

Control Systems Testing

I-SPE-STD-011

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This Engineering Standard was endorsed by an RPEQ on behalf of Seqwater.

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1. Purpose

This Standard Specification provides the minimum requirements for testing requirements for control systems implemented at Principal's assets. This document must be used in conjunction with the documents it references in order to assist in ensuring a fit for purpose asset.

This Standard Specification is not intended to be relied upon solely for design, supply and installation works; advice from specialist engineers and/or Manufacturers may be required on a case-by-case basis.

Testing shall ensure the design functionality is achieved. Key design artefacts that document functionality include Piping & Instrumentation Diagrams (P&IDs), Input / Output (I/O) lists, functional descriptions, alarms registers, cause and effect matrix and drawings depicting the control systems. How the functionality would be assured is documented in testing plans with subsequent execution.

2. Scope

This Standard Specification applies to all Seqwater employees, suppliers, contractors and consultants working for, or on behalf of, Seqwater unless otherwise stated. It applies to all new assets and to all existing assets undergoing refurbishment or modification.

Deviation from the requirements in this Standard Specification requires written agreement from Seqwater as per the deviation process detailed in X-PRO-STD-008 [Asset Standards Management and Application](#). This process includes completion of an Asset Standards Deviation Request Form and submission via the Seqwater Project Representative (for external parties) or via Seqwater's Engineering Mailbox (engineering@seqwater.com.au) (for internal parties).

Where noted in this Standard Specification that Seqwater approval or acceptance shall/must be sought, approval or acceptance must be gained through the Seqwater Asset Standard deviation process, as identified above.

Responsibility for ensuring compliance with Seqwater Standard Specifications lies with those engaged in the management and execution of design, construction and maintenance activities on Seqwater assets. This Standard Specification must be used in conjunction with other relevant Asset Standards and project specific documents to define the technical requirements for asset design and construction.

The Contractor maintains responsibility for a fit for purpose design and compliance with all relevant Australian Legislation, Standards, Codes and Guidelines (including those produced by WSAA). Where no Australian Standard exists for a particular application, work must conform to the most current version of an industry accepted international standard.

In the case that it is identified that a specific requirement within this Standard Specification does not meet the requirements of project specific documents, another Seqwater Asset Standard or Australian Legislation, Standards, Codes or Guidelines, the conflict must be brought to the attention of the Seqwater Principal, Engineering Standards and Assurance (or their delegate) via the Engineering Mailbox, and written agreement must be gained prior to application of the requirement.

Advice must be sought from Seqwater to clarify any ambiguities regarding this Standard Specification.

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Seqwater undertakes regular updates of Asset Standards. Before utilising this Standard Specification, the complete list of Seqwater Asset Standards should be reviewed, to ensure currency and applicability of standards applied to the works.

Standards and Assurance (or their delegate) via the Engineering Mailbox, and written agreement must be gained prior to application of the requirement.

Advice must be sought from Seqwater to clarify any ambiguities regarding this Standard Specification.

Seqwater undertakes regular updates of Asset Standards. Before utilising this Standard Specification, the complete list of Seqwater Asset Standards should be reviewed, to ensure currency and applicability of standards applied to the works.

3. Definitions

The following definitions (Table 3-1) apply to this Standard Specification.

Table 3-1 Definitions

Term	Definitions
Contractor	The Contractor is the entity that, dependent on contracted scope, is responsible for the management and / or execution of the design, construction, commissioning and operation of the asset for the duration of a project (i.e. the “work”). Seqwater can undertake the role of the Contractor.
Control System	Any component that includes PLC, SCADA, network switches, fibre optic or Ethernet communication network, historian, engineering station, operation station, software server, IO modules, remote IO drops, control panels, relay panels, switchboard, AC and DC UPS and AC and DC distribution shall be classified as components of control system.
Manufacturer / Supplier / Vendor / Original Equipment Manufacturer (OEM)	The entity that manufacturers or supplies equipment to meet the specifications of the Contractor.
Owner / Principal / Seqwater	The entity that engages the Contractor to undertake the work and takes custody of the outcome. The Owner may delegate responsibilities to other entities to act on its behalf (e.g., a consultant).
REX	Seqwater Electronic Document and Records Management System
Seqwater Approval / Acceptance	Written sign-off gained via the deviation process, as detailed in XPRO-STD-008 Asset Standards Management and Application.
Shall / must	Indicates a mandatory requirement
Should	Indicates a recommendation

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4. Roles and Responsibilities

Role	Responsibility
DTI Service Delivery	- Promote the Control System Testing Standard within business - Monitor compliance with this procedure within the business - Maintain and update the Control System Testing Standard - Undertake sample checks of works that are required to adhere to the requirements of this standard, as per FRA-00048 Operational Technology Assurance and Controls Framework
DTI Solutions Delivery	- Monitor compliance with this standard on various projects - Advise the project managers on technical aspects of the requirements of this standard - Perform non-compliance investigations - Typically provides OT Engineer resource
Project Manager	- Ensure the compliance of Control System Testing Standard for project planning, schedule, and deliverable. - If any requirements of the control System testing standards can't be met with, make the principal aware of the same through deviation process
Contractor	Responsible for execution on site and deliver all control system related tasks as per project scope
CSM Principal	Responsible for reviews and analyses of the information provided by the Project if needed
OT Engineer	Key "Controls activities" as outlined in FRA-00048 Operational Technology Assurance and Controls Framework and in the context of this standard that is responsible to review and witness technical activities

5. Abbreviations

Abbreviations	Definitions
OT	Operational Technology
AC	Alternating Current
CPU	Central Processing Unit
DC	Direct Current
FAT	Factory Acceptance Test
FTA	Fault Tree Analysis
FOBOT	Fibre Optic Break Out Tray
HACCP	Hazard Analysis and Critical Control Point
I/O	Input / Output

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Abbreviations	Definitions
ITP	Inspection Test Plans
ITR	Inspection Test Reports
MTBF	Mean Time Between Failure
OPC	Open Platform Communications
P&ID	Piping & Instrumentation Diagrams
PLC	Programmable Logic Controller
POPT	Proof of Performance Test
RBD	Reliability Block Diagram
SAT	Site Acceptance Test
SCADA	Supervisory Control and Data Acquisition
TCP/IP	Transmission Control Protocol/Internet Protocol
UPS	Uninterruptable Power Supply
VLAN	Virtual Local Area Network
VPN	Virtual Private Network
VSD	Variable Speed Drive

6. References and Related Materials

The documents listed in Table 5-1 and the requirements therein, are relevant to this Standard Specification. In their latest editions, these documents form a part of this Standard Specification. Note that this is not an exhaustive list of documents relevant to the works.

Table 6-1 References

Document Number	Document Title	REX ID
X-PRO-STD-004	Development and Review of Asset Standards Procedure	PRO-01874
X-PRO-STD-006	Equipment Numbering and Naming Convention	PRO-02190
X-PRO-STD-007	Drawing & Spatial Data Standards	PRO-02187
X-PRO-STD-008	Asset Standards Management & Application	PRO-02205
X-PRO-STD-009	Engineering Design, Construction, Operation and Maintenance	PRO-01617
X-PRO-STD-019	Process Control Systems Information Maintenance	PRO-02329
X-TMP-STD-022	Asset Standards Deviation Request	TEM-00224
B-SPE-STD-003	Commissioning Requirements Standard	SPE-00346
I-SPE-STD-013	Control Systems Design and Construction	SPE-00361
E-SPE-STD-001	Electrical Design & Construction	SPE-00352

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Document Number	Document Title	REX ID
I-SPE-STD-009	Control Systems Architecture	SPE-00358
I-SPE-STD-010	Control Systems Tag Naming Convention	SPE-00359
I-TMP-STD-007	Control Systems Test Sheets	TEM-00212
I-TMP-STD-008	Master Alarms Template	TEM-00254
I-TMP-STD-003	I/O List Template	TEM-00210
I-TMP-STD-005	Functional Description Part B	TEM-00222
	Operational Technology Assurance & Controls	FRA-00048

7. Seqwater Commissioning Requirements

Seqwater outlines its standard commissioning requirements in the standard B-SPE-STD-003 Commissioning Requirements. The following schematic (Figure 6-1) shows the main stages in commissioning. Detailed definitions of these stages are provided in B-SPE-STD-003 Commissioning Requirements.

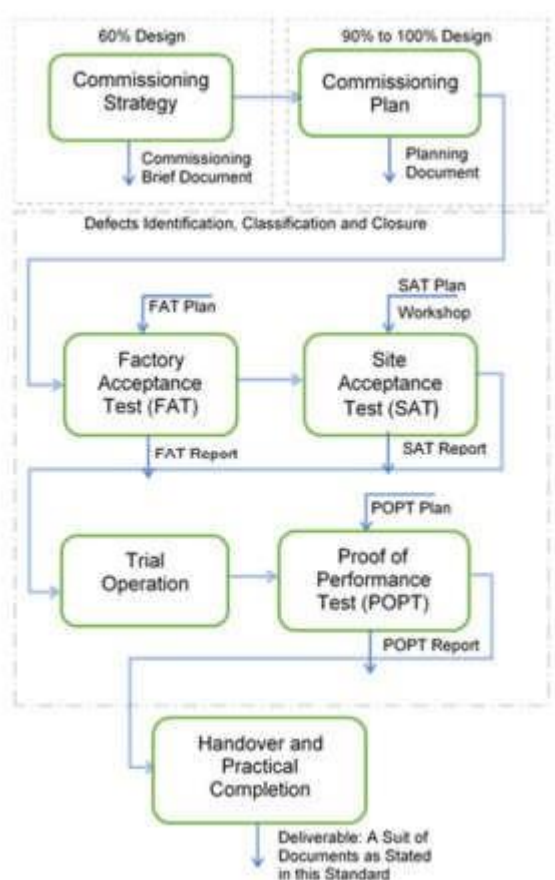


Figure 7-1 Seqwater standard commissioning and handover schematic (reproduced from B-SPE-STD-003 Commissioning Requirements)

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The remainder of this standard expands on specific control systems commissioning and testing requirements relating to the main stages as shown in Figure 6-1.

The main stages shown in Figure 6-1 are defined with deliverables, hold points and timeline requirements as noted in *B-SPE-STD-003 Commissioning Requirements*. These apply to this standard.

8. Testing Documentation

8.1. General

The general requirements of this standard shall apply to the testing of the control system at the Contractor's premises during FAT and subsequent testing of the control systems and its component elements at Principal's sites during SAT and POPT.

This document does not constitute a test specification for any particular part of the control system. However, it provides a structured testing framework designed to ensure that the final delivered control system is reliable, maintainable, traceable and fit for purpose.

The documents that Principal expects to be delivered as part of control system testing are defined in detail below and can be summarised as:

- Test Plan documents (ITP)
- Test & Inspection Reports (ITR)
- Cut-over Plan

8.2. Test Plan document(s) for Control Systems

The Contractor shall submit Test Plan document(s) for the control system, prior to the commencement of each of the following stages:

- Vertical Integration Testing (commonly referred as proof of concept testing)
- Factory Acceptance Testing (FAT) (refer to section 10 for requirements)
- Site Acceptance Testing (SAT) (refer to section 11 for requirements)
- Proof of Performance Testing (POPT) (refer to section 12 for requirements)
- Roll back and Migration Testing (refer to section 8.4)

The timeline requirements for the documents noted above, vertical integration test, are outlined in *B-SPE-STD-003 Commissioning Requirements*. The vertical integration test is a specific requirement for control systems. The requirements for this requirements and associated timing shall be outlined in the project scope of works.

The control system test plan documents shall layout in a logical fashion how the quality documents build upon the testing, completed in previous phases, to confirm system performance. Any review, witness, hold or handover points shall be clearly identified and agreed to.

The Contractor shall consider the following documents to create test plan document:

- a. Technical specifications
- b. Scope of work
- c. Approved detailed design documents (for example functional description, control system architecture, IO list, Equipment list, IP register etc.)

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The test plan document shall positively demonstrate the reliability and application suitability of the control system provided.

The test plan shall also identify requirements for accessing Principal assets and include details on coordination with Principal's personnel to minimise operational impacts. Guidance is provided in *B-SPE-STD-003 Commissioning Requirements* on what would be minimum requirements.

8.3. Cut-Over Plan Document

The requirement to produce a cut-over plan document will be specified in the scope of work of the individual project. If required, the cut-over plan document shall include the following details.

- a. Number of cut-overs required throughout the commissioning
- b. Duration of each cut-over
- c. Control systems tests to be performed during cut-over
- d. Identification of areas in the P&ID's to define the number of process equipment being transitioned during each stage of cut-over
- e. Identifying any need of temporary works to provide parallel operation of systems during cut-over
- f. Manpower requirement during the cut-overs
- g. Roll back mechanism in case the cut-over is not successful
- h. Risk analysis of the cut-over

Additional cut over plan requirements including timing requirements is provided in *B- SPE-STD-003 Commissioning Requirements*.

8.4. Roll Back and Migration Test Plan Document

The requirement to produce a migration and roll back test plan document will be specified in the scope of work of the individual project. Migration test plan document shall include transitional migration of control of existing equipment when old and new code resides within the PLC and SCADA. The roll back and migration test plan document shall include and address the following:

- a. Define how the hardware and software of the control systems migration will be tested during the FAT
- b. Define how to make online incremental changes and undertake a full backup of code and data files.
- c. Testing of roll back mechanism to be carried out during FAT and SAT stages of commissioning.
- d. Roll back mechanism shall identify any potential issues which was not tested during FAT, SAT and resolving.

8.5. General Requirements of Test Plan Document

The test plan document(s) for the control system shall address the following:

- a. Define how the hardware and software of the control systems will be tested during the FAT, SAT and POPT stages of commissioning
- b. The system testing to be carried out during FAT, SAT & POPT stages of commissioning. System testing is done to check such key requirements as the response time, availability of the control system, CPU scan time,

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CPU memory usage, network bandwidth availability and usage, controller's redundancy, network redundancy, communications redundancy and any other system related requirements specified in the scope of work.

- c. The classification of defects (high priority, medium priority and low priority defects) consistent with the definitions from *B-SPE-STD-003 Commissioning Requirements*. The Test Plan document shall clearly define the level of corrective action required to rectify the defects.
- d. All high priority (H) defects should be rectified before progressing further and that medium priority (M) and low priority (L) can progress based on Seqwater approval.
- e. Mechanism of identifying and resolving defects. It should be noted that the defects register will already be active as being handed over from construction. The commissioning defects just need to be added to that register. In the case that such register does not exist, from the design or construction phase of the project, then such a register will have to be prepared prior to testing.
- f. Document test conditions and test configurations including support facilities (i.e. hardware and software) that shall be required to run the test, test rigs and simulators.
- g. Logistics requirements to conduct the test during FAT, SAT & POPT stages of commissioning. For example, the need of an engineering workstation, operator station, stopwatch, protocol analyzer, current injector device or any specific license requirements (for OPC programming, PLC Programming, SCADA configuration, VSD configuration, Power meter configuration etc.).
- h. Date, schedule and duration of the tests (FAT, SAT, POPT) to be performed.
- i. Location of the FAT.
- j. Performance guarantees tests of control system to be done during the POPT stage of commissioning.
- k. The test plan outlines the safety management mechanisms specifically employed during control systems testing.
- l. Number of personnel provided by the Contractor (engineers and technicians) during each stage of commissioning (FAT, SAT, POPT).
- m. Roles and responsibilities of Contractor's team members performing control systems testing.

8.6. Test & Inspection Report for Control Systems

The Contractor shall submit a blank Test & Inspection report (ITR) template to Principal prior to the commencement of each stage of FAT, SAT and POPT for review and comment. Electronic submission of the report (in .pdf or Microsoft word format) is acceptable prior to commencement of FAT, SAT & POPT.

Subsequent to the completion of each stage of FAT, SAT and POPT, the Contractor shall submit the completed ITR; duly signed and witnessed by the Principal's commissioning representative and the Contractor's commissioning engineer. Every individual instrument / loop shall have its own ITR.

The original master copy of the ITRs (that contains comments and pass/fail results) which was used at site during the testing, shall be submitted as a proof of completion of FAT, SAT and POPT stages of commissioning.

In addition to the general ITR requirements outlined in *B-SPE-STD-003 Commissioning Requirements*, shall contain complete record of:

- a. The actual tests carried out, noting deviations from planned

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- b. Action and expected result for each test
- c. The level of simulation performed for each and every test (field environment simulated or any point forced or simulation logic written to perform the test)
- d. Conditions at which the tests were carried out, noting deviations from planned
- e. Any assumptions or considerations made to conduct the test
- f. The results obtained
- g. Any defect observed
- h. Classification of that defect High priority, medium priority or low priority defects
- i. All corrective actions taken to resolve each and every defect shall be recorded. It is Contractor's responsibility to record all the corrective actions against the defects in the ITRs. Any defect's fail reason shall be listed on the bottom comment area within the same test sheet. This shall function as a record to close out defects identified from testing.
- j. Test sheets for all applicable devices and control systems equipment. The Contractor shall refer *I-TMP-STD-007 Control Systems Test Sheets* to develop project specific Test sheets. The fields in this template are mandatory and shall need to be fulfilled by contractor template.

B-SPE-STD-003 Commissioning Requirements outlines the timeline requirements for issuing of ITRs to the Principal. Additionally, hold points are included at the main stages of commissioning test plan document(s) for the control system shall address the following:

8.7. Notice and Witness of Control Systems Tests

The ITPs shall clearly describe the scheduled dates of testing for FAT, SAT & POPT stages of commissioning.

The Principal shall have the right to defer the scheduled dates of testing, in writing, if:

- a. The Contractor has not provided adequately comprehensive ITPs in accordance with this specification, or
- b. The Contractor has not provided adequately comprehensive ITR from the previous stages and hence commissioning should remain in a hold as per *B-SPE-STD-003 Commissioning Requirements*.

The Principal will nominate the representative prior to the commencement of FAT, SAT & POPT to witness testing on behalf of Seqwater. The Principal and the nominated Seqwater representative shall have the right to witness any tests during FAT, SAT, POPT and cut-over stages of commissioning. Such inspection shall not relieve the Contractor of the responsibility for compliance with the requirements and satisfactory operation of the equipment.

The Principal reserve the right to access all original control system testing documents, calculations and design drawings before the commencement of any control system testing or even in the middle of the testing phase of FAT, SAT & POP.

9. Vertical Integration Testing

VIT (vertical integration testing) is not a mandatory test however the Contractor shall perform this testing if it is included in the project scope of work.

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The contractor shall carry out vertical integration testing to demonstrate the feasibility of practical implementation of the proposed system architecture. The testing shall be conducted during the initial design phase of the project unless otherwise stated in the scope of the works. The testing shall be witnessed by the Principal who will provide approval after successful implementation of the testing.

The hardware setup requirements of VIT and the functionalities that needs to be tested, are project specific requirements and will be outlined in either the scope of works and / or project technical specifications.

10. Pre-FAT Verifications

10.1. Verification of the PLC Program

The PLC program will be reviewed by Seqwater against Seqwater standards and functional description document(s). Any non-compliances found shall be recorded on a defect register and will be rectified by the contractor prior to the FAT.

The Principal will implement two reviews of the PLC program:

1. Baseline Review
2. The first review will be conducted on every different type of data object and functional block. This review shall include proposed project structure, any new project specific block requirement, interface requirement to SCADA, Historian or other 3rd party devices or software. This review will be scheduled prior to commencing the main development works, in order to ensure that correct library is utilised and PLC program is constructed in compliance with Seqwater's standards and Functional Descriptions Part B. Quality Review (as a Hold Point)

For second review (Pre-FAT review) contractor will submit all the documentation and Seqwater review time will be minimum 10 days. This review needs to be completed successfully prior to commencing FAT, in order to make sure that PLC program is correctly and efficiently implemented for all control functionality as per Functional Description Part B. This is a hold point prior to FAT. All comment and identify defects as part of pre-FAT review shall be resolved to the satisfaction of Seqwater representative. The Contractor shall provide the PLC program for review by Seqwater. Table 10-1

- Verification of PLC Program outlines the minimum check items for each review.
- Above two reviews needs be cleared satisfactorily to Seqwater requirement before planning FAT.
- Availability of all hardware and software required needs to be assured by contractor prior to planning FAT.

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Table 10-1 – Verification of PLC Program

PLC Stage	Description of the PLC Stage	Seqwater Review	Contractor Deliverables
Review 1	Baseline Review	not a hold point	Email of the program
1.1 Hardware configuration	This stage of the PLC program shall contain completed hardware configuration of the control system including: • controller configuration • module allocation • I/O channel allocation are configured in accordance with detailed design documentation (e.g. I/O lists including tagging)		
1.2 Communication network setup	This stage of the PLC program shall contain completed network setup of the control system including: • ring or star network configuration • Ethernet or fibre optic network configuration • configuration of all the switches, routers and modems in the system. • Communication interface to power meters, VSD, numerical relays etc.		
1.3 PLC library	This stage of the PLC program shall contain imported/loaded PLC library supplied by Seqwater including: • correct version of library • correct version of each function blocks		
1.4 Symbol + Symbol library (Variable/Tags + Instance Tags)	This stage of the PLC program shall contain allocation of all the points and instances in the PLC program including: • all hardware points and alarm points (variables/tags with description) • all asset & tag naming convention is followed • all instances of function blocks including tagging (or a separate list of devices/instruments vs. function blocks with details of description) • all data blocks, if applicable, like for Siemens • memory allocation registers		
1.5 Example control block code	This stage of the PLC program shall contain example code for each type of asset if applicable, including but not limited to: • analogue input and output • digital input and output • valve • motor • PID control loop • duty/standby • supervisory controller • sequencer • HACCp		

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Review 2	Quality Review	This shall be a hold point prior to FAT	Email of the program
2.1 Instantiation of the control blocks	The PLC program shall contain instantiation of all the physical and software control units including, but not limited to: • analogue input and output • digital input and output • valve • motor • PID control loop • duty/standby • supervisory controller • sequencer • interlocks • HACCP		
2.2 Supervisory controller or/and Sequence Logic	The PLC code shall contain all project specific logic for sequential start- up and shut-down of process systems including, but not limited to: • Supervisory control logic • Main sequencer function with interlocks • step transition logic • fault and control monitor logic • action output logic		
2.3 Program structure and scan order	The PLC program shall contain correct code scan order and control object hierarchy, named and described as per its functionality.		
2.4 Program comments	The PLC program shall include reasonable and accurate comments or explanation for: • network/section • data block/data type • function block/section/logic/rung/subroutines • organisation block / routines		
2.5 Comms Functions and Diagnostic Functions.	The PLC program shall contain deployment of all the communication blocks including: • PLC to SCADA • Peer to peer • PLC to third part devices like Power Meters, VSD etc. • Diagnostic blocks for PLC, each rack, I/O module etc.		

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10.2. Verification of the SCADA Program

The Principal will implement two reviews of the SCADA program:

1. Baseline Review

The first review will be conducted on SCADA Page hierarchy, communication with PLC, Historian ,every different type of data object and functional block, and identify any special project specific SCADA object requirement. Trending and reporting structure will also be specified. It will also identify control system architecture including number of servers, EWS and VM requirements. It happens prior to commencing the main development works, in order to ensure that correct library is utilised and SCADA program is constructed in compliance with Seqwater's standards and Functional Descriptions Part B.

2. Quality Review (as a Hold Point)

The second review will be conducted prior to commencing FAT, in order to make sure that SCADA program is correctly and efficiently implemented for all control functionality as per Functional Descriptions Part B. This is a hold point prior to FAT.

Any non-compliances found shall be recorded on a defect register and will be rectified by the contractor. The FAT will not be considered as complete until all PLC and SCADA defects have been corrected. Tests shall be re-witnessed by the Principal unless agreed otherwise.

The successful completion of control system FAT shall be a hold point as per B- SPE-STD-003 Commissioning Requirements.

The Contractor shall provide the SCADA program for review by Seqwater to facilitate the two reviews noted above. Table 10-2 outlines the minimum check items for each review.

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Table 10-2 – Verification of SCADA Program

SCADA Stage	Description of the SCADA Stage	Seqwater Review	Contractor Deliverables
Review 1	Baseline Review	not a hold point	Email of the program
1.1 Architecture configuration	The SCADA program shall contain completed communication configuration of the control system including: • servers configuration (for alarms/trends etc.) • comms to PLC/RTU configuration		
1.2 SCADA library	The SCADA program shall contain imported/loaded SCADA library if supplied by Seqwater including: • correct version of library (objects or SCADA template) • correct version of each objects or SCADA template		
1.3 Database (variable/tag list and example list of alarms, trends, setpoints etc.)	The SCADA program shall contain an example database for each type of asset in the PLC program including but not limited to: • variables/tags (aligned to PLC, are compliant with Principal PLC tag naming convention) • alarms (including description, priority etc.) • trends (including description, sample period etc.) • setpoints/parameters (description, privilege etc.)		
1.4 Example display of each template NOTE: Can be provided by combining with item 1.4 depending on SCADA software.	The SCADA program shall contain example displays for each type of template if applicable including but not limited to: • analogue • digital • valve • motor • PID control loop • duty/standby • supervisory controller • sequencer • HACCP		
1.5 Display overview pages	The SCADA program shall contain all display overview pages if applicable. It's acceptable with no animation on objects, including: • Process control overview page (as per approved Functional Description part B)		

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Review 2	Quality Review	This shall be a hold point prior to FAT	Email of the program
2.1 Instantiation of database for all control units (alarm and trend)	The SCADA program shall contain instantiation of database for all the physical and software control units including but not limited to: • analogue input and output • digital input and output • valve • motor • PID control loop • duty/standby • supervisory controller • sequencer • interlocks • HACCP		
2.2 Instantiation of display for all control units	The SCADA program shall contain all animated objects aligned to all control units including but not limited to: • analogue input and output • digital input and output • valve • motor • PID control loop • duty/standby • supervisory controller • sequencer • interlocks • HACCP		
2.3 SCADA object template (only project specific)	Any project specific SCADA object template (or objects) that are not contained in Seqwater standard library or provided standard SCADA object template is not suitable or not functional. The contractor may have to produce some project specific object template to meet the requirements specified in the Functional Descriptions document (Part B). NOTE: Contractor shall conduct tests to check the functionality of newly created SCADA object template and submit a detailed test report to the Principal. Contractor shall create datasheets for project specific SCADA object template and submit it to the Principal for review and approval prior to use in SCADA project		

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Review 2	Quality Review	This shall be a hold point prior to FAT	Email of the program
2.4 Display overview graphics	The SCADA program shall contain all display overview pages with animated objects (as per approved Functional Description Part B), if applicable, including: • Plant process overview graphic • Functional area graphic(s) for each process area of the plant complete with drill down functionality to sub- processes and equipment • Water Quality graphic		
2.5 Network Overview display graphic(s)	The SCADA program shall contain network overview display graphics displaying SCADA, PLC/Communication deployment including: • Network overview page (as per approved Functional Description Part B), including but not limited to: - PLC diagnostic - PLC Rack diagnostic - Remote I/O racks diagnostic - Software IOs (for Power meter, VSD etc.) - SCADA Server (s) and client (s) stations - Site communication networks (e.g. remote I/O ring network, Modbus TCP/IP network, Profinet network etc.) - AC and DC UPS (via SNMP or hardwired status signals) - Peripheral devices like printers, modems etc. NOTE: Network overview graphic(s) shall be optional depending on scope of work.		

11. Factory Acceptance Test

Each Factory Acceptance Test (FAT) is a major project milestone where the Contractor demonstrates that the system design meets the technical specifications of the contract and the requirements listed in Principal standards by testing the control system.

The FAT will not be considered as complete until all PLC and SCADA defects have been corrected. Tests shall be re-witnessed by the Principal unless agreed otherwise. The successful completion of control system FAT shall be a hold point as per *B-SPE- STD-003 Commissioning Requirements*

11.1. General Requirements for Conducting FAT

The general requirements for the FAT shall be as follows:

- The Contractor shall carry out FAT before delivery of the control system equipment to site to confirm the guaranteed performances. The Contractor shall provide ITRs and completed test sheets of tests as part of the Factory Acceptance Testing.
- The Contractor shall plan, specify, schedule, conduct and record all factory tests. These details shall be included in the Test plan document.

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- c. FAT shall be carried out in the Contractor's premises (unless otherwise approved by the Principal) and shall be at the cost of the Contractor. The Contractor shall be responsible for correcting any omissions or defects to ensure that the control system is fully functional and ready to be commissioned.
- d. FAT shall include a complete integrated FAT (including hardware FAT, software FAT and system FAT as per design, if not then the contractor will be denied commencing FAT.) Some of the tests carried out under system FAT include, but not limited to,
 - i. response time testing,
 - ii. availability testing of the control system,
 - iii. CPU scan time,
 - iv. CPU memory usage,
 - v. network bandwidth availability and usage testing,
 - vi. controller's redundancy,
 - vii. network redundancy,
 - viii. communications redundancy,
 - ix. Any other system related requirements specified in the scope of the work.
- e. If the complete integrated FAT of the control system cannot be tested together due to logistic constraints, then prior approval from the Principal is required to conduct hardware FAT, software FAT and system FAT separately. In case the approval is granted, the Contractor shall prepare individual test plans for each component and include specific methodologies to ensure final system coherence consistent with the design. Risk assessment workshops shall be conducted to identify and address any integration issues that can arise due to the absence of integrated FAT and the results shall be incorporated in the Test Plan document.
- f. FAT shall utilise the actual hardware (CPU, IO module, control panels, UPS, engineering stations, operator stations, SCADA servers etc.) that shall be deployed at site. Size of the operator monitor's screen used in FAT shall be the same physical size and set to the same display resolution as the operator's monitor used in the plant's main control room. For brown field projects consult Principal.
- g. If the control system being designed or commissioned has some redundant components such as PLCs and/or SCADA servers, then the FAT setup shall include all redundant components.
- h. Principal reserves the right to decide the number of staff members witnessing the FAT at Contractor's premises. Contractor can expect a minimum of one Principal's representative from control system discipline and another one from process engineering discipline. If required, Principal can also ask an operator to witness the FAT along with control system and process engineers.
- i. Principal will nominate a lead testing engineer responsible for signing off the test sheets and FAT ITR and verifying defects in the defects register.
- j. To test the stability of the control systems, it shall run for at least five (5) days continuously during FAT. It need not be permanently manned throughout this period provided a comprehensive log of operations tested and faults occurred is logged and reported to the Principal.
- k. It is expected that control system has undergone rigorous tests internally by the Contractor using FAT test sheets prior to the formal demonstration to Principal. Principal can request evidence of these test sheets at any time.

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11.2. Minimum Testing Requirements for Control Systems FAT

Following minimum tests shall be included in the FAT of the control system

11.2.1. Hardware FAT Testing

- a. Cabinet testing for any visual damage, Power Supply, Power Supply Redundancy, Earthing, proper labelling accessories such as cabinet filters and fans, and cable terminations
- b. Testing of PLC controller rack(s) Testing of remote I/O nodes
- c. I/O module testing of digital and analog input and output modules of the PLC
- d. Testing of each and every I/O channel (100% I/O testing to be done and not just the spot/random testing)
- e. Current injection testing of analog input modules (4-20mA)
- f. Testing to check scale, range and engineering unit of all analog points.

11.2.2. Software FAT Testing

- a. Testing to check PLC point names and their descriptions
- b. Device testing of pumps, motors, valves (refer to section 11.5)
- c. Testing of interlocks for all control units
- d. Testing of control modes
- e. Testing of duty/standby changeover of equipment (pumps, valves etc.) and remote I/O drops (wherever applicable)
- f. Testing of PID closed loop controls
- g. Sequence testing of start-up and shutdown sequences during normal mode of operation and abnormal mode of operation (refer section 11.6)
- h. Testing of alarms, events and trends on the SCADA
- i. Testing of remote dial-out alarms on pager or operator's mobile
- j. Testing of report generation
- k. Testing of historical logging in SCADA
- l. Testing of SCADA graphics
- m. Testing of SCADA tags

11.2.3. System FAT Testing

- a. CPU scan time check and memory check
- b. Testing of CPU diagnostic and module diagnostic alarms to SCADA
- c. CPU health check (CPU diagnostic shall not display any errors, warnings or alarms)
- d. Restart of the PLC and SCADA system from failure state to operational state during the power loss condition
- e. PLC communication testing with SCADA

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- f. Peer to peer communication testing between different PLCs (refer to section 11.8)
- g. Control Systems Equipment testing (refer to section 11.9)
- h. Network testing – All the relevant networks (remote IO network, PLC network and SCADA network for example) shall be tested for the following:
 - i. Testing of ring network or star network.
 - ii. Testing of the ring networks to detect single cut and multiple cut. Testing of self-healing time.
 - iii. VLAN to be tested (if existing for the respective project).
 - iv. Network bandwidth to be tested to detect any issues with network traffic and the network reliability
- i. Testing of third party interfaces – If any VSD, power meters, numerical relays or any intelligent devices are communicating with PLC, then all the signals, commands, indications and alarms coming from these peripheral devices shall be tested during FAT
- j. Response time testing – shall be done for at least one analog loop and one digital loop and include the following tests:
 - i. Response time for the field input (limit switch and pressure transmitter for example) to be detected on SCADA screen
 - ii. Response time of the command given from SCADA screen and the field device operating (for example solenoid valve opening or pump starting to run)
- k. In case of a redundant PLC system, the following additional tests needs to be performed:
 - i. Testing of CPU redundancy
 - ii. Testing of redundant communications between PLC and SCADA (if applicable)
 - iii. Testing of redundant OPC communication (if applicable)
- l. In case of redundant SCADA system, the following additional tests needs to be performed:
 - i. Testing of SCADA server redundancy
 - ii. Testing of SCADA server synchronization – the tests shall involve checks to ensure that all the database, graphics and configuration between the two SCADA servers are synchronized and exactly similar to each other.
- m. Each and every section of Function Description Part B shall be tested to ensure compliance at the time of FAT.

11.3. Test Equipment for conducting FAT

- a. The Contractor shall provide all labor, materials, software, hardware and licenses required for the factory acceptance tests
- b. The Contractor shall be responsible for providing adequate and safe seating arrangement to Principal staff to witness the FAT. Independent SCADA operator station shall be made available to Principal staff. Contractor test and program engineers shall use different SCADA operator station than the one allocated to Principal's staff for witnessing FAT. Contractor shall take prior approval from the Principal if independent SCADA operator stations are not possible due to the logistic constraints.

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- c. All test equipment (multi-meters, process meter, current injection device, protocol analyzer, network analyzer, software drivers etc.) used for factory test shall be calibrated prior to the commencement of FAT. All test instruments shall be subject to approval by the Principal.
- d. All electrical equipment used for testing shall have a current electrical safety tag.
- e. The Contractor shall be responsible for the safe operation of any equipment used in the tests.
- f. During Factory Acceptance Test, any test equipment damage shall be replaced by the Contractor at their expense.
- g. During Factory Acceptance Test, any control systems equipment (I/O modules, CPU, switches etc.) subjected to considerable wear and tear must be replaced like for like at the Contractor's expense.
- h. The system to be tested shall be complete at the start of the tests and no interchange of modules or equipment shall be allowed; all temporary equipment used to interact with the test system such as external limit switches and indications lamps or any test kit shall be clarified to the Principal prior to commencement of test.

11.4. Visual Inspection of FAT test environment

Prior to commencement of the FAT the control systems equipment shall be inspected to ensure test environment has been prepared, including but not limited to:

- a. Correct software and firmware versions are used in FAT testing. This information needs to be verified by Principal's representative for the following:
 - i. Firmware version of PLC CPU, communication modules, remote I/O interface modules and/or any intelligent microprocessor based module of the PLC
 - ii. Software version of the SCADA, OPC server and PLC programming software
- b. Seqwater standard library blocks are used in the PLC & SCADA program. In case any of the block in the PLC or/and SCADA program differs in version, date modified or memory size with Seqwater standard block, then the contractor is required to delete that block from the program. The corresponding Seqwater standard block will then have to be imported in the program for the testing to continue.
- c. Correct standards of workmanship and quality
- d. Correct identification labels, cabling, tagging, housing and mounting, etc.
- e. Adequate accessibility
- f. Compliance with the approved drawings as per the design document(s)
- g. Model numbers, quantities of items, etc. against the design documents and BOM (Bill of material) to be verified
- h. Compliance with the Principal standards and specifications Visual inspection for test environment shall be included in ITRs.

11.4.1. PLC & SCADA Configuration Inspection

The configuration within PLC and SCADA systems shall be inspected prior to tests to ensure the following:

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- i. Hardware configuration and the PLC rack layouts are configured in accordance with detailed design documentation
- j. The PLC I/O allocations are configured in accordance with detailed design documentation
- k. All the communication interface (between VSD, power meters, numerical relays etc. and the PLC) has been configured as per the scope of the project

PLC and SCADA configuration inspection test sheets shall be included in ITRs.

11.5. Device Testing

PLC program shall be tested in accordance with the Test Sheets to check the operation of devices during the FAT. The contractor needs to ensure that all devices that are supplied in the project and integrated to the control system are included in the device testing of the PLC program. For FAT, the device testing can be done by simulating the field devices as the control system is not physically connected to the field. However, for SAT, device testing is done in real time environment where the actual field devices are connected to the control system. The device displays on SCADA shall be checked to verify that all details have been configured as per the functional description, equipment list (including drive list & valve list) and the instrument list.

11.6. Sequence Testing

Sequence testing includes proving the functionality of each individual sequence group as defined in the functional description documentation.

Dynamic PLC simulation logic shall be used to simulate process inputs and outputs where applicable.

Sequence testing shall cover the following as a minimum:

- a. Visual inspection of whether Principal's standard control blocks deployed for creating the PLC code for Sequence (where applicable)
- b. Testing of the number of steps in the PLC logic configured as per the functional description
- c. Testing of time delay for each step (if applicable)
- d. Testing of the outcome achieved in each step
- e. Testing of sequences in auto and manual mode and across all states that is part of design outlined in the functional description
- f. Testing of Jump step (if applicable)
- g. Testing of interlocks and permissions for the sequence operation including the 'safe state'.
- h. Testing of sequence interrupt logic such as abort and shutdown sequences
- i. Testing of sequence in power recycle and power break conditions. Sequence shall either hold the current step or start from the beginning during the power break conditions. This requirement shall be specified in the functional description.

In general, sequences are configured for devices, package equipment, process groups and sometimes for the entire water treatment plant. Testing of the sequence logic shall be done in the following order:

- i. Testing of devices sequences (for example logic for duty/standby pump sets)
- ii. Sequence testing of process group (like raw water pump stations or alum dosing system)

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- iii. Sequence testing of package equipment for example UV (ultraviolet) system, centrifuges system etc. (if applicable)
- iv. Sequential start-up and shut-down of the WTP (if applicable for that project).

11.7. Software Functions Testing

Software function testing includes testing of any start up and shutdown sequences for logic process group units in accordance with functional description documentation. The scope of this testing will cover all code not already identified in this specification.

11.8. Peer to Peer Communication Testing

Peer to peer communication is used to exchange process control information such as sequence flags and permissive signals between different PLC controllers communicating on the control systems network.

Each PLC shall have either a single or multiple data tables (Boolean read and write tables, integer read and write tables and floating point read and write tables) containing information which may be needed by other PLCs on the network.

The Peer to peer PLC logic for each PLC is tested against memory mapping lists as defined in the functional description document. Typically, the memory mapping data is represented in the spread sheet listing and signed off once the testing is complete.

Peer to peer communication testing shall involve the following functional testing:

- a. Network bandwidth testing
- b. Response time testing for the data transfer between different PLC's
- c. Load testing to ensure that the network has the capacity to add signals without deteriorating the performance of the communication interface.

Process systems shall also be tested against loss of peer to peer communication. Functional description can ask to hold the last good states for data blocks or to reach the failsafe state for the equipment during loss of peer to peer communication. These requirements have to be tested during the FAT.

11.9. Control Systems Equipment Testing

It is intended that all equipment types that are integrated and interfaced into the control systems design shall be functionally tested for their robustness before installation. Equipment testing includes the following equipment:

- a. SCADA servers
- b. Engineering stations
- c. Operator stations
- d. Printers
- e. Ethernet switches
- f. Media converters
- g. FOBOT

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- h. AC and DC UPS
- i. Power monitors

Equipment testing shall involve visual inspection of make and model of the above listed control systems equipment and comparing them with the equipment list prepared during the detailed design. It shall also include checks on the installation of equipment like Ethernet switches, media converters and FOBOT in the control panels or switchboards as per the installation drawings.

The contractor shall also provide the datasheets along with guarantee and/or warranty certificates of the equipment so that the procured items can be checked against the design specifications. In case of AC UPS and DC UPS systems, the certificates shall include tests to verify the battery size and autonomy time of the batteries.

Equipment testing shall also involve testing of automatic systems for software back-up and recovery management of SCADA servers, PLC controllers and network switches.

11.10. Completion of Factory Acceptance Testing

- a. Contractor shall submit the following documents to the Principal as a proof of completion of FAT. The timeline requirements are specified in *B-SPE-STD-003 Commissioning Requirements*.
 - i. One copy of the FAT ITRs duly completed, signed and commented
 - ii. One copy of duly signed and completed test sheets
 - iii. One copy of the duly signed and completed defect register.
- b. Contractor shall correct the defects and re-test the system (or part of the system) affected by that change at their own expense until the tests are satisfactorily passed. Tests shall be re-witnessed by the Principal unless agreed otherwise.
- c. The successful completion of control system FAT shall be a hold point as per *B-SPE-STD-003 Commissioning Requirements*.
- d. The Principal shall advise the Contractor of the acceptance or otherwise of the factory test results.
- e. The Contractor shall not deliver or install any part of the system until such approval is granted by Principal in writing.
- f. Delivery of the system to site with known test deviations or failures shall be at the discretion of the Principal and confirmed in writing by Principal.
- g. The contractor may include any suggested improvements that may arise during the FAT process in the defects register for handover to the Principal. No action is required to be taken by the Contractor for these items.
- h. Record shall be saved by Project manager in project folder in REX.

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12. Site Acceptance Test

The site acceptance tests cover all of the testing of control systems equipment once it has been installed onsite through to the system becoming operational.

The introduction of electrical power together with other construction and commissioning hazards increases the risk profile during this phase of testing and therefore a heightened awareness of the risks and safe work procedures is required. Contractor shall conduct risk assessment sessions for SAT, if asked by the Principal.

All control system commissioning activities shall be in accordance with the Test Plan document.

12.1. General Requirement for Control Systems SAT

The general requirements for the SAT shall be as follows:

- a. These tests shall follow the Factory Acceptance Test (FAT) and after the equipment has been installed and powered up on site.
- b. These tests shall demonstrate that the overall system, as installed and tested, can perform its intended functions under actual operating conditions in a 'live' data environment.
- c. These tests shall be carried out by the Contractor to the satisfaction of the Principal or representative.
- d. The Contractor shall record that correct equipment (such as model numbers and serial numbers) has been received and installed at site. The Principal will verify these records which are documented in ITRs.
- e. The same format of ITRs & test sheets used during FAT shall be used for SAT however the actual tests conducted in SAT can differ from FAT and shall be clearly identified in ITRs and test sheets.
- f. In a running plant, if the Contractor has to perform updates to the existing PLC and/or SCADA program. A daily back-up of PLC & SCADA program shall be taken from the day following the updates implemented. Copy of the back-up shall be left at site each day of the commissioning period all the way through to handover.
- g. Defects identified in Pre-FAT / FAT needs to be resolved prior to SAT.

12.2. Minimum Test Requirement for Control Systems SAT

Following minimum tests shall be performed during control systems SAT:

- a. Point to point testing
- b. PLC Testing
- c. SCADA Testing
- d. Network Testing
- e. Dry Commissioning
- f. Wet Commissioning
- g. Testing during Plant Start-up

12.2.1. Point to Point Testing

Point to point testing involves testing of all the hardwired inputs and outputs of the control systems. It is two directional testing. The first phase involves testing from the field to ensure that the input data is being

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communicated from field to the SCADA system via PLC. The second phase involves testing digital outputs and analog set points from SCADA system to ensure that it performs the intended function in the field. Digital inputs like Remote/Local switch, level and pressure switches are operated from the field and the signal value is checked in the PLC and then to the SCADA system. In case of outputs, start/stop commands and open/close commands are given from SCADA system and field is monitored to check whether the equipment (pumps, valves etc.) operates correctly.

Analog value displayed on the transmitters in the field is checked against the value being displayed in SCADA graphics to ensure accuracy of the signal. To test the range of the analog transmitters, field input shall be varied from 0%, 25%, 50%, 75% and 100% and corresponding analog values shall be checked in SCADA. Contractor shall vary the process conditions (pressure, temperature, flow, pH etc.) to generate 0% to 100% range of analog signals from the field.

Point to point testing shall ensure that the field wiring for inputs and outputs is correctly installed. It shall also ensure that the I/O configuration in the PLC is complete and accurate, and that the corresponