period.

7.9.4 **Annual Availability**

7.9.4.1 The annual equivalent availability for forced outages in % is defined as:

$$\left[1 - \sum \frac{Duration\ of\ equivalent\ outage}{8760}\right] \times 100$$

7.9.4.2 Guaranteed Availability and Reliability

i) The annual equivalent availability (1-FOU) for forced outages for the SVC system shall be at least 98 %.

ii) The guaranteed forced outage rate (FOR) shall be ≤ 4.

iii) The bidder shall provide a preliminary reliability/availability study with the bid demonstrating compliance with these requirements.

iv) Routine maintenance shall not be required more than once per year. All plant items which require regular inspection shall be listed in the bid together with the recommended service intervals to achieve the required service life of 30 years. The bidder shall list in full details, all those components which have a life of less than 30 years and shall provide detailed proposals for overcoming this deficiency.

v) The bidder shall guarantee the quoted availability performance for applicable warranty period. The Contractor shall be notified of major outages. During the guarantee period, the Company shall maintain records of the number and duration of forced and scheduled outages, hours of operation, and any other relevant data and shall make those records available to the Contractor upon request.

vi) The bidder shall provide data, detailed calculations and results to Company that supports the availability performance estimate. The availability of spare parts, as recommended shall be included in the availability calculations. If the actual performance is below the values stated in items (i) and (ii) above, the Contractor shall provide corrections and modifications to meet the availability guarantees at his own cost and responsibility.

vii) The bidder shall suggest the maintenance interval suitable for its equipment and shall describe any monitoring condition offered.

8. SVC MAIN COMPONENTS & REQUIRED FUNCTIONS

8.1 General

8.1.1 The specification clauses regarding thyristor valves and other main components are intended to be general, i.e., not prescribing the precise form, rating, or quantity of the components, but allowing the bidder to propose an optimum solution. All the offered equipments shall be type tested in accordance with the latest issue of the relevant IEC/Company standards.

8.1.2 All components of the SVC shall be rated taking in to account the following parameters:

i) Any harmonic generated by SVC

ii) The supply system harmonic impedance loci for the system as defined in Annexure-B.

iii) The levels of pre-existing harmonic on the system as defined in Annexure-B and any potential magnification of these harmonics.

iv) The AC system voltage and AC system frequency ranges as given in Annexure-B.

v) The maximum level of negative phase sequence component as given in Annexure-B.

vi) The environmental conditions mentioned under sub-clause 4.1.

8.2 Step-down Transformer

8.2.1 General Requirements

8.2.1.1 The transformer winding configuration shall be determined by the Contractor, as required by the proposed SVC design and Company network requirements.

8.2.1.2 The design of the transformer shall be single-phase and one spare unit shall be provided with the bank. The installation shall be designed to facilitate the connection of the spare transformer into the system and isolation of the failed unit. The spare unit shall normally be energized from the primary side. The transformers shall not be equipped with OLTC. The protection schemes shall also be arranged to facilitate rapid reconnection to the spare transformer CTs. This reconnection shall not require rewiring or reconnection of CT wires.

8.2.2 Rating

8.2.2.1 The transformer shall be designed to comply with the continuous and short-time MVAR requirements mentioned in sub-clause 7.1. The capacity of the transformer (MVA) must be designed to meet these requirements without exceeding normal loss of life or increase in the level of internal partial discharges.

8.2.2.2 The offered transformers shall be ONAN/ONAF cooled. Sufficient reserve capacity shall be provided, so that SVC capacity is not reduced upon loss of a cooling pump, fan, etc.

8.2.3 Impedances

8.2.3.1 The transformer impedance shall be determined by the Bidder as required by the SVC design and shall be chosen so that the transformer will withstand all fault currents at the maximum fault level current specified in Annexure-B.

8.2.4 Voltage Rating and BIL

8.2.4.1 The transformers voltage rating shall be as required by the SVC design. The BIL rating shall be determined by the bidder as required by the SVC design and in accordance with the IEC standards and requirements mentioned under Annexure-B.

8.2.4 Audible Noise

8.2.5.1 Audible noise levels from the step-down transformer shall be coordinated to meet the requirements for the SVC installation in sub-clause 7.7 and applicable IEC standards.

8.2.5 Direct Current Capability

8.2.5.1 The flux density shall be appropriate for the excitation conditions under the voltage range specified.

8.2.5.2 The transformer shall be designed to carry direct current consistent with the SVC design or suitable means shall be incorporated within the SVC to limit this current to a level satisfactory for the transformer. To ensure minimum harmonic generation, the saturation flux density of the transformer shall be higher than the maximum flux density reached during normal operation, and the bidder shall state the margin by which it is exceeded. This maximum flux density is obtained at the highest secondary voltage during any reactive power generation, highest reference voltage, minimum slope, and minimum continuous frequency.

8.2.5.3 The bidder shall clearly indicate the Harmonic content (HV and MV) that the transformer shall be subjected to under the worst case conditions.

8.2.6 Other Requirements

8.2.6.1 As per Company specification P-46.

8.2.7 Standards and Testing Requirements

8.2.7.1 A s per IEC & Company Standards.

8.2.8 Information to be Supplied with the Bid

8.2.8.1 Complete data/drawings, ratings, dimensions, test reports etc as per relevant Company/IEC standards including the following:

i) Type, make & designation
ii) Continuous and short-time MVA and voltage ratings.
iii) Insulation levels.
iv) Number, accuracy and ratio of all bushing current transformers.
v) Type of cooling.

vi) Audible sound level
vii) Direct current capability
viii) Weights and physical dimensions

8.3 **Thyristor Valves**

8.3.1 General Requirements

8.3.1.1 The thyristor valves shall comply with the requirements of Standards/specifications mentioned under clause 3.2.

8.3.1.2 The thyristor valves shall be made up of a number of thyristor levels, electrically connected in series. The number and rating of thyristors used to form each valve shall meet the overall performance requirements. The valves shall have sufficient margin to enable rated output to be maintained continuously with one (1) thyristor level redundant.

8.3.1.3 The voltage rating of the thyristors shall be such that no cascading failure shall result in the event of failure of all redundant thyristors (+1). The bidder shall demonstrate compliance with this redundancy requirement in the bid. Automatic disconnection of the TCR/TSC branch is permissible after the failure of a thyristor with redundancy already used up. The thyristor valve shall be supplied complete with cooling plant & material, all auxiliaries for gating, monitoring and grading. Parallel mounting of unidirectional thyristors is not acceptable.

8.3.1.4 The thyristor valves shall be designed to withstand all stresses expected under steady state, transient and temporary over-voltage conditions specified in this specification including but not limited to the followings:

i) Transient over-voltages due to AC system fault application and fault clearing.

ii) Temporary over-voltages originating in the AC or caused by AC system faults (such faults which result in combined over-current and over-voltage stresses).

iii) Resonant voltage oscillations on the medium voltage side of the SVC transformer excited by system disturbances such as fault application, fault clearing, line switching and transformer energization.

iv) Fast surges transferred from the AC system.

v) Over-voltages due to control malfunction such as false firing of the valve, loss of firing signal, maloperation of the voltage control loop and loss of synchronization.

vi) Transient over-voltages due to partial blocking caused by, i.e, improper firing, forward recovery protection or VBO firing.

8.3.1.5 Transformer saturation shall not be considered in calculating the above stresses except where it increases those stresses.

8.3.1.6 Voltage grading shall be provided to uniformly distribute the voltage across each thyristor level within the valve and together with the over-voltage protection devices to protect the thyristors against forward and reverse blocking voltages above the thyristor rating.

8.3.1.7 The thyristor valve components which are the main heat-generating components (e.g. thyristors, damping and grading components, valve reactors, gating circuits and current carrying connections within the valve) shall be designed to withstand the thermal stresses which affect their operating characteristics.

8.3.1.8 The thyristor valves shall be capable of withstanding the highest over currents expected in service and be capable of blocking corresponding voltages at the highest thyristor junction temperature reached. It shall be possible to replace faulty thyristors without interruption to the cooling circuit and with minimum disturbance to other plant and material.

8.3.1.9 The valve firing must be robust. Misfiring due to control system maloperation, or power grid disturbances, shall be prevented. The thyristor valve arrangements shall permit easy access for visual inspection, routine maintenance, removal, replacement and handling of the thyristor. Such work shall result in minimal loss of coolant and the bidder shall provide means of retaining any coolant. For liquid cooled valves it shall not be necessary to open any cooling water connections to replace a thyristor or other electrical component. Any special tools required for replacement of thyristors or other valve component shall be provided. Each single phase thyristor stack (or equivalent) shall consist of anti-parallel series connected thyristor, including all necessary heat sinks, snubber circuits, voltage grading circuits and firing circuits.

8.3.1.10 In each phase of a TSC branch, the thyristor valve shall be connected in series with a capacitor bank and a current limiting reactor. The current limiting reactor shall be designed to limit the inrush-current during fault conditions and misfiring. In each phase of TCR branch, the single phase thyristor valve shall be connected in series between two reactors.

8.3.1.11 Thyristor valve design shall include a minimum of 10% redundant series thyristors, but not less than one redundant series thyristor, in each single-phase thyristor valve. All rating, performance and protection requirements shall be met with all redundant thyristors short-circuited.

8.3.1.12 The bidder shall guarantee the annual failure rate of thyristors stated in its Availability Evaluation report. The guaranteed annual failure rate of thyristors shall include failures caused by malfunction of the firing system and of auxiliary components associated with a thyristor.

8.3.1.13 The failure of thyristors shall be monitored by the Company. The annual failure rate of the thyristors will be calculated during the availability guaranteed period commencing after the start of commercial operation of the SVC system and will not include failures directly attributable to operating and maintenance error and other incidents unrelated to the system.

8.3.1.14 The bidder shall provide full details of the complete thyristor valve, including control and protection circuitry, valve cooling facilities, including their means of control, temperature and flow monitoring and alarms, etc. This shall be included in the thyristor valve design report.

8.3.2 <u>Valve Maintenance & Monitoring</u>

8.3.2.1 Thyristor monitoring and maintenance requirements are as follows:

i) A monitoring means to identify any thyristors that have failed shall be provided. A continuous monitoring system shall be provided to detect failed thyristors and provide indication of each failure and its location in the valve. The SVC shall be automatically tripped if the number of failed thyristors and associated electronics is more than the number of redundant thyristors.

ii) The thyristor valves shall be designed to allow easy replacement of failed thyristors. Other TSC, TCR, etc., or filter branches shall be capable of continued service while a thyristor is being changed or during similar maintenance.

8.3.3 Valve protection

8.3.3.1 The bidder shall state the methods of over-voltage protection of the valves and the voltage levels at which these protections operate, as follows:

i) TCR valves shall be protected against over-voltage by a forced-firing system.

ii) TSC valves shall not be fired under over-voltage, and interlocks and latches shall be provided to avoid false firing.

8.3.3.2 The individual emergency firing protection of TCR valves can be coordinated with the valve surge arrester. If so, the latter shall operate first.

8.3.3.3 Light-triggered thyristors (LTT) and electrically triggered thyristors (ETT) shall have built-in over-voltage protection, or the bidder shall explain how the consequences of a faulted light source or light guide are handled.

8.3.4 Thyristor Valve Cooling System

8.3.4.1 General Requirements

8.3.4.1.1 The purpose of the thyristor valve cooling system is to remove the heat produced by the thyristor valve operation and transfer this heat to the outside ambient air. In either cooling systems i.e. water cooled or air cooled, the system shall be completely furnished with all necessary interconnecting piping, ductwork, circulating pumps, blowers, heaters, make-up reservoirs, heat exchangers, filters, water treatment plant, instrumentation, automatic controls, alarms, control power systems, and other necessary equipment. The redundancy for the cooling equipments shall be appropriate to the SVC availability requirements and shall be stated by the bidder.

8.3.4.1.2 The cooling system shall provide adequate cooling for operation under all conditions up to and including maximum specified rated loads and extreme ambient conditions.

8.3.4.1.3 Replacements of thyristors shall be possible without the need for opening the cooling circuit and the cooling system shall be designed to permit work on the defective pump unit without restricting the SVC operation.

8.3.4.1.4 Maintenance of the cooling system shall not be required more than once per year.

8.3.4.1.5 The audible noise of the outdoor heat exchanger shall be co-ordinated to meet the requirements for SVC installation mentioned in sub-clause 7.7.

8.3.4.2 Liquid Cooling

i) A closed-loop recirculating system shall provide full heat rejection capacity with redundancy for pumps, heat exchangers, and fans, appropriate to the SVC availability requirements. The cooling system shall be able to maintain full capacity at maximum ambient temperature and maximum SVC reactive power output. The cooling system shall be able to operate at the lowest ambient temperature and with SVC in floating condition. The bidder shall describe how this operation is done.

ii) Replacement of certain cooling equipment (e.g., pumps, fans, cooler unit), if defective, shall be possible while the cooling system still operates.

iii) A purifying loop to maintain liquid resistivity shall be provided. The bidder shall state the design value of liquid resistivity and describe methods of detecting and responding to abnormal conditions.

iv) The quantity of deionising material shall be sufficient for a period longer than the specified maintenance interval operation without replacement. Deionising materials shall be replaceable without cooling system shut down. Instructions for frequency of inspection and change shall be given. The bidder shall describe the necessary maintenance actions and their frequency.

v) Maintenance of closed loop systems and make up for loss of liquid shall not be required more than once a year.

xxv) The cooling system shall use two motor driven pumps that each are normally capable of supplying 100% of the required maximum cooling medium flow. One pump will be in operation while the other pump is standing by. It shall be possible to operate either pump as primary operating pump. In case of single pump failure, the second pump shall automatically be switched in without the necessity of blocking the firing of the thyristors. The cooling system specific to thyristor valves shall be installed with complete redundancy with no chance of failure of cooling system. It shall always be available irrespective of SVC switched OFF/stopped/AC supply failure i.e. sufficient ride-through shall be provided so that SVC must remain available to regulate voltage under all circumstances.

vi) Make up scheme shall be described and submitted to the Company by the manufacturer at design stage.

vii) All valves, strainers, pumps, tubes and piping in the cooling system shall be made of stainless steel and designed for high reliability.

viii) Make-up for loss of liquid shall be done automatically without SVC shutdown. A make-up tank for supply of additional cooling medium shall be supplied together with a pump unit.

ix) The liquid to air heat exchangers shall have at least one standby fan.

x) An automatic control system shall regulate and sequence the operation of the cooling equipment to maintain the temperature within the design limits. The control system will allow for a transfer from main to standby pumps without a cooling system or SVC system shutdown. Each pump, cooling fan and/or mixing valve shall have both automatic and manual control modes.

8.3.4.2 Gauges of the following properties shall be included in the cooling system as a minimum:

i) Expansion tank fluid level
ii) Cooling medium resistivity
iii) Cooling medium temperature
iv) Cooling medium pressure
v) Cooling medium flow in each thyristor branch

8.3.4.3 Air cooling

i) Either a non-recirculating (i.e., once through) or a recirculating air system may be provided, depending on the requirement of the thyristor selected by the Contractor and on specific site conditions.
ii) An air cooling system shall provide full heat rejection with redundancy in blowers, filtering, monitoring, and heat exchangers. The cooling system shall permit work on a defective unit without shutting down the system.
iii) The bidder shall describe the air filtering system and details of monitoring status of blowers, filters, and other components.
iv) Sufficient gauges and indicators shall indicate the status of any part of the unit for both normal operations and maintenance.

8.3.5 Cooling System Protection

8.3.5.1 For Liquid Cooled System

8.3.5.1.1 The redundant cooling control and protection system shall provide for the necessary cooling of the SVC system valves and shall monitor its own operation and the condition of cooling water. An automatic control system shall regulate and sequence the operation of the cooling equipment to maintain the temperature within the design limits. The control system will allow for a transfer from main to standby pumps without a cooling system or SVC system shutdown. Each pump, cooling fan and/or mixing valve shall have both automatic and manual control modes. The cooling system control shall have sufficient indication of status, temperature, pressure and flow to allow for safe manual operation of the cooling system in the event of the automatic cooling system control failure. The control system shall include as a minimum the following alarm signals:

i) Pump stopped, failure
ii) Low cooling medium resistivity
iii) Low expansion tank level
iv) Abnormal liquid flow
v) High coolant temperature
vi) High coolant pressure
vii) Fan stopped, failure
viii) Leakage

8.3.5.1.2 The protection system shall include as a minimum the following shutdown signals:

i) Low expansion tank level.
ii) Abnormal liquid flow.
iii) High coolant temperature.

8.3.5.1.3 All alarms, indications and measured values shall be displayed in the local control system.

8.3.5.1.4 The control and protection of the cooling system shall be supplied from the dc station battery. Loss of the dc supply to the cooling controls shall not result in damage to the cooling equipment or the SVC valves. Pumps and fans shall be supplied from the station service (AC).

8.3.5.2 For Air-cooled System

8.3.5.2.1 For air-cooled systems, the protection system shall include, as a minimum, the following warning alarms:

i) Blower transfer
ii) High exhaust air temperature
iii) High differential pressure across the filter
iv) Low air flow.

8.3.5.2.2 For air-cooled systems, the protection system shall include, as a minimum, the following shutdown alarms:

i) Excessive exhaust air temperature
ii) Loss of air flow

8.3.6 Standards & Testing Requirements

8.3.6.1 The design and testing shall comply with the relevant standards specified in sub-clause 3.2 of the specification.

8.3.7 Information to be Supplied with the Bid

8.3.7.1 Complete data/drawings, ratings, dimensions, test reports, etc as per relevant standards including the followings:

i) Overall diagram of the cooling system and its components including gauges.
ii) Rated values on flow, temperature, pressure drop and liquid volume.
iii) Cooling medium.
iv) Ratings of pumps and fans.
v) Alarm and trip signals from the control system

8.4 Thyristor Switched Capacitors (TSCs)

8.4.1 The oscillations occurring at TSC energization with the capacitor voltage differing from the system voltage shall be efficiently suppressed. In case of operation without harmonic filters the oscillations must be practically damped out in not more than 5 cycles.

8.4.2 The thyristors shall have the ability to be switched off and successfully block the applied voltage at 1.5 p.u primary voltage.

8.4.3 The control and valve firing system shall be designed to minimize the risk for generation of false firing pulses at normal or disturbed mode operation. The system shall be insensitive to variations in or complete loss of station auxiliary AC supply voltage.

8.4.4 The thyristors must be protected against harmful voltage during their recovery period at partial turn off situations, i.e. recovery protection.

8.4.5 In case of severe power grid disturbances resulting in difficulties to maintain proper firing pulse synchronization, the valve must not misfire to such a degree that thermal valve overload leading to reduced thyristor blocking capability are caused. Voltage build up on the capacitors exceeding 2.0 times of their voltage rating is not allowed.

8.4.6 In case the misfiring itself cannot be prevented, the negative effects thereof shall be limited by suitable state of the art methods and the system must be designed to handle multiple misfirings on the worst point of wave at 1.5 p.u primary voltage. The buildup of the capacitor voltage at each misfiring must be accounted for.

8.5 Thyristor Controlled Reactors (TCRs)

8.5.1 Each thyristor level in the TCR valve shall be protected by over-voltage protection. This protection shall provide emergency firing of thyristors in event of an over-voltage or failure to deliver firing pulses to one or more individual thyristors.

8.5.2 The thyristors shall be fully phase angle controllable for primary over-voltages up to 1.3 p.u. without operation of voltage break-over devices.

8.5.3 All components in the TCR shall be designed to allow for the trapped decaying component of current caused by a three phase zero impedance fault on the primary side of the step-down transformer which is cleared in 5 cycles and followed by temporary over-voltage specified in sub-clause 7.1. The fault shall be assumed to occur at the peak of the current waveform in the TCR.

8.5.4 The thyristors must be protected against harmful voltage during their recovery period at partial turn off situations, i.e. recovery protection.

8.5.5 The control and valve firing system shall be designed to minimize the risk for generation of false firing pulses at normal or disturbed mode operation. The system shall be insensitive to variations in or complete loss of the auxiliary AC supply voltage.

8.5.6 In case of severe power grid disturbances resulting in difficulties to maintain proper firing pulse synchronization, the valve must not misfire to such a degree that thermal valve overload leading to reduced thyristor blocking capability are caused.

8.5.7 Standards and Testing Requirements

8.5.7.1 The design and testing requirements of the thyrister valves shall comply with the standards specified in sub-clause 3.2 of the specification.

8.5.8 Information to be Supplied with the Bid

8.5.8.1 Complete data/drawings, ratings, dimensions, test reports etc. as per relevant standards including the followings:

i) Continuous and short-time current and voltage ratings of thyristor valve.
ii) Voltage and current capability of thyristors.
iii) Number of thyristors in series and number of redundant thyristors.
iv) Insulation level.
v) Principles of Firing system and Monitoring system
vi) Weights and physical dimensions.
vii) Valve overvoltage, overcurrent and misfiring protection scheme.

8.6 **Reactors**

8.6.1 The reactors are utilised in the TCR branches to provide the inductive MVAR output and in the TSC branches to limit inrush currents. Reactors are also used as tuning elements of the harmonic filters.

8.6.2 Design requirements for TCRs shall include but not limited to the followings:

i) The reactors used for TCR branch and filter components shall be of single phase, air-cored, self-cooled and suitable for outdoor installation.
ii) All structural and fence metalwork, including foundations, shall be designed to avoid metallic loops and parallel circuits in which induced currents can run.
iii) The purpose of the filter reactors is to tune the capacitor banks to provide the necessary reduction of harmonics.
iv) Reactors shall be capable of withstanding short circuit forces based on maximum design fault levels.
v) The reactor voltage rating shall be as required by the SVC design. The BIL and BSL rating shall be determined by the Bidder as required by the SVC design and the insulation requirements specified in Annexure-B.

vi) Audible noise levels from the reactors shall be co-ordinated to meet the requirements for the SVC installation in sub-clause 7.7 and the applicable IEC standards.

vii) The magnetic field strength at any point where personnel have access during operation shall not exceed 2 mT.

8.6.4 Standards and Testing Requirements

8.6.4.1 The design and testing requirement shall comply with the relevant standards specified in sub-clause 3.2 of this specification.

8.6.5 Information to be Supplied with the Bid

8.6.5.1 Complete data/drawings, ratings, dimensions, test reports etc. as per relevant standards including the followings:

i) Inductance including manufacturing tolerances

ii) Continuous and short-time current and voltage ratings, indicating contribution from the harmonic currents

iii) Design criteria for maximum temperature

iv) Insulation level

v) Weight and physical dimensions

8.7 **Capacitor Banks**

8.7.1 The capacitors are utilised in the TSCs to provide capacitive MVAR output, and in harmonic filters.

8.7.2 The capacitor banks shall be designed to avoid resonance with other SVC branches as well as the network on the primary side of the step-down transformer. Possible resonance phenomena shall be included for in the design.

8.7.3 Reactors for limiting of inrush currents shall be connected in series with the capacitor banks in the TSCs.

8.7.4 The capacitor units shall be constructed with materials resulting in minimum losses and maximum reliability. Each unit shall be free of PCB.

8.7.5 The capacitor units shall be identical and interchangeable among all capacitor.

8.7.6 The capacitor voltage rating shall be as required by the SVC design. The rated voltage shall be based on an arithmetical addition of individual harmonic voltages that will appear across the capacitors. The harmonic currents generated by TCRs and pre-existing harmonic voltages (Annexure-B) applied on PCC has to be simultaneously taken into account in SVC component design. The BIL and BSL rating shall be determined by the Bidder as required by the SVC design and the insulation requirements specified in Annexure-B. The bidder shall show how the protection system matches the capability of the capacitors with full regard to the harmonic content of the currents and voltages.

8.7.7 The individual capacitor units shall be individually fused. Anyhow, either internally or externally fused capacitors can be used. For the dimensioning of the capacitor fuses parallel charged elements must be considered.

8.7.8 Audible noise levels from the capacitor banks shall be co-ordinate to meet the requirements for the SVC installation and the applicable IEC standards.

8.7.9 All conduction within the capacitor bank shall be insulated and insulating caps shall be provided for all capacitor units bushing terminals or conducting mounting points.

8.7.10 Capacitor dielectric losses shall clearly be stated by the bidder in the bid.

8.7.11 The capacitor units shall reduce the residual voltage by suitable state of the art methods.

8.7.12 The Bidder shall guarantee the filter and AC shunt capacitor unit maximum annual failure rates. The capacitor unit annual failure rate in service shall be calculated based on the actual level of capacitor unit or element failures during the availability guaranteed period mentioned under sub-clause 7.9, commencing after the start of commercial operation of the SVC system. The above shall apply to each type of capacitor unit supplied individually where type refers to the unit capacitance & voltage, current, and kVAr rating.

8.7.13 The configuration of the individual units shall be determined by Contractor. The kVAr and voltage ratings of the individual capacitor units are not specified herein and shall be determined by the Contractor.

8.7.14 The units shall be identical within each branch vertically or edge mounted, and suitable for mounting in open type structure racks for outdoor use with the service conditions and system ratings given in this Specification.

8.7.15 Any capacitor unit found leaking during the warranty period shall be replaced with a new one by the Contractor at its own cost and responsibility. Repair of leaking units will not be accepted.

8.7.16 The capacitor racks shall be designed to allow the change-out of any capacitor unit without disassembly of the rack or disturbance of any other capacitor unit.

8.7.17 The structural members of the racks shall not be used as electrical buses. To ensure safe earthing of all parts, all structural members of the rack shall be electrical connected together and earthed with a provision of earthing to all structure members during maintenance.

8.7.18 <u>Standards & Testing Requirements</u>

8.7.18.1 The design, manufacturing and testing requirements of the relevant latest IEC standards shall be met with.

8.7.18.2 A suitable capacitor bank test device shall be delivered as part of the contract which will facilitate the testing of the bank without removal of any connections.

8.7.19 <u>Information to be Supplied with the Bid</u>

8.7.19.1 Complete data/drawings, ratings, dimensions, test reports etc. as per relevant standards including the following:

i) Capacitance including manufacturing tolerances and redundancy.
ii) Rated voltage of capacitor units
iii) Insulation level.
iv) Description of fuse system.
v) Weights and physical dimensions.
vi) Losses.
vii) Bank configuration, including number of series and parallel units.

8.8 **Circuit Breakers**

8.8.1 The circuit breakers shall be of SF6 type. The breaker shall be rated for the switching and current carrying duty imposed upon them in their intended location.

8.8.2 The breakers shall be capable of the amount of operations expected, considering the SVC application with both inductive and capacitive loads.

8.8.3 Interrupting units shall have flags, visible from ground level to indicate open/ closed position.

8.8.4 There shall be auxiliary contacts for indication of low gas pressure.

8.8.5 Operating mechanism shall have electrically operated trip circuits. There shall be two parallel trip coils.

8.8.6 Thermostatically operated heaters shall be supplied for temperature control and prevention of condensation build-up.

8.8.7 Mechanically or electrically operated non-resettable operation counters shall be provided.

8.8.8 All operating equipment, including auxiliary switches shall be housed in a weather/water/vermin proof cabinet.

8.8.9 All other general requirements of Company's specification P-193 shall be compliance with.

8.8.10 Standards and Testing Requirements

8.8.10.1 The design and testing of the main SVC breaker shall comply with relevant latest editions Company specifications and relevant International standards mentioned under sub-clause 3.2 of the specification.

8.8.11 Information to be Supplied with the Bid

8.8.11.1 Complete data/drawings, ratings, dimensions, test reports etc. as per relevant Company/International standards including the following:

i) Continuous current and voltage rating.
ii) Making and breaking current capability.
iii) Insulation level.
iv) Creepage distances.
v) Weights and physical dimensions.

8.9 **Disconnectors & Earthing Switches**

8.9.1 The switches shall be adequately sized to carry the maximum steady-state and overload currents including fault, inrush, harmonic currents and over-voltages.

8.9.2 The switches shall meet the insulation requirements specified in this specification.

8.9.3 Thermostatically operated heaters shall be supplied for temperature control and prevention of condensation. All cabinets shall have sufficient ventilation ducts.

8.9.4 Disconnectors & earthing switches shall be designed and constructed to operate satisfactorily in the environmental conditions described in this specification.

8.9.5 All operating equipment, including auxiliary switches, shall be housed in a weather/water/vermin proof cabinet.

8.9.6 Disconnectors shall be both manual and motor operated. Disconnectors shall electrically and mechanically be interlocked. Earth switches shall mechanically be interlocked.

8.9.7 Grounding equipment for maintenance and repair shall be supplied with each separate circuit that can be out of service while the remainders are in continuous operation. Grounding equipment for the SVC secondary bus system/transformer shall also be supplied.

8.9.8 The disconnectors and earth switches shall be positioned to enable maintenance work to be carried out in complete safety on the whole SVC and, where appropriate, on its component parts when any depleted mode operation is adopted.

8.9.9 For the secondary side of the SVC transformer the disconnect switches are required to isolate any apparatus for which maintenance is needed. At a minimum the following major components shall have disconnect and earthing switches:

i) Each thyristor controlled reactor branch
ii) Each thyristor switched capacitor bank
iii) Each fixed capacitor bank
iv) Filter branches

8.9.10 The disconnectors shall be used to isolate an affected filter, TCR or TSC branches when a fault is developed. The disconnectors and earth switches shall be fitted with safety interlocks. This isolation shall be carried out through either of the following methods described below:

i) TCR and TSC: Tripping of the HV circuit breaker either locally or from remote and switching the SVC off the system before the disconnector is opened. After successful isolation of the affected branch, the SVC shall be available to be immediately switched back on again.

ii) TCR only: Blocking of the thyristor valves of the affected TCR branch before opening the disconnector. The normal operation of the SVC shall remain unaffected except for the loss of reactive power range resulting from the isolation of the affected TCR branch.

iii) Filter branches only: Tripping of the affected filter branch circuit breaker before isolation of this branch, The SVC HV circuit breaker shall not operate during this sequence.

iv) Auxiliary transformer branch: Tripping of the auxiliary branch circuit breaker before isolation of this branch, the SVC HV circuit breaker shall not operate during this sequence.

8.9.11 All disconnect and earthing switches shall be indicated on the SVC Single Line Diagram provided by the Bidder.

8.9.12 <u>Standards and Testing Requirements</u>

8.9.12.1 The design and testing of the disconnectors/earthing switches shall comply with relevant latest editions of Company specification P-128 and standards mentioned under sub-clause 3.2 of the specification.

8.9.13 <u>Information to be Supplied with the Bid</u>

8.9.13.1 Complete data/drawings, ratings, dimensions, test reports etc. as per relevant Company/International standards including the following:

Type and rating.

i) Insulation level.
ii) Creepage distances.

8.10 **Surge Arrester**

8.10.1 All necessary surge arresters shall be supplied by the Contractor for the protection of the equipment particularly the main SVC transformer, thyristor valves, reactors and filter banks. The surge arresters shall be properly designed to meet the insulation co-ordination and discharge requirements in accordance with IEC & Company Standards.

8.10.2 Only gap-less arresters of the Zinc oxide type shall be accepted. The arrester shall have sufficient pressure relief capability in order to make them explosion free and to sure that personnel and equipment safety is guaranteed. On the primary side of the step-down transformer, it is recommended that the arresters shall be of class 4 or better. On the low voltage side of the transformer the arresters shall be of class 3 or better referring to IEC 60099.

8.10.3 All arresters placed on the high voltage side of the transformer shall be equipped with surge counters. Filter energisation shall not activate any surge counter.

8.10.4 The activation of a surge arrester on the primary side shall be indicated to remote centre also.

8.10.5 The surge arresters supplied for the SVC shall comply with the Company Standard selection/sizing taking also into account future shunt capacitors to be located in the nearby substations and over-voltages due to switching, ferro-resonance etc.

8.10.6 <u>Standards and Testing Requirements</u>

8.10.6.1 The design and testing of the surge arresters shall comply with relevant latest editions of Company specification P-181 and standards mentioned under sub-clause 3.2 of the specification.

8.10.7 Information to be Supplied with Bid

8.10.7.1 Complete data/drawings, ratings, dimensions, test reports etc. as per relevant Company/International standards including the following:

i) Type and Rating.
ii) Energy discharge capability
iii) Insulation level
iv) Creepage distances
v) Weights and physical dimensions

8.10.7.2 All surge arresters shall be indicated on the SVC Single Line Diagram provided by the Bidder.

8.11 **Instrument Transformers**

8.11.1 The successful Bidder shall supply all necessary voltage and current transformers on the high voltage as well as on the low voltage side of the step-down transformer. These instrument transformers shall be manufactured and tested according to IEC and Company standards. The quantity of instrument transformers and corresponding current and voltage rating shall be calculated and designed by the bidder. The Bidder shall provide description, rating, performance, dimension and proposed tests for the instrument transformers.

8.11.2 All the insulation, minimum creepage and strike distance and local environmental conditions shall be met.

8.11.3 Current Transformers

8.11.3.1 CTs shall be suitably rated to match the full capabilities of the SVC. CT transformation ratios, outputs, and accuracy classes within the SVC scheme shall be selected by bidder to meet the requirements of the specific CT application. Full details of all the CTs being offered shall be provided by bidder.

8.11.3.2 All the current transformers for SVC component protection, indication, measurement and control purposes shall comply with the latest IEC & Company Standards.

8.11.3.3 The CT secondary's which are used for measurement; indications or control devices shall not be used for protection purposes.

8.11.4 Standards and Testing Requirements

8.11.4.1 The design and testing of the CTs shall comply with relevant latest editions of Company specification P-90 and standards mentioned
under clause 3 of the specification.

8.11.5 Information to be Supplied with Bid

8.11.5.1 Complete data/drawings, ratings, dimensions, test reports etc. as per relevant Company/International standards shall be furnished with the bid. The numbers of current transformer and corresponding ratings shall be indicated on the Protection Block Diagram-to be provided with the bid.

8.11.6 Voltage Transformers

8.11.6.1 VT transformation ratios, outputs, and accuracy classes within the SVC scheme shall be selected by the bidder to meet the requirements of the specific VT application. Full details of all the VTs being offered shall be provided by the bidder.

8.11.6.2 All the voltage transformers included in the bid for SVC component protection, indication, measurement and control purposes shall comply with latest IEC & Company Standards.

8.11.6.3 The voltage transformers shall be designed to avoid saturation at voltages up to at least 1.3 p.u. Further, no ferro-resonance conditions shall occur between voltage transformers and capacitors including stray capacitances.

8.11.7 Standards and Testing Requirements

8.11.7.1 The design and testing of the VTs shall comply with relevant latest editions of Company specification P-129 and standards mentioned under clause 3 of the specification.

8.11.8 Information to be Supplied with Bid

8.11.8.1 Complete data/drawings, ratings, dimensions, test reports etc. as per relevant Company/International standards shall be furnished with the bid. The numbers of voltage transformers and corresponding ratings shall be indicated on the Protection Block Diagram-to be provided with the bid.

8.12 **Control & Monitoring System**

8.12.1 General Requirements

8.12.1.1 The Contractor shall provide the necessary systems for the purpose of control, protection, operation, interlocking, indication and alarms for all equipment supplied as part of this contract. The Contractor shall also be responsible for defining and providing the co-ordination of the controls, protection, interlocking and switching sequences required for equipment during operation, testing and maintenance of the equipment. Reliability of operating equipment, availability of SVC system and safety of the personnel shall all be considered in the design.

8.12.1.2 The design and testing of all control and protection equipment shall comply with the latest applicable IEC Standards.

8.12.1.3 All events and alarms generated by the control system and external input signals (events and alarms) to the control system shall be stored in the control and protection system. It shall also be possible to analyze retrieved events and to print out these messages. All recordings and messages shall be given with a real time stamp. Correct time tagging must be ensured. The accuracy and resolution of the time tagging must at least be 1 ms. The station master clocks of the SVC must be synchronized. In case of loss of synchronization, the station master clocks must continue operation with the internal crystal with an accuracy of 1 ppm.

8.12.1.4 Software in the control system determines to a great extent the performance of the SVC system. Software quality assurance is therefore essential. In this respect the entire life cycle of the software shall be considered:

i) Experience with compareable system
ii) Planning and design of software
iii) Implementation of software
iv) Testing of software during commissioning
v) Maintenance of software after commissioning
vi) Possible future extension of software

8.12.1.5 The design, quality requirements, testing and documentation of all software for the control system shall comply with the latest revision of relevant IEC standards. The application software shall be written and documented in a high level language, using graphical symbols for functional blocks, logic circuits and numerical elements.

8.12.1.6 Dedicated software for debugging of existing software as well as for the maintenance of existing software and development of additional software shall be part of the supplied package.

i) The software shall be designed if possible for standard hardware. Later upgrades of the hardware shall not necessarily result in major software changes.
ii) The software may be benchmarked with the results of RTDS studies performed in the factory before delivering of the SVC.

8.12.2 SVC Control - General Requirements

8.12.2.1 The control systems shall achieve the functional objectives given in clause 7. The primary purpose of the control of the SVC is to control system voltage in response to measured system variables, auxiliary inputs for supplementary control, or operator inputs. The voltage and current measurements are included in the SVC scope of supply in order to ensure that they are compatible for the required response of controls.

8.12.2.2 A digital programmable controller shall be supplied to regulate the reactive output from the SVC. All necessary equipment for control, protection, monitoring, alarms and indications shall be housed in a relay panel provided by the Contractor. The controller shall have diagnostics and self-checking features for both itself and interface circuits. The control and monitoring equipment shall be used to implement the functional requirements in this specification. Complete redundancy of control system must be ensured to meet the requirements of sub-clause 7.9 – SVC Availability and Reliability.

8.12.2.3 The accuracy of voltage shall be within ±1% of the reference voltage. The accuracy of linearity of the slope delivered by the SVC shall be ±5% of the slope setting of current, expressed as a percentage of nominal current at maximum output.

8.12.2.4 The valves and controls shall be designed to avoid any “cross-talk” interference between anti-parallel thyristor pairs.

8.12.2.5 When TSC switching is included, the bidder shall detail the method of coordination between TCR and TSC switching in and out in order to achieve vernier control on smooth net output change.

8.12.3 Operator Interface

8.12.3.1 The control interface shall provide for local and remote control points. Only one control point shall be active at any one time and as determined by a master control point, but it shall be possible to view plant status, control settings, and other SVC parameters at all control points.

8.12.3.2 The local control point shall be near the SVC control hardware. It shall permit the following control functions to be carried out:

i) Sensing and regulation of 132kV bus voltage.

ii) Alternate modes of operation, as required, including a manual mode for site testing and emergency shutdown by the operator.

iii) Voltage, current and reactive power measurements.

iv) SVC control by generation of appropriate firing pulses to the thyristor valves.

v) Orderly start-up and shutdown sequencing of the SVC to facilitate smooth SVC energization and de-energization.Monitoring and protecting the control itself in progress and the components it controls.

vi) Coordinating and controlling opening and closing of circuit breakers and disconnect switches.

vii) Performing certain protective functions.

viii) Change of reference voltage and slope settings.

ix) Alarm acceptance and where appropriate reset them.

x) The control and monitoring system shall be designed to meet the demands for availability and reliability specified.

8.12.3.3 A synchronizing scheme shall be used to produce properly spaced timing pulses synchronized to the AC system. The synchronizing function shall be designed to:

i) Be immune to severe harmonic distortion of voltage wave form.

ii) Be immune to large phase shifts in voltage wave form.

iii) Continue to operate during and following large voltage & frequency excursions.

8.12.3.4 The controls may also contain one or more of the followings:

i) Automatic return to manual mode of operation at the most recent voltage setting on the loss of input voltage measurement signal.

ii) Automatic voltage control, operative during start-up to prevent unnecessary switching of the reactive elements.

iii) Self-check facility at regular intervals which operates equipment to verify its correct operation.

iv) Supplementary control modules for damping and var control.

v) Control system damping with gain supervisor and gain optimizer. On gain supervision, details shall be given especially in the context of instability. This function shall also include an adjustable emergency gain. The criteria for detection of instability includes:

a) Frequency range of the oscillation
b) Amplitude of the oscillation
c) Number of consecutive oscillations above an adjustable threshold

8.12.4 Control System Construction Requirements

8.12.4.1 Possible requirements of control system construction are as follows:

i) The control system components shall be mounted in free-standing, indoor, metal-clad cabinets with appropriate rating, where necessary.

ii) Control equipment shall be designed to operate properly at the expected maximum allowable ambient indoor air temperature. Supplemental cooling may be provided.

iii) Printed circuit cards shall have built-in test points indicating lights to facilitate testing and maintenance. Microprocessor-based systems shall have self-checking and fault diagnosis features to be described by the bidder.

8.12.5 **Station Control and Monitoring Requirements**

8.12.5.1 The Contractor shall submit a local digital station control and monitoring system with the following minimum capabilities and features:

i) The system shall give the operator detailed information regarding the status of the equipment. Functional overview of the SVC, displays for the control of the SVC, status lists, measured values, indications, alarms etc. shall be present on the screen. Setting/adjustment of certain control parameters/protection settings and command of operating equipment (breakers, disconnectors etc.) shall be given from this system. Interlocking for safety of equipment and personnel shall be included.

ii) The control desk shall be equipped with a monitor for the current control of the SVC. The operator can freely select which information is to be shown on the monitor. All features of the local Station Control and Monitoring system shall be precisely identified to enable proper use by the system operators. The operator interface shall be realised using the standard Windows environment. Different levels (at least three) of access shall be distinguished, using passwords.

iii) The Contractors solution shall use two monitors. One being for local and the second for either local or remote control. In the commissioning phase both monitors are located at the local control location. Both monitors can be used for monitoring functions however only one for controlling the SVC.

iv) Supervision and recording of events, internal and external. Resolution shall be 1 ms or better. The event information shall be stored on recoverable data media in a standard format, for later access. In case of disturbances of the SVC, the system shall handle all the events without losing information.

v) All alarm, event and help texts presented to the operators in the local station shall be in English. All messages must be identified by a unique index. The structure of one event line shall at least include date, time, alarm number, source, text, status.

vi) The system shall be equipped with a powerful on-line help function to advise local operators in the actions that have to be taken in any fault situation within the SVC.

vii) There shall be a possibility for a remote dialled up connection to the local control system for maintenance purposes (PC anywhere). Measures to prevent unauthorised system access must be taken. There must be different levels of user access available for a dialled up connection.

8.12.5.2 A power quality measurement system shall continuously acquire, store and present information with respect to the quality of the AC voltages and currents.. At a minimum the following measured values shall be determined:

i) True RMS measurement of the phase voltages and currents
ii) Reactive and apparent power per phase and total
iii) Voltage and current unbalance
iv) Voltage sags and swells
v) Current sags and swells
vi) Individual harmonic distortion in the currents and voltages up to the 40^{th} harmonic
vii) Total harmonic distortion
viii) Voltage dips ($\Delta U/\Delta t$)

8.12.5.3 The device for power quality supervision shall automatically supervise the limits of voltages and currents according to IEC and register any violation of these limits. It must be possible for Company to define their own limitations which shall then be supervised accordingly.

8.12.5.4 The monitoring/recording of the AC harmonics shall comply with the latest applicable IEC standard.

8.12.5.5 The stored information in the recording equipment shall be accessible for later evaluation. Dedicated software to present all measured values and to allow for additional mathematical processing of the data shall be included.

8.12.5.6 The Contractor shall present the proposed system to the Company.

8.12.5.7 SCADA RTU will be required to accommodate all the SVC SCADA system requirements including 20% spare capacity without using the existing spare capacity. Communication of SVC analogue, status and alarm points to the substation operator via SCS Human Machine Interface in the line terminal substations.

8.12.5.8 A state of the art sequence of event recorder will be required. Resolution shall be 1ms or better. To the maximum extent practical, the SOE functionality shall monitor internal variables in the SVC_Control and Protection System. It will monitor to the maximum extent possible, signals on an individual phase basis and identify each as such.

8.12.5.9 A state of the art Transient Fault recorder (TFR)/ DFR (or equivalent) will be included to monitor the status of various SVC parameters. The TFR/DFR Device shall have a pre-fault capture and a post-fault capture. The TFR/DFR Device shall have a variable sampling rate for short and long duration power system disturbance events. Disturbance and event recording facilities are required for local monitoring of the SVC following a disturbance on the power system or on the SVC. SVC voltages, currents, thyristors, TSC/TCR and filter currents will be monitored by the Transient Fault Recorder in addition to various other control and protective variables.

8.12.5.10 A state of the art Voltage Quality Recorder (VQR) shall be provided which shall monitor the SVC HV voltage (three phases) and current (three phases). The VQR shall be set up to measure power quality parameters in accordance with international standards from IEC/IEEE.

8.12.5.11 A state of the art DSM shall monitor all the main 220 kV and 132 kV circuits' voltages and currents – incoming and outgoing lines and transformers. It shall include all three phases of each circuit. The DSM shall also monitor the system frequency.

8.12.5.12 The integrated SVC controller together with the HMI, SOE, TFR, DSM and VQR shall be designed and configured that will allow future connection/interfacing to a network via Ethernet TCP/IP protocol, for remote access, fault diagnostics, data download and viewing. This is inclusive of all the hardware and software requirements for the SVC site and remote site but excludes the communication cabling/links.

8.12.6 Local/Remote Control

8.12.6.1 SVC may be controlled either locally or remotely.

8.12.6.2 In case of remote control, the control system must spontaneously prepare all signals and changes in analogue values from the SVC control system for transmission to the control centre without delay.

8.12.6.3 Details of the response time of the signals shall be provided by the bidder in the bid.

8.12.6.4 There shall be no limitations in the transmission capacity to the control centre other than the limitations given by the available communication speed and the communication protocol.

8.12.6.5 Control selection

i) The control system shall be designed to permit a free choice between necessary setting and monitoring of the system from the local control room at the substation or from the control centre. Switching between local and remote control is to be carried out in the local control room.

ii) The "Switch" between local and remote control has to be placed locally in the SVC control room. It shall only be possible to control the SVC either from remote or from local. A key switch will be installed locally in the SVC control room.

iii) The switch "LOCAL" - "REMOTE" shall have two positions:

a) **LOCAL:** only local control shall be possible. The operator in the SVC station can select whether all signals and measurements shall be transmitted to the remote control centre or not. Alarms and measurements shall be registered locally and presented on the HMI.

b) **REMOTE:** only remote control shall be possible. All local audible functions shall be blocked. Alarms and measurements shall be registered locally and presented on the HMI.

iv) A switch between local and remote control shall neither result in an unintentional jump in the power exchange nor in any electrical disturbances or unintended control actions.

8.12.7 Telecommunication Failure

8.12.7.1 Any telecommunication failure must not cause any unintentional operation of the control system. If the telecommunication link between SVC control system and corresponding remote control centre breaks down during remote operation, the settings shall be frozen at the value at the time of the loss of the telecommunication link or a predefined status should be achieved. Any active control actions shall be terminated in a safe state.

8.12.7.2 When the telecommunication link is re-established, the remote control of SVC shall automatically be re-established. All alarms and indications issued in the SVC during the failure shall be transmitted in chronological order to the control centre.

8.12.8 Indications

8.12.8.1 Each control point shall indicate as a minimum:

i) Starting or stopping sequence in progress
ii) Reference voltage and slope settings
iii) The control point selected
iv) Any other settings such as supplementary stabilizing signals
v) SVC “on” indication
vi) SVC “off” indication
vii) Three-phase high-side line currents of the main transformer
viii) Total reactive power generated or absorbed by the compensator
ix) Primary voltage, single phase
x) Secondary voltage, single phase
xi) SVC branches in/out (where applicable)

8.12.9 Annunciations/Alarms

8.12.9.1 The central control unit shall monitor its own operation and the operations of the various SVC components. Two levels of protection i.e. warning and shutdown shall be provided. The first-level alarm (warning) indicates that a problem exists, but the equipment itself or its proper operation is not in immediate danger. The second-level alarm (shutdown) initiates a reduction in output range or a shutdown of the SVC due to equipment problems that might cause damage if left unattended.

8.12.9.2 The first-level alarms include the following as a minimum:

i) Auxiliary power supply failure; back-up supply in use
ii) Cooling system fan or pump failure; back-up pump or fan is available
iii) Cooling system problems (e.g., low water resistivity, primary pump stopped)

iv) Capacitor failures can exist, but within an acceptable quantity
v) Loss of redundant thyristors
vi) Branch availability
vii) Loss of signal-measuring controlled bus bar voltage, with the control continuing to maintain the last SVC operating point unless the regulated bus bar voltage is also the source of synchronizing voltage.

8.12.9.3 The second-level alarms include the following as a minimum:

i) Loss of all control power
ii) Loss of cooling system rated capabilities
iii) Loss of source of synchronizing voltage
iv) Excessive number of capacitor failures
v) Excessive over-current in a thyristor valve
vi) Loss of thyristors in excess of redundancy margin

8.12.9.4 The central control unit shall also have a built-in protective system for self-monitoring.

8.12.9.5 It shall be possible to transfer alarms to the remote control centers as individual alarms and as combined alarms. The control system shall contain software that makes it possible to create combined alarms on the basis of detailed alarms of the SVC. Combined alarms shall be able to function as detail alarms at the creation of new combined alarms. Both detailed and combined alarms shall be stored in an archive in the local control system. On request from the HMI the alarms can be retrieved, displayed and sorted.

8.12.9.6 It shall be easy to block any erroneous detail alarm from being part of a combined alarm. It shall be possible to use logical operators without restrictions in the creation of combined alarms.

8.12.9.7 The SVC plant indications and alarm system shall register all real changes and shall ensure that the changes are also transferred to the remote control interface. Multiple alarms, for instance due to contact bouncing shall be prevented. False indications and alarms shall be avoided.

8.12.9.8 The alarms shall always show the real current status of the SVC equipment. Alarms shall not be pulsed. They shall disappear by themselves, once the activation criterion has disappeared, without having to be acknowledged in the station.

8.12.9.9 It will be considered as advantage if this selection is made by parameter definition or with graphical tools.

8.12.10 <u>Standard and Testing Requirements</u>

8.12.10.1 All control plant and material shall be type tested for Surge Withstand Capability according to IEC 1000-4-5, Electrostatic Discharge according to IEC 1000-4-2, Electrical Fast Transient Burst according to IEC 1000-4-4 and Radio Freq. Interference according to IEC 1000-4-3.

8.12.11 <u>Information to be supplied with the Bid</u>

8.12.11.1 An overall description of the structure of the control and monitoring system shall be supplied in the bid. Key performance data (e.g. resolution in voltage control, resolution and symmetry in triggering angle, response time in voltage acquisition, intrinsic filtering of voltage harmonics etc.) shall be given and explained.

8.13 SVC Protection

8.13.1 Depending on the technical specifications, operational requirements of the SVC as well as technical specifications of the existing protection system of the substation, the Contractor will be responsible for providing the appropriate protection solutions. The following solutions, but not limited, shall be provided/performed by the Contractor:

i) The SVC system supplied by Contractor shall be self-protecting.

ii) The protection relays and equipment shall be mounted separate from the SVC control and interface cabinets.

iii) The protection system shall, to the extent applicable, be built on the principle of a main and a back-up protection, for each protected zone/object. The two independent protection schemes, each capable of detecting all faults segregated to the extent that each uses separate secondaries of common current transformers, independently fused supplies from common voltage transformers, separate DC supplies and each tripping a separate circuit breaker trip coil through its own latching tripping relay, are required. The system must enable easy and clear identification of fault location and faulted element. The functionality of the protection system shall be given in a protection matrix.

iv) The functional requirements for the protection system are:

a) Protection equipment and personnel from damage and injury

b) Determination of the faulted zone

c) Protections shall be arranged in overlapping protective zones. A fast main protection shall be available for each fault type. This main protection shall be supported by a back-up protection function, preferably based on a different measuring principle, that may be part of another main protection

d) Testing of protections shall be possible on-line without affecting the operation of the SVC

v) The protection relays and equipment shall receive their primary input from CTs, VTs etc., that will be supplied as part of the SVC equipments by the Contractor. Redundant protective functions shall be included and demonstrated.

vi) All protection equipment and systems shall be properly coordinated to prevent incorrect operations of the protection equipment or systems during normal SVC operation, including anticipated abnormal conditions on the transmission system of the Company, as specified. Fail-safe principles shall be applied throughout. The protection system shall be selective and the total protection time shall never exceed 100 ms in any case (including circuit-breaker time).

vii) Single point of failures in the protection system shall be avoided by a complete physical subdivision of the protection system (incl. analogue and digital input signals) in two parts. Both subsystems shall be connected to a separate auxiliary supply. Tripping paths to circuit breakers shall be redundant.

viii) There must be no possibility that working/programming in the control system can influence the function on the protective devices.

ix) The Bidder shall provide a report on the protection system and protection co-ordination with detailed drawings. This report shall provide a description of each type of protection, the co-ordination of the protective devices and the recommended protective settings. The rating and performance of the instrument transformers as well as the co-ordination with the protective relays is also part of this report.

x) The Contractor shall supply a comprehensive electrical interlocking scheme to permit safe manual or automatic sequential connection and isolation of equipment. The interlocking scheme shall be designed to provide complete safety to personnel, hazard free equipment operation, failsafe operation in the event of component failure and maximum flexibility in operating the equipment.

xi) During on-line testing of the SVC, 100% protection of the SVC and the associated AC equipment must be ensured.

xii) The power supply for the control and protection equipment and the trip paths shall be designed redundant.

8.13.2 Component Protection

8.13.2.1 The following is a list of the possible required protection. Additional protection may be provided if deemed necessary.

i) Transformer and 132kV Bus

a) Transformer and SVC bus differential
b) SVC primary bus over-current
c) Ground Over-current
d) Breaker failure function
e) Low oil-level
f) Sudden pressure relay/Buchholz relay
g) Over temperature (oil and windings)
h) Cooling circuit supervision

ii) SVC Low Voltage Bus

a) Over-voltage
b) Under-voltage
c) Residual voltage
d) Differential
e) Voltage zero-sequence
f) Over current
g) Overvoltage

h) Ground over current

iii) Thyristor Controlled Reactors (TCRs)

a) Three phase over-current
b) Three single-phase differential
c) Thermal overload protection of reactors.

iv) Thyristor Switched Capacitors (TSCs)

a) Three phase over-current
b) Three single-phase differential
c) Capacitor bank unbalance protection for the TSC delta
d) Negative phase sequence
e) Zero phase sequence
f) Overload
g) Ground over current

v) Thyristor Valves in TCRs/TSCs

a) Over-voltage
b) Overcurrent
c) Thyristor failure
d) Thermal overload

vi) Harmonic Filters

a) Neutral voltage shift
b) Unbalance
c) Overvoltage
d) Differential
e) Ground Over current
f) Three phase over-current
g) Overload protection

vii) Master control

a) Loss of control power
b) Loss of synchronization signal

viii) Cooling media

a) Temperature
b) Flow
c) Resistivity
d) Leakage
e) Transfer failure or power loss

8.13.3 **Accessories**

8.13.3.1 The term "hardware" is understood to cover both the central processing unit and the directly connected subsystems, e.g. the power supply, I/O-gates, communication equipment and terminal equipment.

8.13.3.2 Only components of a high quality shall be used in the equipment. The Contractor shall use standard components. Connecting equipment for the terminal equipment shall be of a standard type.

8.13.3.3 The redundancy in the control and protection system shall be so arranged that loss of one auxiliary power source does not result in loss of control, cooling system or protection system. Two independent auxiliary power supplies shall be available. The design shall be such that the stand-by control system and cooling system can be tested and maintained during normal operation of the SVC.

8.13.3.4 Electronic components which are designed to be operated between 0% and 100% of rated voltage, current or power shall not be operated long-term at more than 70% of their rated voltage, current or power. Resistors shall be operated at not more than 50% of their rated power. Integrated digital and analogue circuits and others such as electronic components designed to be operated between a minimum voltage not equal to zero and a maximum voltage shall be operated approx. at the midpoint of their designed voltage range.

8.13.3.5 All cables between control cubicles, control desk etc. shall be terminated in terminals in the cubicles etc. The cubicles shall be of IP class 21 or higher. All components in the cubicles which have to be read or adjusted shall be located at a height above the floor of between 70 and 180 cm.

8.13.3.6 It is not permitted to fix more than one wire under a terminal. Multithread wires must be terminated with multicore cable ends.

8.13.3.7 Binary inputs of protective systems shall not operate on capacitive charge currents caused by earth faults in the DC-auxiliary voltage.

8.13.3.8 Design of cubicles has to be according to IEC standards. Terminals and all electrical connections must be of such a type that accidental contact with voltage is impossible.

8.13.3.9 The cross section of cables shall be determined according to the requirements of the detailed engineering phase. However the lowest permissible cross section is:

i) For secondary circuits of current transformers - 4 mm² (1 A rated current)

ii) For secondary circuits of voltage transformers – 2.5 mm²

iii) For trip circuits – 2.5 mm²

iv) For control circuits – 1.5 mm²

8.13.3.10 Current inputs of protective relays have to be designed for $100*I_N$ for 1 sec.

8.13.4 Standards and Testing Requirements

8.13.4.1 The design and testing of the protection equipments shall comply with relevant latest version of IEC standards.

8.13.5 Information to be Supplied with the Bid

8.13.5.1 A detailed preliminary protection block diagram shall be included in the bid. Details of protection equipment including type, make, rating etc shall also be furnished with the bid.

8.14 **Auxiliary Power Supplies**

8.14.1 The SVC equipment shall include all the power supplies necessary for its operation, including step-down transformer, AC distribution boards, batteries, battery chargers, etc. The power supplies shall be sufficient to supply all pumps, fans, valves, valve cooling system and controls, building cooling and heating systems.

8.14.2 The SVC auxiliary power distribution shall include both AC & DC distributions. The following principle requirements shall be met:

i) Two independent sources (one from SVC MV bus bar and other from the existing 11kV panel) shall be installed for the AC auxiliary supply. The power quality of the supply and the required load from the SVC shall be specified by the Contractor. The redundant feeders from the existing 400V distribution of the substation will be used for the auxiliary supply of the SVC. The connection cables shall be provided and installed including end termination by the Contractor.

ii) An automatic switching sequence, for selection of input AC feeder shall be provided. Switching must not cause significant disturbances in the MVAR output of the SVC.

iii) Auxiliary supplies must provide LVRT (Low Voltage Ride through Capability) and Fault Ride through Capability for at least 10 sec.

iv) The SVC control and protection equipment shall be supplied from the DC distribution. This is specifically valid for the subsystems being critical for continuous operation of the SVC. Certain more peripheral parts of the control system, e.g. subsystems and components related to the operator interfaces, can have AC supply, in these cases a non-interruptible source (type UPS) has to be used.

v) The DC distribution for the control and protection equipment, concerning batteries, shall be divided into two independent circuits. Each battery shall be rated for the full load in order to assure unrestricted SVC operation in case of battery failure. The requirements regarding availability and reliability have to be considered.

vi) All required rectifiers and inverters shall be supplied by the Contractor.

vii) The capacity of the batteries shall be chosen for at least 10 hours operation without charging.

viii) All AC and DC sub-distributions shall be built with at least 20% spare outgoing circuits for possible extension.

ix) The design and testing of the AC and DC distribution, the batteries, the rectifiers and the inverters shall comply with all relevant NTDC Specification and IEC standards.

x) Control & Auxiliary Voltages

a)	Type of System	3-phase,4wire,neutral
b)	Nominal voltage	230/400 V
c)	Limits of supply voltage which an AC operating device or auxiliary equipment shall be capable of operating correctly within the tolerance	+10% -15%
d)	Rated frequency	50 Hz
e)	Frequency limits	48-51 Hz
f)	Initial symmetrical three phase short circuit current	15kA
g)	One minute Power frequency withstand voltage for the auxiliary circuits	2kV
h)	DC Voltage	
i)	Tolerance	+10%, -15%

8.15 **Spares**

8.15.1 General Requirements

8.15.1.1 The basic supply of the SVC shall include a full complement of essential spare parts, which are to be furnished at the same time and as part of the SVC supply. It is the Contractor's responsibility, based on the particular design for the SVC to provide adequate spare parts to meet the specified reliability and availability requirements.

8.15.1.2 All spare parts offered must be of the same quality and completely interchangeable with the original parts.

8.15.1.3 The Bidder shall submit a complete list of spare parts to be supplied for the SVC system including information regarding type, make, rating etc.

8.15.1.4 The Contractor shall allow enough room for storage of the recommended spare parts.

8.15.1.5 The Bidder shall guarantee that sufficient spare parts shall be available from the bidder for purchase by the Company after acceptance of the system for a sufficient period of time stated by the bidder.

8.15.1.6 If any items which are necessary for safe operation and maintenance fail during the guarantee period, they have to be replaced by the Contractor at his expense and new spare (s) has to be delivered.

8.15.2 Spares Strategy

8.15.2.1 A strategy for spare parts shall be developed to demonstrate that the complement of spare parts will be adequate to meet the specified reliability requirements.

8.15.2.2 The spares strategy shall be based on a tabulation of all of the components in the SVC, down to the level of the lowest replaceable module i.e. all components suitable for unit replacement at the first level of maintenance shall be included in the tabulation but individual devices that would not be replaced except as part of a shop or bench repair of a replaceable component shall not be in this tabulation.

8.15.2.3 Each component in the tabulation shall be identified for its importance to the operation of the SVC, according to the following classification:

i) Category A: SVC operation is not possible until this component has been repaired or replaced (e.g., main step-down transformer, shunt reactor).

ii) Category B: SVC operation can continue (or resume) at reduced rating but further failures may lead to an SVC outage (e.g., TCR, TSC, MSR, MSC).

iii) Category C: SVC operation can continue on an emergency basis, but a critical function has been lost or bypassed. Some risk of further complications or equipment damage exists until the function is restored (e.g., one of two pumps out of service, protective relaying, UPS, or cooling alarm sensors not in service).

iv) Category D: Operation can continue without serious impairment (e.g., building services such as lighting or heating).

v) The tabulation shall include the failure rate or the expected replacement rate of the component over a 15 year period.

vi) The tabulation shall include the information regarding manufacturer, type, make, ratings and estimated delivery cycle etc.

vii) Each device shall either be:

a) Included on an inventory list of all site spares. The inventory list shall show the description, quantity, and storage location of each spare, assuming that any time that a spare is used, the item is reordered.

b) Provided with a contingency plan to obtain a replacement on short notice, if a spare is not being kept on hand.

8.16 **Engineering Studies**

8.16.1 The Contractor shall perform studies to determine the design ratings and requirements of all plant and material to be supplied under this contract. The CONTRACTOR shall confirm the design ratings and requirements of all plant and material to be supplied under the contract. Engineering studies shall be performed within the scope of supply. Studies are required to demonstrate that the SVC meets all specified performance criteria. The bid must contain a list of all engineering studies.

8.16.2 Prior to manufacture of the SVC, the Contractor shall perform simulation studies within agreed time frames for review, comment and participation by the Company. The Company reserves the right to perform parallel verification studies on its own or by a third party. The Contractor shall provide all required information for independent design verification and system modelling. The Contractor will be utilizing the system analysis software of PSS/E and electromagnetic transient simulation package (PSCAD/EMTDC) for verification and require the data to be either in the correct format or available EMTDC data format. The results will be verified by performing studies on Real Time Digital Simulator (RTDS) as well, before delivery of the SVC.

8.16.3 Transient and stability studies using PSS/E (version 30) to verify the SVC control system performance, evaluate SVC control system function and optimize the control of SVC during system disturbances, such as major faults and load rejection in the Company network. The design shall investigate the adequacy of the SVC to ensure stability and prevent under-voltages & over-voltages during system transient, dynamic and fault conditions. This is inclusive of degraded modes for the SVC system.

8.16.4 Detailed harmonic impedance, impact design and measurements to verify the filter design. The detailed filter configuration shall be supplied. This is to verify the adequacy of the SVC harmonic filter design through simulation of the Company's equivalent network response to SVC harmonics. It shall include evaluating maximum harmonic levels at the SVC point of common coupling (PCC).

8.16.5 The Contractor shall provide the following digital models to enable simulation of the SVC and its control and protective functions during steady-state operation, dynamic, and transient conditions in different timeframes:

i) PSCAD/EMTDC (latest version) model for time simulations from 1.0 ms up to 10.0 s.

ii) PSS/E (version 30) model for time simulations from 1.0 ms up to 60 s.

8.16.6 If the Company's or third party's studies indicate disagreement with the Contractor's results, the Contractor shall be required to work with the Company or his representatives to reach an agreement on the controversial issues and/or to make the required design corrections, in accordance with this specification.

8.16.7 The studies made by the Contractor shall result in a report which shall be submitted to the Company for information. The reports shall include but not be limited to:

i) <u>Main Component Design</u>

In this report, the analysis for the SVC equipment rating required to cover all modes of the SVC operation, considering the worst possible combination of manufacturing tolerances and frequency deviations, shall be presented. Power system characteristics shall be clearly stated and a summary of the rating of the SVC components shall be given including the calculation of fault currents for thermal and mechanical design.

ii) <u>Insulation Coordination</u>

In this report, analysis for the insulation levels shall be presented.

iii) Thyristor Valve Design and Protection

In this report, the calculations for the rating of the thyristor valves shall be presented. Coordination of break over device levels and other protective functions shall be described. Control strategies for possible misfirings shall be specified in detail and cooling requirements shall also be stated in this report.

iv) Control System Strategy

In this report, the control strategies implemented in the control system shall be described in detail. The verification of the main strategies shall be done by running the real control system together with a simulator implementing a network equivalent together with the SVC high voltage components. The verification can be done during the factory validation test of the control system

v) Protective Relay Coordination

In this report, the calculation of relay protection setting levels shall be presented together with the principles for protection coordination. A summarized list of the protection settings shall be given.

vi) Loss Evaluation

In this report, the total SVC losses shall be calculated and compared with guaranteed values. Explanations to discrepancies, if any, shall be given. The Loss Evaluation report shall be based on component loss data obtained from factory tests and from calculations. Refer to sub-clause 7.8 of this specification as well.

vii) Harmonic Filter Design and Performance

In this report, the harmonic filter design shall be described and the resulting maximum harmonic distortion generated by the SVC shall be presented.

viii) Reliability Study

The Contractor shall be required to demonstrate that the SVC design will achieve availability specified in sub-clause 7.9. The Contractor shall resubmit during the SVC design phase, the Reliability Study updated to reflect the performance of actual components used in the SVC.

ix) Site Noise Level Study

The Contractor shall submit the details/data indicating how the noise limits of sub-clause 7.7 shall be meet with. During the SVC design phase the Contractor shall perform a detailed site noise level study to confirm compliance with the noise limit specified. This study shall also determine site noise levels at extreme operating points and indicate how SVC generated noise varies across the full operating range (MVAR and voltage).

8.17 Documents and Drawings

8.17.1 In addition to the detailed information requested elsewhere in this specification, the Bidder shall submit all technical documentation necessary to give a detailed and clear picture of the proposed delivery. The bid documentation shall further provide ample proof of the Bidder's compliance with all aspects of this specification.

8.17.2 Drawings, technical descriptions, instruction, manuals etc shall be in English.

8.17.3 The following guidelines apply for the presentation of technical documentation being part of the bid:

i) A descriptive document shall be included, which shall present the proposed SVC configuration, and its compliance with the rating and functional requirements. Assumptions and methodology used for calculation of fundamental frequency and harmonic stresses and performance, shall be presented within this document.

ii) A single-line diagram of the SVC shall be included.

iii) A protection block diagram of the SVC shall be included.

iv) The losses of the proposed SVC, as a function of reactive power output, shall be presented as described in sub-clause 7.8.

v) The audible noise levels, with consideration the Company requirements, and the proposed SVC layout shall be presented. This description shall also give the principles of the methodology used for calculation of noise levels.

vi) The reliability and availability of the proposed SVC shall be addressed. Results of availability calculations shall be presented, along with the assumptions taken and methodology used.

vii) Layout drawing showing the proposed SVC site and the location of the main components shall be included. Also a 3-D plan of the SVC installations and building shall be provided.

viii) Preliminary inspection and test plans shall be provided for the factory tests of thyristor valves and SVC control system & allied equipment/material alongwith the commissioning tests, and the field verification tests.

8.17.4 The following documentation is, typically, required to be furnished by the bidder:

i) Technical reports
ii) Equipment specifications
iii) Quality assurance documentation
iv) Equipment test reports, if any
v) Control elementary drawings
vi) Plan and profile drawings, as built
vii) Civil/mechanical/architecture
viii) As built drawings

8.17.5 Plant Documentation

8.17.5.1 The Contractor's plant documentation for the delivered SVC system shall contain documents, drawings, instructions and manuals necessary to operate and maintain the SVC system. As a minimum the following documentation (divided into groups) shall be provided:

i) System Description

This group shall provide overall system related information such as SVC system descriptions, single-line diagrams, function block diagrams and plant circuit diagrams. The design reports in sub-clause 8.16 of this specification shall be provided as part of this group.

ii) Operation and Maintenance

This group shall provide information on the operation, fault tracing and maintenance of the plant, such as operation instructions, general maintenance instructions, list of alarms and spare parts, etc.

iii) Equipment Documentation

This group shall provide information on the equipment included in the SVC system. The information shall include circuit diagrams, dimension prints, technical descriptions, assembly drawings etc.

iv) Plant Construction

This group shall provide information on items such as civil works, erection and installation, cabling and inter-connection. The information shall include architectural drawings, station layouts, bills of materials, installation manuals and lists of cables.

v) Factory Testing:

This group shall include Inspection and test plans, and factory test records.

vi) Commissioning Documentation

This group shall contain field test records created and logged during the testing and commissioning of the SVC system.

vii) Field Verification Test report

The Field Verification Tests shall be documented in a report. This document shall include appropriate references to the performance requirements and to the performed design studies.

8.17.5.2 All drawings and documentation shall be in accordance with relevant International/IEC Standards.

8.18 **Trainings**

8.18.5 The Contractor shall arrange following training courses for the Company's Engineers:

8.18.5.1 Basic Engineering and Studies Regarding SVC Technology

i) The Contractor shall provide courses from operational aspects with respect to hardware and software as well as training of the Engineers who will be responsible for operation, maintenance and repair. Appropriate training documentation shall be included. All the training shall be given in the English language.

ii) The courses shall also include training in the factory during the testing of the complete SVC control system and allied equipments to Ten Company's Engineers on design, operation maintenance and repair of the system.

iii) The Contractor shall arrange/provide courses from system analysis, planning and design aspects to verify and modify, if required, some control parameters of the SVC.

8.18.5.2 On-site Training

i) A comprehensive training programme including complete system design and function, operational aspects and preventive maintenance shall be arranged by the Contractor for Ten Company's Engineers.

8.18.5.3 Site Visits

i) The Contractor shall arrange at his expense/cost the study tours/visits for five engineers of NTDC on at least two sites of SVCs, similar in size and performance as of this project within 3 months after award of contract.

9. TESTING REQUIREMENTS

9.1 General Requirements

9.1.1 The Contractor shall be responsible for organizing and performing all tests in accordance with the applicable standards and any additional requirements in this specification. Where standards are not suitable or applicable, other common industry procedures and mutually acceptable methods shall be used.

9.1.2 All equipment included as part of the SVC system shall be tested before being placed in final operation. The bidder shall furnish the test plan/procedures.

9.1.3 The bidder shall submit a list of tests clearly stating the type tests that will be carried out for this project, and stating the type tests where instead a report from a previously performed test shall be considered in lieu of actual test performance. The list of tests shall also include routine tests and factory acceptance tests to be performed for this project.

9.1.4 The results obtained from type tests must demonstrate that the equipment conforms to the requirements of this specification and the latest applicable standards.

9.1.5 The results obtained from tests must be compiled and organized in writing. All test results must contain the appropriate signature of the Contractor.

9.1.6 Company reserves the right for itself and/or its nominated representatives to be present and witness all tests.

9.1.7 The Contractor shall furnish all labour, materials, instrumentation, testing facilities and inspection test plan (ITP) for all tests.

9.1.8 If any piece of equipment provided as a part of the SVC does not pass a test or is damaged, the Contractor must replace or repair the failed or damaged equipment and modify the equipment design, if necessary. The Contractor may be required to repeat the tests previously done on any equipment which is replaced, repaired or modified. All expenses for the material, re-installation and re-testing will be borne by the Contractor.

9.1.9 The Contractor, at all times, must obtain permission from Company to perform field verification tests when the SVC is connected to the power system.

9.2 **SVC Control System Testing**

9.2.1 A Factory Simulator Test shall be performed for the original control and protection system. The Contractor shall thoroughly test all control and protection functions on RTDS in the factory in the presence of Company's Engineers. These tests shall provide an initial verification of performance before the control and protection equipment is shipped to site. These tests shall include but are not limited to:

i) Verification of each control function
ii) Verification of control linearity
iii) Verification of the monitoring system
iv) Verification of the protection system
v) Verification of overall system performance for minor and major system disturbances
vi) Verification of processor loading of all digital controllers

9.3 **SVC Sub-system Testing Before Energization**

9.3.1 The SVC subsystem tests are those tests to be performed at the site on the fully assembled SVC subsystems in the presence of Company's Engineers, without having the SVC connected to the power system. The Contractor shall submit a list of these tests. Company reserves the rights to approve the test plan.

9.4 **SVC Commissioning Test & Field verification**

9.4.1 Upon satisfactory completion of the subsystem tests, energization of the SVC and field verification tests shall be performed in the presence of Company's Engineers. These tests are performed at the site on the fully assembled SVC with the SVC operating and connected to the power system. These tests need close co-operation with the responsible remote control centre from the Company. The Contractor shall submit a list of these tests. Company reserves the rights to approve the test plan.

9.5 **Schedule of Testing**

9.5.1 The Contractor shall give the Company **an** advance notice of type, routine and factory acceptance tests 2 months before the actual testing date.

9.5.2 Inspection and test plans shall be submitted for the Company's information prior to commencement of the test.

9.5.3 Company reserves the right to approve inspection and test plans.

9.6 **Trial Operation**

9.6.1 As soon as commissioning and field verification tests have been completed, the Contractor shall advise Company in writing that the equipment is ready for service.

9.6.2 After successful commissioning and field verification tests of the SVC itself, the SVC will be part of the scope of testing within the grid reinforcement project of the Company.

9.6.3 A trial operation shall start according to the time schedule agreed upon. It lasts for a period of 3 months as a minimum extendable to another 3 months in case of maloperation during initial trail period. The Contractor will be responsible for the operation of the plant until it is formally taken over by Company. This applies even if operating periods fall outside normal working hours. During the trial operation Company's operating procedures shall be followed regarding switching, dispatching and access to high voltage areas. The Company will provide the staff necessary for taking care of these safety precaution tasks.

9.6.4 During trial operation the Contractor shall provide the agreed number of supervising engineers and service personnel on Site. The supervising engineers shall supervise the equipment on site, instruct the personnel of the Company and at the same time assist during testing etc.

Annexure-A

SVC & Power System Description

A-I The SVC system is to be installed at 220/132 kV New Kot Lakhpat AIS, outdoor manned substation situated in Lahore, Pakistan.

A-II The following ac power system characteristics shall apply at the point of connection prior to SVC installation. Normal SVC operation is required within the parameter values and durations given hereunder:

i) The nominal capacitive reactive power output of the SVC at point A in Figure 1 (sub-clause 7.1) shall be 450 MVAR at 1.0 per unit AC bus voltage, nominal system frequency and at 50 °C ambient temperature.

ii) The nominal inductive reactive power output of the SVC at point B of Figure 1 (sub-clause 7.1) shall be 50MVAR at 1.0 per unit AC bus voltage, nominal system frequency and at 50 °C ambient temperature.

iii) The nominal slope of the characteristic shall be adjustable in steps of not greater than 0.5% between 0% and 3%, on a basis of 100 MVA (sub-clause 7.1, Figure 1).

iv) The SVC shall continue to generate reactive power during a temporary under voltage down to a value of 0.3 per unit for duration of 10s (point C in Figure 1). The SVC may be tripped if the under voltage persists for more than 10s.

v) The SVC shall continue to absorb reactive power during a temporary overvoltage in a controlled manner up to the value of 1.3 per unit for duration of 3s (point D on Figure 1). The SVC may be tripped if the overvoltage persists for more than 3s.

vi) These are the minimum requirements and the Contractor shall determine the maximum overload and over voltage requirement based on the network data provided in the specification. The SVC shall be rated and designed to withstand these over voltages.

A-III SVC Configuration

i) The SVC shall consist of either six-pulse or twelve-pulse topology. The inductive part of the SVC system shall consist of TCR(s) branch. In case of more than one TCR branch, TCR branches shall be of equal size. The capacitive thyristor switched part of the SVC system shall be implemented by means of TSC branch. In case of more than one TSC branch, TSC branches shall be of equal size. Multi TCRs and/or TSCs shall operate on the principle of a master-follower.

ii) The SVC system design has to allow partial operation in case of any single branch (TCR, TSC and FC) out of service.

iv) The fixed capacitive part of the SVC will consist of filter branches of equal size, rating and configuration. Each one of the filter branches will consist of either a group of (3 single tuned LC filters) or a double tuned filter group. Damping on the filters may be needed.

Annexure-B

B-I Frequency

i) Nominal AC system frequency 50 Hz

ii) Maximum continuous AC system frequency 49.8 Hz

iii) Minimum continuous AC system frequency 50.2 Hz

iv) Maximum short-term AC system frequency 50.5 Hz

v) Minimum short-term AC system frequency 49.4 Hz

vi) Network earthing Directly earth

B-II **Insulation Co-ordination**

	Parameters Based on prevailing Standards	**132kV**	**220kV**	**500kV**
	Lightning impulse level (1.2/50µSec)			
a)	To earth and between phases, kV peak	650	1050	1550
b)	Between open isolator contacts, kV Peak	750	1200	1865
	One minute power frequency withstand test			
a)	To earth and between phases, kV rms	275	460	620
b)	Between open isolator contacts, kV rms	315	530	800

B-III **Short Circuit Levels**

Parameters	132kV	220kV	500kV
Three phase symmetrical short circuit current, kA rms	31.5/40	40	40
Three phase symmetrical peak withstand current, kA peak	80/100	100/125	100/125

B-IV **Transmission Data for Harmonic Studies (To be provided Later on)**

i) Harmonic impedance sectors or performance)	See Figure ____________
ii) Harmonic impedance sectors for rating filter components	See Figure ____________
iii) Background harmonic voltage (or current) spectrum (for rating filter components)	See Figure ____________
iv) Harmonic requirement Existing single harmonic distortion value v) Total harmonic distortion value	$U_v \leq$ %; THD ≤ %
vi) Permissible single harmonic distortion value from 2nd to 25th harmonics vii) Maximum allowed total harmonic distortion value	$U_v \leq$ 1.5% THD ≤2.5%
viii) TIF	≤
ix) Total Harmonic current factor (IT)	≤ 2.0 %
	to ν =

NATIONAL TRANSMISSION AND DESPATCH COMPANY (NTDC)

SPECIFICATION P- : 2009

CIVIL WORKS

Prepared by
DESIGN DEPARTMENT (NTDC)

CIVIL WORKS

1. **INTRODUCTION**

This section comprises the Standards and Specifications pertaining to the fundamental requirements of design, material, workmanship, construction, testing, inspection and maintenance of the Civil Works required or specified under the Contract. The Contractor shall perform the work in accordance with these specifications and other specifications supplemental to these specifications as may be specified by the Engineer from time to time. Should the Contractor follow other specifications, these must be approved by the Engineer prior to carrying out these works.

1.1 **Works:**

The Contractor shall carry out all the works required for the design, construction, completion and maintenance of the Civil Works required under the Contract including foundations, cable trenches, pavements, roads, buildings, drainage and other allied work as required or specified in the Contract and as shown in the drawings.

The prices of all additional works which are not shown in “Price Schedule” but specified in the Contract Documents, shall be included in the prices of other items of “Prices Schedule”. The Contract Documents shall not claim additional cost for any item, which is required to be executed as per Contract Documents but not specially mentioned in the “Public Schedule”.

1.2 **Materials:**

i) The Contractor shall furnish all materials and equipments for the performance of civil work.
ii) Materials to be used for civil work shall conform to the relevant ASTM standards and specifications. However in case of using other standards, the Contractor shall obtain prior approval of the Engineer.
iii) In all matters relating to the acceptance or otherwise of the equipment and offered under this contract the decision of the Engineer shall be final.

The Engineer shall have the right to reject any material and/or equipment which does not meet the requirements of the Contract Documents. All rejected material or equipment shall be removed from the Site as soon as possible.

The Engineer reserves the right to witness any test on material if necessary. The Contractor shall provide proper facilities to witness tests and shall also bear all the expenses on this account. Should the Engineer require the detailed data on material, the Contractor shall furnish the same in writing to the Engineer.

2 **DESIGN CONDITIONS**

2.1 **General**

All drawings and statements shall be in the English language and metric system of measurements shall be used.

The following design conditions shall be used for the design of civil work and shall not be deviated unless approved by Engineer.

2.2 **Design Condition**

The values used in this project are as follows:

Seismic Coefficient:

Vertical	Kv = 0.0
Horizontal	Kh = 0.1

i) Wind Load:

Wind pressure	Fw = Cxq
Where	$q = 1/2xpV^2$
	p = Air density/ acc.(0.125 kG sec^2
	V = Wind velocity (45m/sec)
	c = Shape factor (for circular equipment 0.8 (for Angular equipment 1.2)

2.2 **Design of Foundations:**

1) Geotechnical Investigations

The Contractor shall carry out the Geotechnical investigations at Site just after award of the Contract under the supervision of the Engineer to design the foundations. For this purpose the Contractor shall submit his proposal regarding the type of tests and their locations at Site for review/approval of the Engineer. After performing Geotechnical investigations, the Contractor shall submit Geotechnical investigation report and his recommendations for design of civil works for review/approval of the Engineer.

2) Foundations

All foundations shall be designed upto 200 mm or as shown in the drawings from top of gravel level, appropriate slope shall be provided on the top end of the foundation in order to ensure sufficient drainage. The load for design of foundation shall be taken from the foundation reactions calculated in the design of gantries and respective equipments after applying appropriate load factors.

The Contractor shall submit to the Engineer for his approval calculations and load analysis used for design of gantries, equipment foundations and building works.

The size and type of foundations i.e. spread footing, mat footing or pile foundations including soil replacement if any shall be based on Geotechnical Investigation Report.

The gantry stubs and anchor bolts shall be available at Site before pouring of concrete for gantry and equipment foundations. If block outs are to be provided in the foundations due to any constraint, pre-mixed non-sprink grout shall be used for the embedment of stubs and anchor bolts as per approval of the Engineer.

3) Leveling Concrete

A leveling concrete shall be placed in thickness of 100mm or as shown in drawing.

2.4 **Design Standard and Code**

For foundations and building designs, the Contractor shall conform to the applicable requirements of the latest revisions of following standards and publications, in principle.

1) ASTM (American Society for Testing and Material)
2) ACI (American Concrete Institute)
3) BS (British Standards) – where specified only

2.5 **Testing**

In addition to following tests on coarse and fine aggregate to be used for constructions;

i) Specific gravity of aggregates
   - Coarse grading
   - Fine grading

ii) Unit weight

iii) Gradation analysis

iv) Flakiness and elongation indices

v) Log Angle Abrasion:
   - Coarse grading
   - File grading

vi) Soundness

vii) Water absorption

viii) Aggregate impact value

ix) SASR test for aggregates

x) Petrographic test:
   - Fine aggregates
   - Coarse aggregates

The following chemical analysis shall be carried out for water to be used in concrete, ground water and for soils which are to come in contact with concrete:

- pH
- Chloride mg/litre
- Magnesium, mg/litre
- Ammonium, mg/litre
- Sulphate. mg/litre
- Potassium permanganate, mg/litre
- Total hardness milli equivalent/litre
- Non carbonates
- Carbonic acid

Cement to be used shall have an alkali content less than 0.5% of soda equivalent. Test reports for the tests carried out to verify the alkali contents shall be submitted to the Engineer for review and approvals.

The Contractor shall compare chemicals found in water, soil and construction material with those values allowable in design code and submit report for Engineer's approval. The Contractor shall take precautions in designing civil works and shall add admixture in concrete and take remedial measures to prevent structure from any expected attack from chemicals observed.

3 **TEMPORARY WORK**

3.1 **General**

1) This clause covers the furnishing of all appliances, labour, materials tools, transportation and services required to perform and complete all preliminary work and temporary construction.

2) Immediately after award of the Contract, the Contractor shall submit to the Engineer in writing the schedules for machinery and equipment to be supplied and temporary work to be constructed by the Contractor in connection with the execution of the permanent work.

Even though such schedules have been submitted to the Engineer, by no means the Contractor shall be relieved from any liabilities and responsibility to be borne by him in accordance with the Contract.
However, the schedules for minor and simple work may not be submitted if allowed by the Engineer.

4) Any drawing and design calculation sheets for the equipment to be used and for the temporary work specified in the specifications shall be submitted to the Engineer for his approval.

3.2 **Scaffoldings and Path**

In order to complete the construction, the Contractor shall furnish and maintain all required scaffolding, stairways, platforms and other necessary pertinent.

3.3 **Temporary Transportation Road**

1) The Contractor shall carry out investigation, design and construction of the temporary transportation road required for execution of the work at his expense, and submit such design in writing to the Engineer and obtain his approval.

2) The Contractor shall, at his expense, carry out maintenance and management of the temporary transportation road.

3) After completion of the work, the Contractor shall dismantle or leave the temporary transportation road as mutually agreed by the concerned parties subject to the approval of the Engineer.

4 **EARTH WORK**

4.1 **General**

This clause covers the performance of all works in connection with the required cutting, filling, leveling and compaction of site area, excavation for the various type of foundations as shown in the drawings, or any other excavation and banking that may be necessary during the progress of works including the removal, use or disposal of all excavated material.

4.2 **Clearing and Grubbing**

1) Clearing and grubbing shall include dismantling and removal of structures, removal of trees and shrubs, stumps and other obstacles from the area necessary for the execution of work. The Contractor shall cut and remove all such objects from the project area upto any lead as approved by the Engineer.

2) The Contractor shall not cut any tree outside the premises of the construction site without permission of the parties concerned.

3) Clearing and Grubbing shall also include removal of unwanted top layer upto 150 mm, if required.

4.3 **Excavation**

1) Excavation under this section shall consist of the removal, hauling dumping, and satisfactory disposal of all materials from required excavations for leveling the site area and construction of

civil works. Excavation in rock by means of drilling, blasting, chemicals etc. shall also be done by the contractor wherever required.

2) The excavated slope surface shall be protected against any erosion due to heavy rains during construction period. Should any damage be caused on any face of slope, the Contractor shall immediately repair any such damage at his expense.

3) Excavation shall be carried out by adopting a suitable method for excavation of the ground so as not to loosen the ground outside the excavation. If necessary, temporary sheeting shall be constructed.

5) During excavation, work shall be performed carefully so as not to cause any damage to adjacent structures and buried structures owned by the public or third party. The execution of work in such areas shall be carried out following instructions of the Engineer

6) If the excavated material is to be temporarily stockpiled, designated spaces shall be kept at suitable distance from the shoulder of the road while considering the earth pressure at the excavated surface and the working space. Temporary sheeting or other such structures, if necessary, shall be constructed so that the stockpile can be protected from damage or being washed away

7) After completion of excavation, excavated widths and bottoms shall be subject to inspection by the Engineer.

8) Any and all excess excavation for the convenience of the Contractor or over-excavation performed by the Contractor for any purpose or reason, except as may be ordered in writing by the Engineer, and whether or not due to fault of the Contractor, shall be at the expense of the Contractor. All such excess excavation shall be filled at the expense of the Contractor with materials as approved by the Engineer. However, for the switchyard equipment, gantry and building foundations, excess excavation underneath the foundations if any done, shall be filled with lean concrete at the expense of the Contractor.

9) The Contractor may request the Engineer in writing to change the excavation line as required according to the soil conditions of the foundation during the progress of excavation line, the Contractor shall prepare the revised design of the said foundation and submit it to the Engineer for his approval.

4.4 **Filling and Back Filling**

1) Filling and back-filling shall be executed as construction proceeds alongwith the removal of shoring and other materials at the filling and back-filling site.

When sheeting is to be let and buried in order to prevent shear failure of soil or due to some other inevitable reasons, it shall be done according to the direction of the Engineer.

2) Except as noted otherwise in the specifications or the drawings, all the materials for filling and back-filling shall comply with the following requirements.

a) Material shall not include any harmful materials, such as fertile soil or pieces of wood, slurry mud organic and other unsuitable material.

b) Material shall not be of an extreme swelling nature.

c) The gradation of the general fill material shall conform to the following limits:

Material Size, U.S. Shieve Series	Percent Finer Than, by Weight
No. 10	100
No. 50	70-95
No. 100	25-75
No.200	10-15

However, for the engineered fill under the light structures i.e. foundations, proposal of well graded gravelly sand shall be submitted by the Contractor for approval of the Engineer.

d) No stones or the like shall be used for filling and back-filling.

e) Impermeable clay shall not be used for back-filling of a structure which is susceptible to earth pressure.

Location of borrow pits and method of obtaining materials for banking shall be reported to the engineer in advance for the approval.

3) If the inflow of water exists at the site of filing and back-filling, it shall be appropriately handled at the expense of the Contractor.

4) The compaction shall be made in the filed by ramping machines or other mechanical means as approved by the Engineer. The layer of compacted earth filling shall not be more than 5 cm per lift, and it shall be graded at horizontally as possible, and shall be sufficiently compacted to produce not less than 95% o laboratory maximum dry density as determined by ASTM Designation D1557-00 "Test Method for Laboratory Compaction Characteristics of Soil Using Modified Effort". Field dry density shall be measured according to ASTM D-1556-00 – Standard Test Method for Density and Unit Weight of Soil in Place for Sand – Cone Method or ASTM D-2937-00 "Standard Test Method for Density of Soil in Place by the Drive – Cylinder Method" or other methods as approved by the Engineer.

5) If there is any surface or buried structure owned by the public or the third party at the site of filling and back-filling, care shall be taken so as to cause no harmful effect to them and the execution of the work shall be carried out following instructions by the Engineer.

6) For back-filling adjacent to a structure, compaction and back-filling shall be carried out in such a manner that will prevent damage to the structure.

4.5 **Disposal of Excavated Materials**

1) Spoils produced by excavation shall be piled, graded, sloped or disposed of at the locations as directed by the Engineer.

2) In transporting the spoils, care shall be taken so as to neither hamper traffic nor cause trouble to the third party by scattering the spoil over the road.

4.6 **Inspection:**

The instructions and tests specified herein shall include the following:

1) Volume of work executed

2) Inspection of test of construction materials

3) Inspection of excavation (including bed surface)

4) Inspection of disposal of excavated materials

5) Inspection of compaction test of back-filling

6) Other tests and inspections which the Engineer deems necessary

7) Other tests and inspections required according to pertinent regulations, codes and standards

The works for which the Engineer deeds inspection necessary, shall be executed in the present of the Engineer.

5. REINFORCED CONCRETE WORK

5.1 General

1) This clause covers the performance of all reinforced concrete work for permanent structures in accordance with the drawings and these specifications.

2) The Contractor shall furnish all materials and equipment for the performance of concrete work.

3) Reinforced concrete work and plain concrete work shall comply with all requirements of ACI 318-02 (latest revision). Also test on material shall, in principle, follow relevant ASTM Standard or equivalent approved by the Engineer.

4) Concrete shall have the uniform quality with the required strength, durability water lightness etc.

5) Strength:

a) The strength of concrete shall generally be based on 28 days compressive cylinder strength

b) Compression tests for concrete shall be performed in accordance with relevant ASTM standards or approved equivalent.

o28 = 350 kg/cm²	For grouting under base plate of equipment steel structure with mixing of non-shrinking agent.
o28 = 280 kg/cm²	For water retaining structures.
o28 = 211 kg/cm²	For foundation of each equipment gantry towers, cable trenches, buildings and other structures as specified. The minimum cement contents shall be 350 kg per cubic meter of concrete.
o28 = 71 kg/cm²	For leveling concrete.

Where o28 means concrete compressive cylinder strength at the age of 28 days.

Table-1 – Basic Mix Data

Design Strength σ28 kg/cm²	Max Size of Aggregate (mm)	Slump (cm)	Air E/ment (%)	Description
350	As per Table-3	4 ± 2	-	Grouting under base plates of equipment steel structure.
280	As per Table-3	10 ± 2	4 ± 1	Water retaining structures.
210	As per Table-3	6 ± 2	4 ± 1	Foundation, buildings and other structures.
140	As per Table-3	10 ± 2	4 ± 1	Leveling

Note:

1. Specific gravity in design
   Cement – 3.15, Fine Aggregate – 2.62, Coarse Aggregate and Crushed Stones – 2.62.

2. The Contractor shall submit proposal of mix design for approval of the Engineer.

3. Maximum size of coarse aggregate may be reduced for columns, beams and slabs etc. as directed by the Engineer.

5.2 **Material**

1) **Material for Reinforced Concrete**

a) **Cement**

Classification shall be Ordinary Portland Cement to be complied with British Standard 12:1971 "Specifications for Ordinary and Rapid Hardening Portland Cement" or to ASTM Designation C150-99a Standard Specification for Portland Cement for Type-I", or equivalent and Sulphate Resistant (SR) cement shall be used in water logged area and as per requirements of Geotechnical investigations and this shall be according to ASTM C150-99a Type-V.

b) **Water**

i) Water shall be clean and free from injurious amounts of oils, acids, alkalis, salts, organic materials or other substances deleterious to concrete or reinforcement.

ii) Sea, river or canal water shall not be used in mixing concrete for reinforced or plain concrete.

iii) Test as described in clause 2.5 shall be within acceptable limits.

iv) Non-potable water shall not be used in concrete unless specifically approved by the Engineer.

c) **Fine Aggregate**

i) **General**

Fine aggregate shall be clean, strong, hard, durable, suitably graded and free from injurious amounts of dust, mud, organic impurities, salts etc. Beach sand shall not be used for concrete.

ii) **Grading**

Fine aggregate shall consists of large and small particles suitably mixed, and its grading shall, as a standard, be within the range shown in Table-2.

Table - 2 - Standard Grading of Fine Aggregate

Sieve Designation U.S. Standard Square Mesh	Percent Passing
0.375 in (9.5 mm)	100
No. 4 (4.75 mm)	95 to 100
No. 8 (2.36 mm)	80 to 100
No. 16 (1.18 mm)	50 to 85
No. 30 (600 mm)	25 to 60
No. 50 (300 mm)	10 to 30
No. 100 (150 mm)	02 to 10

The sand equivalent value of the fine aggregate, as determined by ASTM Designation D-2419-02 "Standard Test Method for Sand Equivalent Value of Soils and Fine Aggregate", shall not be less than 75. The Fitness Modules shall range between 2.3 to 3.1.

d) **Coarse Aggregate**

i) **General**

Coarse aggregate shall be clear, strong, hard, durable, suitable graded and free from injurious amount of flakes, elongated pieces, organic impurities, salts etc.

ii) **Crushed Stones**

Coarse aggregate shall consist of large and small particles suitably mixed and its grading shall be within the range shown in Table-3 as a standard.Sieve analysis shall be performed in accordance with ASTM Designation C33-02a, or equivalent.

Table - 2 - Standard Grading of Coarse Aggregate

Percent by weight finer than each laboratory sieve

US Standard Sieve Size	1.5 in. to 0.75 in.	0.75 in. to No. 4	0.5 in. to No. 4
2	in.100	-	-
1.5	in.90 to 100	-	-
1	in.20 to 55	100	-
0.75	in.0 to 15	90 to 100	100
0.5	in.	-	90 to 100
0.375	in.	0 to 10	20 to 55 40 to 70
No. 4	-	0 to 10	0 to 15
No. 8	-	0 to 5	0 to 5

e) **Reinforcement**

Steel bar reinforcement, shall be deformed bars conforming to the provisions of ASTM Designation A615/A615M-01b, "Standard Specification for Deformed and Plain Billet-Steel Bars for Concrete Reinforcement" and shall have a minimum yield stress of 40,000 psi. Steel bar reinforcement in the openings to be filled with second stage concrete shall be of mild steel. At least 45 days prior to issuing each order for reinforcing steel, the Contractor shall notify the Engineer in writing of the Contractor's proposed sources of supply so that the Engineer may make arrangements for plant examination, testing and inspection. A similar notification shall be given prior to each shipment to the Site. The Contractor shall provide such assistance, instruments, machines, labour and materials as are required for examining, measuring and testing the quality, weight or quantity of steel at the mill and at the Site. If and when required Contractor shall provide all necessary facilities to Engineer for the selection of test pieces and shall prepare these to the required shape and length and submit it to the laboratory where directed for tests at Contractor's cost. No steel shall be incorporated in the Works without prior approval of the Engineer.

f) **Admixture**

i) The Engineer shall select the source and brand of air-entraining admixture, if required. The air-entraining admixture will be an approved substance or compound conforming to the requirements of ASTM Designation C260-01, "Standard Specification for Air-entraining Admixtures for Concrete", which will produce entrained air in the concrete as hereinafter specified. The air-entraining admixture shall be added to the batch in solution in a portion of the mixing water. This solution shall be batched by means of mechanical batcher capable of accurate measurement and in such a manner as to ensure uniform distribution of the admixture throughout the batch during the specified mixing period.

ii) The source, brand and types of suitable water-reducing cement-dispersing admixtures, if required, shall be selected by the Engineer.

The water-reducing admixture will be compatible with the air-entraining admixture specified above and shall be batched and added to the concrete in the manner specified for the addition of air-entraining admixture but separate from the portion of the mixing water containing the air-entraining admixture. The quantities of water-reducing cement-dispersing admixture to be used shall be in accordance with the instructions of the Manufacturer, as approved by the Engineer. Water-reducing admixture will conform to the requirements of ASTM Designation C494-99a "Standard Specification for Chemical Admixtures for Concrete". Water-reducing admixtures shall be sampled at the source of supply and tested at the expense of the Contractor. Additional tests if deemed necessary shall also be arranged by the Contractor without any claim of cost under the supervision of the Engineer.

iii) Admixture for non-shrinking of concrete shall be used for grouting wherever required.

g) **Mortar**

Before placing the fresh concrete a mortar cost, approximately two cm thick, shall be placed on construction joint. The proportion of the mortar mix shall be one part of cement to two parts of sand of fineness of between No. 100 and No. 4 sieves, with a consistency which allows spreading it over the surface and completely filling of all irregularities in the old concrete. Before concrete is placed over a construction joint, the joint shall be thoroughly cleaned and wetted. Any excess water shall be removed prior to concreting.

2) **Storage of Materials**

a) **Storage of Cement**

i) Cement shall be stored separately for each type in either silos or damp-proof warehouses.

ii) Silos to store cement shall be built or equipped with suitable means so that cement will not be retained at the bottom without being conveyed out.

In case of sacked cement, it shall be stacked on the floor rising atleast 30 cm from the surface of the ground, and shall be stored in such a manner as to facilitate conveyance and inspection. Height of each stack shall be at most 13 sacks.

iii) Any bag for which portion of cement has hardened during its storage shall not be used at all. Cement stored for long period shall be tested for its quality prior to its use.

iv) Cement with excessively high temperature shall be used only after lowering the temperature.

b) **Storage of Aggregate**

i) Fine aggregate, coarse aggregate and other aggregate of different type and grading shall be separately stored with dividers between each.

ii) When receiving, storing and handling aggregate, facilities shall be well maintained and handling shall be carefully performed so that no segregation of large particles from small ones may occur, no foreign materials may become mixed, or in case of coarse aggregate, no particles may be crushed.

iii) Storage facility of aggregate shall be equipped with a suitable drainage system, and shall have a suitable capacity so that the aggregate with uniform surface water may be used separately and the aggregate received may be used after being tested.

iv) In hot weather, aggregate shall be stored in a place with a facility to avoid direct exposure to the sun etc. so that extreme drying or temperature rise in the aggregate does not occur.

c) **Storage of Reinforcement**

Reinforcement shall not be directly placed on the ground, and it shall be stored in a warehouse or a place with suitable cover.

d) **Storage of Admixture**

i) Admixture shall be stored so as to be free from dusts and other impurities. Admixture in powder form shall be stored in such a manner that absorption of water and hardening are prevented and admixture in liquid form shall be stored in such a manner that segregation and change in quality are prevented.

ii) Admixture material shall be carefully handled.

iii) Admixture material shall be stored in silos or warehouses which are damp-proof and shall be used in the same order as they are received.

iv) Admixture stored for a long period or found to have changed shall be tested prior to its use. Should it be found in the test that admixture does not possess the required characteristics, its use shall not be allowed.

5.3 **Mix Proportions**

1) Mix proportion for concrete shall be determined in such a manner that the unit quantity of water its minimized while the required strength, durability, water tightness and the workability suitable or the work are secured.

2) Mix proportion for concrete and results of tests mixing shall be determined so as to provide the required strength, workability, uniformity and durability. The scheme of mix proportion shall be submitted to the Engineer for approval. The form of submission as per Table-4 shall be used. The design strengths of the concrete shall be the classes indicated below.

o28 = 350 kg/cm² For grouting under base plate of equipment steel structure

o28 = 280 kg/cm² For water retaining structures.

o28 = 211 kg/cm² For foundation and buildings

o28 = 71 kg/cm² For leveling concrete.

Where o28 means concrete compressive cylinder strength at the age of 28 days.

The Contractor shall prepare concrete mix design according to basic design data for mixing as indicated in the Table-1 herein.

Table-4 (Concrete Mix Design Report)

					Quantity (per Mixed 1m³)				
Mix Size of Aggregate	Slump (cm)	Air-Entrain ment (%)	Max Water/ Cement w/c (%)	Sand percent s/a (%)	Water (W) kg	Cement (C) kg	Fine Aggre. (S) kg	Coarse Aggre. kg	Add mixture gm/cm³

Note: The quantity of admixture shall be indicated in cm³ or gram without solution or dilution.

5.4 **Batching**

Each material to be used in concrete shall be obtained through batching.

1) **Batching Equipments**

a) Batching method and batching equipment for each material shall be subject to the approval of the Engineer in advance.

b) Batching equipment for each material shall be inspected and adjusted if necessary, prior to the commencement of the construction work and periodically during the construction.

2) **Batching of Materials**

a) Batching shall be made in accordance with the mix design approved by the Engineer. Test for surface water of the aggregate shall be in accordance with relevant ASTM Designation of equivalent or as directed by the Engineer. Test for the quantity of the effective absorption of water, in case of dried aggregate, shall be as directed by the Engineer.

b) Volume of one batch shall be determined as directed by the Engineer.

c) Each material shall be batched by weight and/or by volume as approved by Engineer except the water and the solution of admixture, which may be measured by only volume.

d) Error in the measurement in each batch shall be within the permissible error range given n Table-5.

Table-5 Permissible Error in Measurement

Type of Materials	Permissible Error (%)
Water	± 1
Cement & admixture material	± 2
Aggregate	± 3
Solution of admixture agent	± 3

5.5 **Mixing**

Materials for concrete shall be thoroughly mixed until the mixed concrete becomes uniform in quality.

1) **Mixers**

a) Mixers shall be either tilting batch mixers or forced batch mixers

b) Any concrete mixers to be used under this project shall be subject to approval of the Engineer.

c) Mixers shall be such that they will not cause any separation of materials at the time of discharging.

2) **Mixing**

a) When charging a mixer, all the materials shall be charged uniformly and simultaneously in principle.

b) Mixer shall be rotated at a speed recommended by the manufacturer.

c) Mixing time shall, in principle, be determined based on tests. As a standard, it shall be at least 1 minute and 30 seconds for tilting type mixers and 1 minute for forced mixers.

d) Mixing shall not be continued for more than three times the specified mixing time.

e) Materials for new batch shall not be charged into the mixer until all the concrete in the mixer is discharged.

f) Mixers shall be thoroughly cleared before and after their use.

g) Concrete which is left mixed and has commenced setting shall not be used after re-tempering.

h) Hand mixing shall not be allowed

5.6 Conveying and Placing

1) General

a) Prior to the commencement of the construction work, a plan for conveying and placing shall be made, and this shall be subject to the approval of the Engineer.

b) Concrete shall be conveyed by methods which will prevent separation and loss of materials, shall be placed immediately and then, shall be thoroughly compacted. Even when it is impossible to place the concrete immediately due to some special reasons, the time between mixing and the completion of placing shall not exceed 30 minutes.

c) When segregation is observed in concrete during its delivery or placement, it shall be made uniform in quality by remixing.

2) Conveying Equipment

Equipments to be used in conveying concrete shall be those which can easily deliver the concrete to its required place. Should the delivery distance be long, they shall equipped with such facility as an agitator.

3) Buckets

Structure of buckets shall be such that they will not cause any separation of materials when charging or discharging concrete, and that the concrete can be easily and swiftly deposited from them.

4) Conveyer Belts

Should conveyer bolts be used, they shall be suitably located so that they will not impair the quality of the concrete and the end of the line shall be provided with baffle plates and an elephant trunk so that the segregation of concrete can be prevented.

5) Buggies and Trolleys

Should buggies or trolleys be used, a level runway or path shall be constructed so that separation of material will not occur in conveying concrete.

6) Chutes

a) Should any chute be used, it shall be drop-chute in principle. The drop chute shall be connected to an elephant trunk so that the separation of materials is minimized.

b) Open chutes may be used, only when approved by the Engineer. Each open chute shall be inclined at uniform angle all along its length and the slope shall be such that it will not cause any separation of materials of the concrete to be placed. The distance between the bottom end of the chute and the surface on which concrete is to be deposited, shall be at most 1.5 m. The discharging end shall be equipped with a suitable elephant trunk.

7) **Preparation of Placing**

a) Prior to the placement, the arrangement of reinforcement, forms etc. shall be approved by the Engineer.

b) Prior to the commencement of the placement, it shall be certified that conveying equipments and placing equipments are in conformance to the plan of placing.

c) Prior to the placement, conveying equipments, placing equipments and the inside of forms shall be thoroughly cleaned to prevent foreign materials from being mixed into the concrete. Portions expected to face concrete and to absorb water shall be moistened in advance.

d) Water in pits and sumps shall be removed prior to the placement of the concrete. Suitable protective measures shall be taken so that water running into these pits and sumps will not wash the concrete just placed.

8) **Placing**

a) Concrete shall be placed in accordance with the plan of placing should it be inevitable to change the placing method, it shall be so done as directed by the Engineer.

b) When concreting is done in hot weather, special attention may be given to the materials, placement, curing etc.

c) Portions such as the ground and foundations which may absorb the water in concrete shall be thoroughly wetted prior to the placement of concrete.

d) Temperature in concrete at the time of placing shall be at most 25 deg. C for gantry foundations and 32 deg. C for equipment foundations and other structures. If the temperature goes up, precautionary measures approved by the Engineer have to be taken.

e) Conveying equipments for concrete shall be such that they will protect concrete from being dried or heated.

f) Concrete shall be protected as soon as the placement is completed or interrupted. Special care shall be exercised to keep the surface of the concrete moist.

g) During the concreting operation, attention shall be paid not to disturb the arrangement of the reinforcement.

h) Concrete shall be placed in such a manner that it will not be required to be moved after being deposited.

i) Should any notable separation of materials be observed during concreting, the concrete shall be remixed to obtain the uniform quality and necessary measures to prevent separation shall be taken before the placing operation is resumed.

j) Concrete for one section shall be placed continuously until it is complete.

k) Concrete shall, in principle, be placed in such a manner that the surface of the placed concrete will be horizontal within the section. One lift in placement shall be at most 30 cm, in principle, if the length of the vibratory rod is larger than the concrete lift.

l) Should concrete be placed in layers, each succeeding layer shall be placed while the one below it is still plastic. Should it become necessary to place concrete on top of layer which has started setting, it shall be done in accordance with the relevant clause.

m) When height of the formwork is great, it shall be provided with openings for concrete placing or the placement shall be done using droop chutes in order to prevent the concrete from being segregated or from adhering to the reinforcement or to the forms above the layer to be placed.

n) The height of the end of buckets and hoppers shall be at most 1.0 m above the level of placement.

o) Should there be any water coming out and accumulated during the placement, the concrete shall not be placed further until the water is removed by suitable means.

p) When concreting high structures such as walls and columns continuously, the consistency of the concrete and the rate of lifting shall be controlled, in such a manner that separation of materials during the placement and the compaction is minimized.

5.7 **Compaction**

1) In principle, internal vibrators shall be used to compact the concrete. When it is difficult to use internal vibrators in the case of thin walls suitable means shall be adopted. Vibrators to be used shall be subject to the approval of the Engineer.

2) Concrete, shall be thoroughly compacted immediately after placement, and shall be thoroughly worked around the reinforcement and into the corners of the form. Where conditions make compaction difficult, batches of mortar containing the same proportions of cement, sand and water as used in the concrete shall first be deposited to ensure the compaction.

3) When compaction is achieved by vibrators, it shall be inserted into the layer below the one just placed by about 10 cm. The vibrators shall be pulled out very slowly so that no hole will form in the concrete.

4) When concreting is to be compacted by internal vibrators the spacing and the time of their application shall be as directed by the Engineer.

5.8 **Additional Placing**

Should additional placing be made on top of a layer which has already started to harden, it shall be thoroughly and carefully worked on a directed by the Engineer so that the top and the lower layer becomes monolithic.

5.9 **Curing**

1) **General**

a) Concrete, after being placed, shall be sufficiently cured without being subjected to injurious effects caused by low temperature, drying, sudden change in temperature etc.

The Contractor shall report the said method to the Engineer and obtain his approval

b) Concrete shall be protected from vibrators, impacts and loads while it is hardening.

2) **Wet Curing**

a) Concrete being placed and compacted shall be protected form the sun, wind, showers etc. until it starts hardening.

b) Any exposed surface of concrete which has hardened to a degree that works can be done without impairing it shall be either covered with wet mats, canvas, sand etc. or directly watered and shall be kept moistened continuously for at least seven (7) days after the placement in case Ordinary Portland Cement is used.

c) When sheathing boards are expected to become dry, they shall be watered.

5.10 **Joints**

1) **General**

a) Location and structure of joints including expansion joints shall be as per relevant standards and codes and shall be shown and specified in the drawings.

b) Should any joint not specified in the design be made, its location, direction and method of construction shall be determined in the plan of construction so that it will not impair the strength and the appearance of the structure, and this shall be subject to the approval of the Engineer.

2) **Construction Joints**

a) Construction joints shall be located where the shear forces are minimum and with their faces in perpendicular, in principle, to the direction of compression in the member as approved by the Engineer.

b) Should it be unavoidable to make a construction joint at a location where large shear is acting, it shall be reinforced by forming tendons or grooves, or embedding suitable steel as approved by the Engineer.

3) **Construction of Horizontal Construction Joints**

a) Sides of the surface of a horizontal construction joint intersecting the forms shall be kept as horizontal and straight as possible.

b) When new concrete is placed, the surface of the old concrete shall be removed of all laitance, interior concrete, loosened aggregate etc. and shall be thoroughly wetted.

c) Prior to the placement of new concrete, the forms shall be tightened, standing water removed and either cement paste or mortar with the same mix proportion as in concrete shall be applied on the surface of the old concrete.

4) **Construction Method for Vertical Construction Joints**

a) When a vertical construction joint is to be made, the forms at the joint shall be rigidly supported and the concrete in the vicinity of the joint shall be thoroughly compacted by vibrators.

b) Fresh concrete shall be placed after the surface of the aged concrete at the joint is removed of the surface film or is roughened and thoroughly wetted or after the surface is treated as directed by the Engineer.

c) Fresh concrete shall be thoroughly compacted at the time of placement so that the fresh and aged concrete is in tight contact with each other.

5.11 **Reinforcement Work**

1) **Processing of Reinforcement**

a) Reinforcement shall be processed to the shape and the dimensions as shown in the drawings by a method which will not impair the quality of the material.

b) Reinforcement shall be processed in ordinary temperature. When it is unavoidable to heat for processing, the whole process shall be subject to the approval of the Engineer.

2) **Placing of Reinforcement**

a) Prior to fabrication and at time concrete is placed, reinforcement shall be thoroughly cleaned and free from must, oil, loose rust and any other non-metallic coatings which may impair the bond between the reinforcement and the concrete.

b) Reinforcement shall be accurately placed to the designated position, and shall firmly be supported so that it will not be dislocated during the placement of concrete. Erection bars, if required, shall be used for this purpose.

Important crossing of reinforcement shall be fastened by either annealed wire of at least 0.9 mm in diameter or binding wire.

c) Clearance between reinforcement and sheathing board shall be maintained correctly by use of spacers.

d) Reinforcement shall always be inspected by the Engineer before placing of concrete.

3) **Covering of Concrete**

a) The covering shall be at least one diameter of the reinforcement.

b) In general, the minimum covering shall be as shown in Table-6, unless otherwise noted on the drawings.

Table – 6 Minimum Covering (cm)

Conditions	Slabs, Walls	Beams, Columns
When not directly exposed to severe weather or ground	2.0	4.0
When effective coating is not applied on the portion which may be subjected to injurious chemical reaction due to	5.0	6.5

smoke, acid, alkali, oil, deicing salts, brackish water etc.

c) In case of footings and important members of a structure, it is recommended that the covering be at least 7.5 cm when concrete is placed directly facing the ground, and at least 5 cm for bars with diameter or more than 19 mm and 4 cm for bars with the diameter of less than 19 mm when the concrete is buried and directly facing the ground or when it is subjected to severe weather conditions. However, the covering at the bottom side of slabs may be at least 2.5 cm even if the portion of it is subjected to extreme weather conditions.

d) The covering in structures which are required to be specially fireproof shall be determined based on the temperature of the fire, duration, characteristics of aggregate to be used etc.

Joints of Reinforcement

a) Lap joints of reinforcement shall be made by lapping the required lengths and fastening them together at several points with annealed wire of at least 0.9 mm in diameter. Lap length shall be according to ASTM Designations.

b) Reinforcement projecting from the structure and exposed for future jointing shall be protected from damage, corrosion, etc.

5.12 **Forms and Timbering**

Forms and timbering shall be so designed and constructed as to have the required strength and rigidity, to secure correct position, shape, lines dimensions of the structure and to secure the satisfactory quality in concrete.

1) **Design of Forms**

a) Forms shall be those which can easily be fabricated and stripped; joints of sheathing boards and panels shall be forced in parallel with or perpendicular to the axis of the member so that it will have to structure which is tight against mortar.

b) The structure form shall be such that the corners of concrete can be mould even hen it is not particularly specified.

c) Temporary openings, if necessary, shall be made at suitable locations to facilitate cleaning and inspection of the forms and the placing of concrete.

2) **Design of Timbering**

a) Suitable type of timbering shall be selected and the load carried by them shall be correctly transferred to the foundation by appropriate means.

b) As design of timbering for important structures is concerned they shall be subjected to the approval of the Engineer.

3) **Construction of Forms**

Stripping agents shall be applied on the inside of the sheathing board.

4) **Construction of Timbering**

a) Timbering shall be constructed so as to have sufficient strength and stability.

b) An amount of the settlement of the form works due to the weight of the placed concrete shall be estimated and a camber shall be introduced, if necessary, in the shoring.

5) **Removal of Forms and Timbering**

a) Forms and timbering shall not be removed until the concrete reaches a strength required to carry the concrete weight and the load applied during the construction work.

b) Time and sequence of the removal of the forms and timbering shall be subject to the approval of the Engineer.

Loading on a structure immediately after the removal of the forms and timbering shall be subject to the approval of the Engineer.

5.13 **Finishing**

1) **General**

When the uniform appearance should be obtained on the exposed surface, special attention shall be given to place the concrete for the predetermined section continuously without changing the materials, proportions and the method of the placement.

3) **Surface Note Facing Sheathing Boards**

a) Surface of the concrete compact and approximately leveled to the required level and shape shall not be finished until the water coming out ceases and is removed.

b) Cracks formed after finishing but before hardening shall be removed by tamping or re-finishing.

4) **Surface Facing Sheathing Boards**

a) Concrete which will be exposed shall be placed and compacted in such a manner that the surface solely composed of mortar will be secured.

b) Projections and lines formed on the surface of concrete shall be removed to ensure surface flatness. Honeycombs and chipped places shall be removed and the surface shall be moistened and patched with appropriately proportioned concrete or mortar to be finished flat.

c) Cracks formed after the removal of the forms due to temperature stress, drying, shrinkage, etc. shall be repaired as directed by the Engineer.

5.14 **Tests**

Contractor shall submit to the Engineer six copies of reports as directed by the Engineer.

1) **Test of Material**

a) All the materials (cement, water, fine aggregate, coarse aggregate, reinforcement, admixture, etc.) to be used shall be approved by the Engineer after the Contractor submits the test results.

b) The testing method shall comply with relevant ASTM Designation or equivalent.

2) **Tests of Concrete**

Materials of concrete, reinforcement, equipments, and workmanship shall be controlled to produce reinforced concrete of the required quality economically.

a) During construction the following tests shall be carried out as directed by the Engineer.

i) Slump test

ii) Temperature test

iii) Compression test of concrete

Samples for compression tests of each class of concrete placed each day shall be taken not less than once a day, nor less than once for each 100m3 of concrete, nor less than once for each 450m2 of surface area for slabs or wall.

b) In order to determine the suitability of the curing method and the time to remove the forms, and in order to certify the safety for early loading, strength tests shall be performed on specimens cured under the conditions as similar as possible to those of the concrete at the site. Should the result of the test indicate that the obtained strength of the specimen is much smaller than that of the specimens cured under the control condition, the method of curing at the site shall be changed as directed by the Engineer.

c) For compression test of concrete, minimum six (6) test specimens shall be required with a minimum of one set of sample per concrete, pour from a randomly selected batch of concrete, taken at point of discharge from mixer or truck, cured under standard conditions.

Three (3) specimens shall be tested for seven (7) or fourteen (14) days strength, the remained three (3) specimens shall be tested for twenty eight (28) days strength.

d) Should it become necessary after the completion of the work, non-destructive test of concrete or tests on concrete specimens cut out from the structure shall be carried out.

The expenses for the above tests shall be included in the unit prices.

3) **Control of Concrete by Compressive Strength**

a) Control of concrete by compressive strength shall be based on 28 days compressive strength. Specimens, in this case, shall be taken in such a manner that they will represent the concrete of the structure for at least each separate pour.

b) Test results of compressive strength to be used for the control of concrete shall generally be considered satisfactory if arithmetic average of strength tests for specimens taken from the same batch, equals or exceeds specified compressive strength and not individual strength test falls below specified compressive by more than, 35 kg/cm^2.

4) **Inspection of Quality of Concrete**

a) The Contractor shall submit to the Engineer the results of the tests of concrete obtained according to the quality control test in the preceding paragraph 4.05.14. and obtained approval of the Engineer.

b) When the results of tests show that the strength of any concrete is below the minimum specified, Engineer may give instructions for the whole or part of the work concerned to be removed and be replaced at the expense of Contractor. The Contractor's Works which has to be removed and replaced as a result of the defective concrete. If any concrete is held failed, Engineer may order the proportions of that class of concrete to be changed in order to provide the specified strength.

5) **Test of Reinforcement Bars**

In the case where there is no test certificate of reinforcement bars (mill sheet) or in case the Engineer deems necessary, the Contractor shall carry out the characteristics and strength test of reinforcement bars and obtained approval from the Engineer for its use.

a) **Test Method**

Test method shall conform to the relevant ASTM Designation or equivalent, unless directed otherwise by the Engineer.

b) **Report**

The result of the tests shall be reported to the Engineer without delay.

5.15 **General**

The inspection and tests specified herein shall include the following:-

a) Volume of work executed
b) Inspection and test of construction materials
c) Inspection of reinforcement bar assembly
d) Inspection of forms
e) Inspection of the lines, grades and dimensions of the structures
f) Identification test of the quality of concrete at site (cast-in-place concrete).
g) Other tests and inspections required according to pertinent regulations, codes and standards or as deemed necessary by the Engineer.

The following tests and inspections shall be executed in the presence of the Engineer.

i) Strength test of reinforcement steel
ii) Compression test of concrete
iii) Other tests and inspections the Engineer deems necessary.

2) **Inspection of Reinforcement Bar Assembly**

Prior to placement of concrete, the Engineer shall inspect reinforcement bar assembly to confirm the classification and diameter of reinforcement bar, space between reinforcement, length of lap joint and covering etc. are according to the Drawings.

3) **Inspection of Forms**

Prior to placement of concrete, the Engineer shall inspect the form work and shall give approval for concreting.

4) **Inspection of the Dimensions of the Structure**

Inspection of the dimensions of the structures shall be made as required by the Drawings.

Concrete work shall not exceed, in general, the tolerance limits specified below:

a) Variation from plumb or specified batter for surface of stems and lines.

i)	In any 3.0 m of length	5 mm
ii)	Maximum for the entire length	15 mm

b) Variation from the level for slabs

i)	In any 3.0 m of length	5 mm
ii)	In any 6.0 m of length	8 mm
iii)	Maximum for the entire length	15 mm

c) Variation in cross sectional dimensions of stems and thickness of slabs.

i)	Minus	5 mm
ii)	Plus	10 mm

d) Variation and level specified at tope of foundations.

i)	Minus	10 mm
ii)	Plus	10 mm

e) Variation in protective covering of reinforcement steel.

i)	With cover of 40 mm or less	-5 mm
ii)	With cover more than 40 mm	-10 mm

f)	Variation from effective depth of reinforcement steel.	20 mm

5.16 CABLE TRENCH WORK

5.16.1 General

The Contractor shall provide all cable trenches leading from the outdoor equipment in the switchyard to the indoor equipment in the buildings as shown in the Drawings.

The design shall cover the following requirement.

1) The design of cable trenches shall be similar to the design shown in bidding documents and with draining system.

2) Cable trenches shall be made of complete monolithically reinforced concrete work. Each type of cable trench shall be provided with expansion joint at intervals of max. 20 linear meter.

3) All trench covers shall be of reinforced concrete to withstand a load of 300 kg at the centre except those at road crossing which should withstand a load of 5 tons at the centre.

4) The trench covers shall be of such size as to facilitate their handling by manual labour.

5) Trenches in substation will be built with the top of the trench cover 150 mm above the gravel level or as shown in the bid drawings.

6) The trenches shall be connected to a drainage system, designed and constructed by the Contractor in such a manner that sub-oil water due to water logging can not enter the trenches and rain water collecting in trenches is drained out efficiently. The drainage system for trenches shall be designed with proper slope for flow of water, entering the trenches.

7) All cable trenches shall set on a layer or leveling concrete of thickness 100 mm.

8) Cable trays shall be provided in trenches at adequate intervals horizontally and with sufficient vertical spacing between trays to freely accommodate the cables, Plenty of working space shall be provided for handing the cable during installation and maintenance.

9) Each trench shall have two sections, one to accommodate cables for primary and other for secondary protection system. The later shall also accommodate power cables.

10) Trench-road & trench-trench crossings shall be culvert type and so designed that plenty of space is available for handling the cables during installation, future requirements of bays and maintenance at these crossings. Proper water drainage system shall also be designed on these crossings.

11) Trench entrances into the buildings shall be designed to seal off entry of any water or vermins and pests into the building through these entrances.

12) The trench covers shall be upper covers type for trench-road-crossings where embedded covers shall be used.

13) Small openings shall be provided in the walls of cable trenches as required for entry of cable carrying pipes during construction stage which shall be sealed later with appropriate sealing compound as approved by the engineer. The appropriate measures shall be adopted to protect these pipes against corrosion and damages. All joints of these pipes shall be properly sealed to prevent/ingress of subsurface water.

5.16 **Inspection**

The Engineer shall inspect the cable trenches as for the compliance of the specifications and drawings approved by the Engineer.

6. **GRAVEL PAVEMENT WORK**

The Contractor shall provide a blanket of river run gravel in the switchyard area along equipments foundation and as shown in the drawings.

A 200 mm layer of hard, durable, gravel shall be provided by the Contractor in the switchyard area around the equipments above the reference ground level. The size of gravel shall generally vary from 20 to 75 m. The material shall be placed to its full thickness of 200 mm in one layer and in such manner as to avoid displacing the under laying material. The material shall not be compacted.

The gravel shall conform to the following gradation limits, unless otherwise specified.

U.S. Standards Sieve Designation	Percentage Passing by Weight
(3 inch) 75 mm	100
(2 inch) 50 mm	85-100
(3/4 inch) 20 mm	0-100

Crushed rock shall not be allowed, the gravel which shows any sort of chemical reaction as per site conditions shall also be not allowed. Contractor shall get the approval of the source of supply from the Engineer prior to placement of gravel.

7. **ROAD WORK**

The Contractor shall prepare roads in the substation as shown on the drawings. Proper slopes shall be maintained.

7.1 **Foundation for Road**

1) **Sub-Grade Work:** Any excavation required for sub-grade construction shall be carried out in accordance with the respective provisions in the clause of earth work.
The materials required for banking and displacement shall be so placed that the finished thickness of one layer after compaction will become 20 cm or less.

2) **Sub-Base Course Work** The material to be used for sub-base course shall be as approved by the Engineer. The Contractor shall submit a report concerning the quality of materials and the method of sampling to the Engineer for approval.

3) **Testing:** The sub-grade surface shall be finished by proof rolling in order to obtain the contract pressure sufficient to permit smooth traffic of vehicles of 8 tons or over.

Should any defects be detected as a result of proof rolling, such defective sub-grade surface shall be finished again to the satisfaction of the Engineer.

4) **Inspection**

a) **Sub-grade:** The finished sub-grade surface shall be within ± 5 cm of the design elevation.

b) **Sub-base:** The finished sub-base course shall be within –10 mm and + 5mm of the design elevation.

7.2 Asphalt Concrete Pavement

1) Material

a) Asphalt

Bituminous material shall be used in the design of Asphalt Concrete Pavement Work.

The asphalt material shall conform to the requirements of AASHTO M-20, M-81, M-82 and M-40. The type shall be as directed by the Engineer.

b) Fine Aggregate

Fine aggregate passed a 2.5 mm sieve and shall be clean, strong, hard, durable, suitable graded and free from injurious amounts of dust, mud organic impurities, salts etc.

c) Coarse Aggregate

Coarse aggregate which retained on a 2.5 mm sieve, and shall be clear, strong, hard, durable, suitably graded and free from injurious amount of flakes, elongated pieces, organic impurities, salts etc.

Coarse aggregate for pavement shall comply with the following requirements.

i)	Specific gravity	more than 2.5
ii)	Absorption value	less than 3.0%
iii)	Percentage wear	less than 35.0%
iv)	Soundness test	less than 12.0%
v)	Content of shale and soft fragment of stone	less than 5.0%
vi)	Content of slender and thin fragment of stone	less than 25.0%

Note: Ratio of longer width and the other is more than three times, and on thin fragment ratio of thickness and width is more than three times.

d) Filler

Particles of stone means the material which was crushed a limestone or igneous rock and water content of filler shall be less than 1%.

Grading range of the filler shall comply with the following requirements.

Sieve	Percentage Passing
0.6 mm	100%
0.15 mm	90-100%
0.074 mm	70-100%

2) **Storage of Material**

a) **Asphalt**

Asphalt shall be stored in exclusive tank.

b) **Aggregate**

i) Storage facility of aggregate shall be equipped with a suitable drainage system

ii) Fine aggregate, coarse aggregate and other aggregate of different type and grading shall be separately stored with divides between each.

iii) When receiving, storing and handling aggregate facilities shall be well maintained and handling shall be carefully performed so that no segregation of large particles from small ones may occur, no foreign materials may become mixed, or in case of coarse aggregate, no particles may be crushed.

iv) During storage of fine aggregate, water contents should not change rapidly.

3) **Mix Proportions:** Mix proportions for the dense grade asphalt concrete shall be determined in such a manner that the test piece which conform stability flow value, percentage of void and degree of saturation by marshal testing of the asphalt volume at intervals of five percentage and submit such data in writing to the Engineer for approval.

Material for dense grade asphalt concrete, shall in principle, comply with the following requirements .

a) Thickness of surface shall be 5 cm

b) Maximum size of aggregate shall be 20 mm:

Material Size	% age Passing
25	100
20	90 - 100
13	75 - 90

c) Weight percentage of those passing a sieve:

Material Size	% age Passing
5	45 - 65
2.5	35 - 50
0.6	18 - 29
0.3	10 - 21
0.15	6 - 16
0.075	4 - 8

d)	The volume of asphalt	5 – 7 %
e)	Penetration test	80 - 100

Percentage of passing weight:
(on permissible error)

5 mm	+ 5 %
2.5 mm	+ 4 %
0.56 mm, 0.3 mm, 0.15 mm	+ 3 %
0.075 mm	+ 1.5 %
Percentage of asphalt volume	+ 0.3 %

4) **Working:** Asphalt concrete shall be placed on the clean and completely dry base course. The temperature in the working area shall not be less than 20 deg. C for at least one hour prior to the commencement of operations.

Asphalt concrete layer shall be compacted upto 95% maximum dry density. Curing period shall be minimum 24 hours and during this period no traffic shall be allowed to move on the road.

5) **Testing:** The marshal test shall be observed in the dense grade asphalt concrete for surface.

On standard values of marshal testing.

Soundness	more than 600
Value of flow	20 – 40%
Porosity	75 – 85%
Submerged marshal retained soundness	more than 75%

6) **Inspection:** Inspection of surface shall comply with following requirements.

Thickness of surface	10 – 15 %
Profile index part of each work	less than 5%

The mixture shall be spread uniformly, rolled and finished into the specified thickness. Then the finished surface shall be measured in parallel to the center.

7.3 **Reinforced Concrete Pavement/Service Road**

1) **Material**

a) Cement, water, fine aggregate and coarse aggregate shall be in accordance with the relevant clause ”Material for Reinforced Concrete”.

b) Water reducing agent shall conform to the standards for water reducing agent by relevant ASTM Designation or approved equivalent.

c) Reinforcement steel shall be deformed bars conforming to ASTM 615-96a grade –40 or equivalent as approved by the Engineer.

d) The Contractor shall submit the report of tests for quality of the materials as directed by the Engineer for his approval.

e) If on receipt of tests from laboratory any change is observed in material, the matter shall be referred to the Engineer for his approval.

2) **Concrete Mix:** The following requirements shall be observed in concrete pavement.

a) The bending strength at 28 days of concrete is 45 kg/cm^3 and this test shall, in principle, be performed in accordance with relevant ASTM Designation or approved equivalent.

b) Maximum size of coarse aggregate shall be 40 mm.

c) Consistency in concrete shall be less than 2.5 cm by slump test and initial setting time is 30 sec.

d) Air content shall be between 3 to 6 percent.

3) **Form Work** Form material shall be straight and have width for designed thickness of pavement which is more than 3m in length, and it shall be fixed on the position in accordance with the drawings.

4) **Detachment of Form:** It shall not be detached within 20 hours after concrete placing. However, if increase in concrete strength delays under certain conditions, approval of removing forms shall be given by the Engineer.

5) **Joint:**

a) The joints shall be provided at appropriate locations as per relevant standards

b) Flouring of joint shall be done after form is cleaned up and dried sufficiently.

6) **Placing:** Placing for concrete pavement shall, in principle, be in accordance with relevant tender clause ”Conveying and Placing of Reinforced Concrete”.

7) **Installation of Reinforcement:** Mesh and reinforcement bar shall be set correctly at a position designated as shown in the drawings.

8) **Finishing:** Finishing of surface shall be done after leveling and compaction of concrete.

9) **Curing:** Curing of concrete pavement shall, in principle, be in accordance with relevant tender clause “Curing” of Reinforced Concrete Work.

10) **Testing:** The Contractor shall submit to the Engineer six copies of report on these tests.

a) During placing of concrete following tests shall be carried out as directed by the Engineer.

i) Slump test

ii) Temperature of concrete

iii) Compression/bending test

The test of concrete shall be executed not less than once for each one hundred (100) cubic-meters of concrete to be poured on the same day with a minimum of one set of sample per concrete pour.

b) **Test of Material**

Coarse aggregate shall provide limit of wear reduction maximum 30 by Loss Angeles test of ASTM Designation.

11) **Inspection:** Finishing of concrete pavement shall meet the following requirements.

Profile index	Less than 10
Different from maximum height	Less than 3 cm
Difference at two points picked up arbitrarily at intervals of 20 cm.	Less than 1 cm

Joints shall not have the difference of more than 3 mm between adjoining pavement slab by measurement rectangularly against inclination with a 3 m ruler and the depth of any section shall not exceed 5 mm.

8. **BRICK WORK**

1) Prior to commencing the brick masonry work, the surface of brick shall thoroughly be cleaned and sufficiently moistened in order to ensure smooth adherence of mortar to the brick surface. Ist class bricks shall be used which shall be approved by the Engineer.

2) The masonry joints shall in principle be 10 mm in thickness and mortar (1:3 c/s ratio or as shown in drawings) shall be filled sufficiently between each masonry joint in order to eliminate any void between brick and mortar.

9. **DRAINAGE WORK**

1) The drainage work shall be as described in the drawings and carried out in accordance with general provisions “Earth Work” and “Reinforced Concrete Work”.

2) The water-plumbing facility for drainage shall be of such a system as not to cause any trouble against the surrounding area and structures. The Contractor shall submit the design and execution schedule for the water plumbing work to the Engineer for approval.

10. **FENCE WORK**

1) The design of fence shall conform to the drawing included in Volume-III of Bidding Documents.

2) The galvanized iron shall be used in accordance with ASTM Designation or equivalent.

3) Construction of fence, welding shall comply with ASTM Designation or equivalent.

11. **BUILDINGS**

The scope of work under this Contract includes all civil works I the existing substation buildings (control house building and mechanical services building) required to complete the scope of work under this Contract. Modifications in the buildings, dismantling and reconstruction of entry of cable trench type 1 from 500 kV switchyard, providing openings in RCC slab, providing supports for new panels, providing foundation

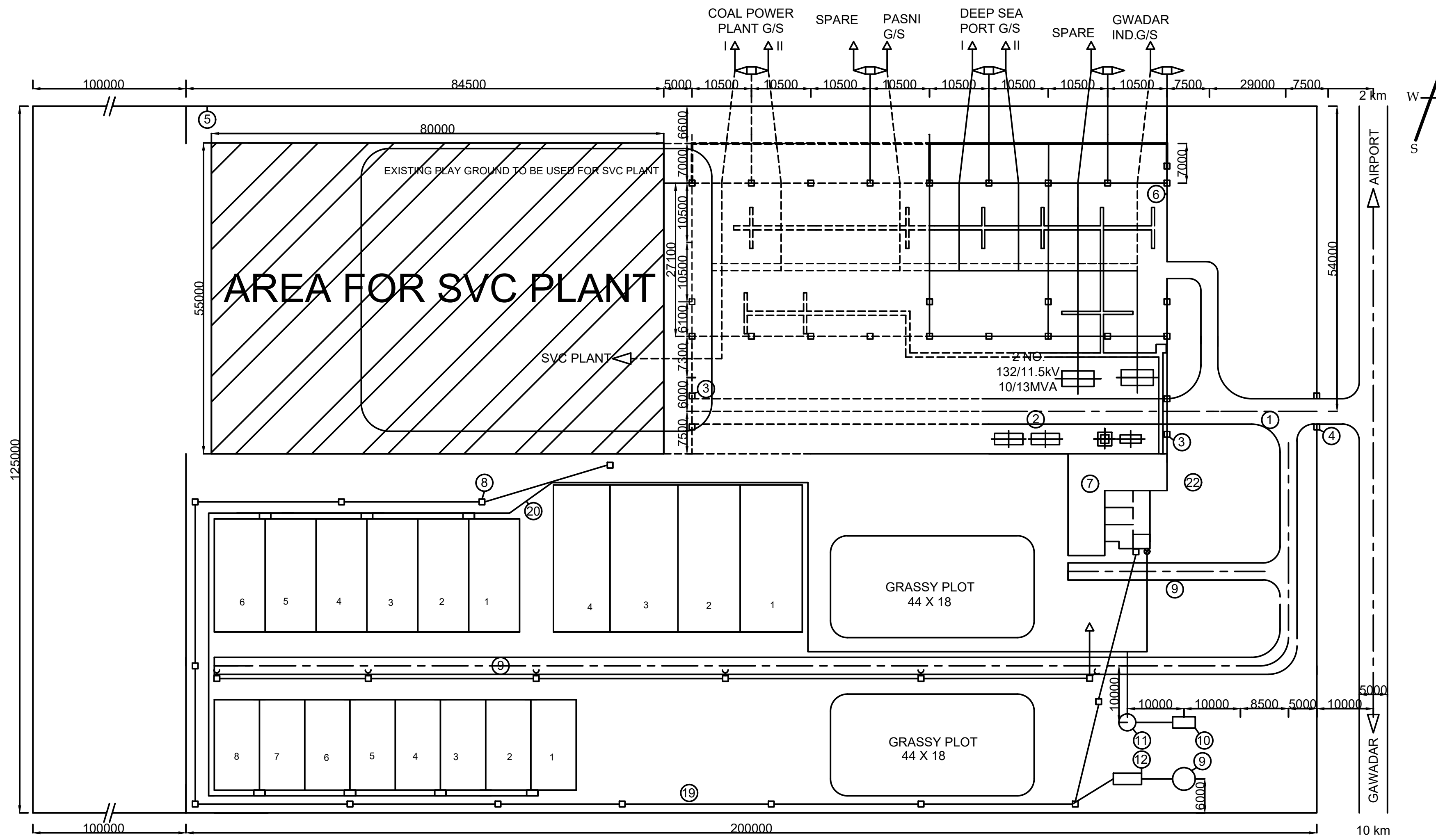
channels for diesel generator and any other work necessary for meeting the specified requirements shall be the Contractor’s responsibility.

12. **PREPARATION OF SITE AREA AND DISMANTLING WORK**

A number of partially constructed foundations are existing in the 500 kV switchyard area and area in which new 220 kV bays are to be constructed under this Project. The Contractor shall investigate if these partially constructed foundations can be used and submit detailed report in this regard. However, the Contract Price shall be deemed to include the cost of complete dismantling of existing of civil works and construction of new foundations. Use of existing civil works or part thereof by the Contractor will be subject to approval of the Engineer and in such case the Contract Price will be adjusted appropriately.

The Contractor shall also dismantle the concrete structures/foundations inside the outside the foundation area which are not required, cut the projecting reinforcing bars and fill up the excavated pits to level the area.

DRAWINGS



LOT # 2(B) GWADAR OLD

LEGENDS

1. APPROACH ROAD
2. TRANSFORMER WAY
3. SWITCHYARD GATE
4. MAIN GATE
5. BOUNDRY WALL
6. SWITCHYARD FENCE
7. CONTROL HOUSE BUILDING
8. MANHOLE
9. ROAD 300M WIDE
10. SECURITY GUARD CABIN
11. OVERHEAD WATER TANK
12. PUMP HOUSE
13. SEPTIC TANK (100 USERS)
14. COLLECTING TANK (100 USERS)
15. FOUNDATION FOR CONTROL BUILDING
16. STEEL STRUCTURE WITH MERCURY BULB
17. STEEL STRUCTURE WITH INCANDESCENT BULB
18. GUY
19. SEWERAGE
20. WATER SUPPLY
21. FIRE HYDRANT

REFERENCE DRAWINGS

1. SINGLE LINE DIAGRAM DWG. NO SL-002
2. SWITCH YARD LAYOUT DWG. NO. SW-002
3. FOUNDATION LAYOUT DWG. NO. SW-002
4. FOR OTHER DRAWINGS REFER TO WAPDA GLO DWG NO PDW/TS-3859 DT. 13-08-1989.

PROPOSED: SHOWN AS DOTTED.

NOTE: PREPARED FROM WAPDA DRAWING NO. PDW/TE -1108.

NO.	DATE	REVISION	BY
2.	18-02-20	MARKED AREA FOR SVC PLANT.	
1.	17-01-20	ADDED 3 NO. 132kV LINE BAYS, 2 FOR COAL POWER PLANT, 1 FOR PASNI. CONVERSION OF 132kV BUS INTO TWIN BUNDLE CONDUCTOR. EXTENDED SWITCHYARD BUILDING FOR 4 NO. 132kV BAYS.	EnMasse

CLIENT:- **QESCO**

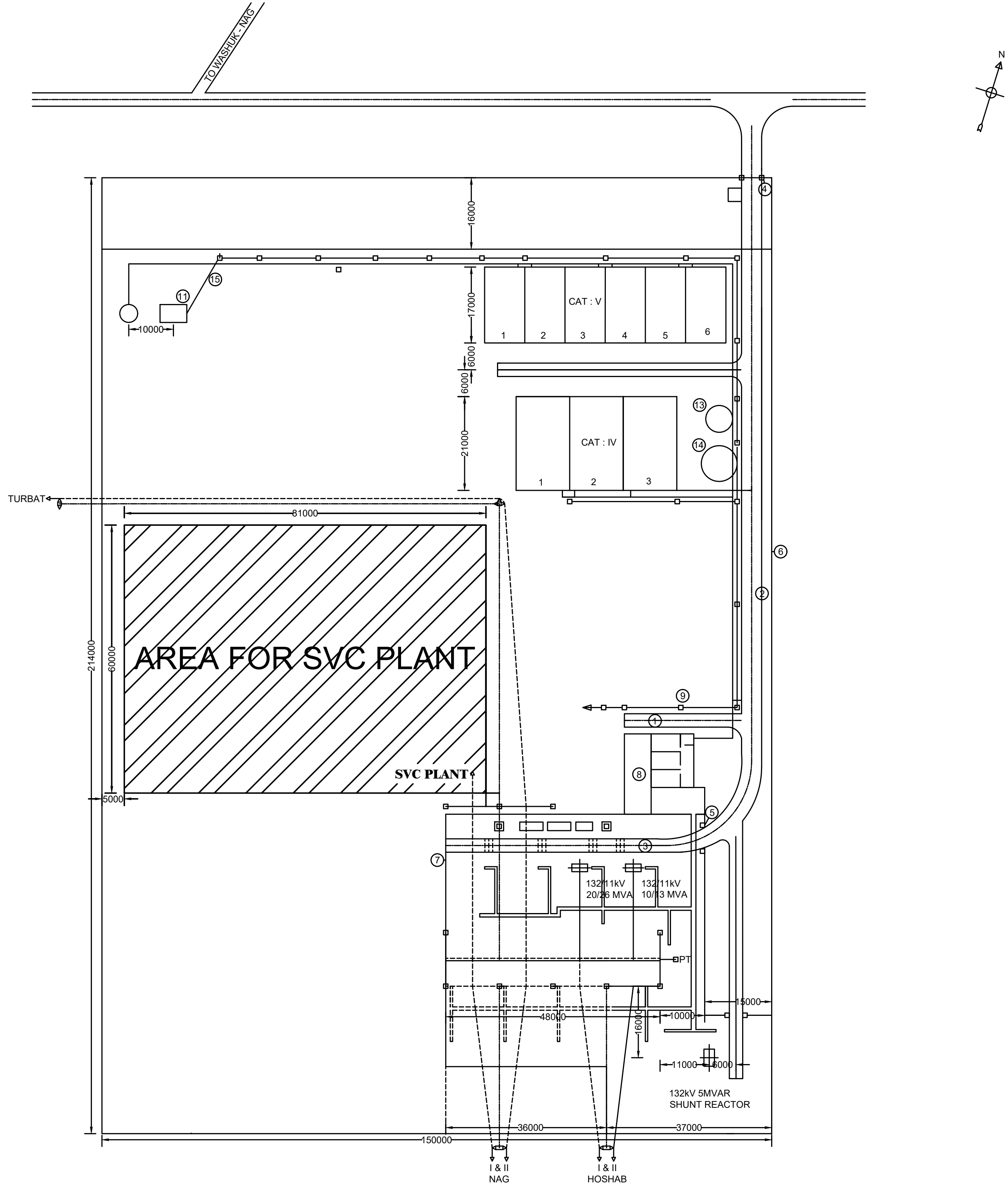
CONSULTANT :- **EnMasse**

EXISTING: 3 NO. 132kV LINE BAYS,
2 NO. 10/13MVA,132/11.5kV T/F BAYS.

NAME		SIG.
PREPARED	MM	
CHECKED	HA	
APPROVED	CAL	

TITLE :- **132kV GWADAR OLD GRID SUB-STATION GENERAL LAYOUT**

SCALE:- N T S | DRAWING NO. GL-0002 | DATE:



LOT # 2 (F) PANJGOOR

NOTE :
1. 2NOS. BAYS OF 132kV BUS TO BE EXTENDED OF WEST SIDE OF BUS

LEGENDS

1. BITUMINOUS ROAD 3000mm WIDE
2. BITUMINOUS ROAD 4500MM WIDE
3. TRANSFORMER WAY
4. MAIN GATE
5. SWITCHYARD GATE
6. BOUNDARY WALL
7. SWITCHYARD FENCE
8. CONTROL HOUSE BUILDING
9. SEWERAGE MANHOLE
10. SEPTIC TANK
11. PIT
12. SECURITY GUARD CABIN
13. WELL
14. OVERHEAD WATER TANK 5000 GALLONS
15. SEWERAGE

PROPOSED: SHOWN AS DOTTED.

REFERENCE DRAWINGS

1. SINGLE LINE DIAGRAM DWG. NO SL-005
2. SWITCH YARD LAYOUT DWG. NO. SW-005
3. FOUNDATION LAYOUT DWG. NO. SW-005
4. FOR OTHER DRAWINGS REFER TO WAPDA GLO DWG NO PDW/TS-571 DT. 05-09-1993.

NOTE: PREPARED FROM WAPDA GLO DRAWING NO. PDW/TS -571.

NO.	DATE	REVISION	BY
2.	18-02-20	MARKED AREA FOR SVC PLANT	EnMasse
1.	17-01-20	ADDED 4 NO. 132kV LINE BAYS, (1 FOR HOSHAB G/S, 2 FOR NAG G/S, 1 FOR TURBAT G/S). CONVERSION OF 132kV BUS INTO TWIN BUNDLE CONDUCTOR.	

CLIENT:- **QESCO**

CONSULTANT :- **EnMasse**

EXISTING: **1 NO 132kV LINE BAY, 1 NO. 20/26 MVA, 132/11.5 kV T/F BAY & 1 NO. 10/13 MVA, 132/11.5 kV T/F BAY.**

NAME		SIG.
PREPARED	MM	
CHECKED	HA	
APPROVED	CAL	

TITLE :-

132kV PANJGOOR GRID SUB-STATION GENERAL LAYOUT

SCALE:- N T S | DRAWING NO. GL-0005 | DATE: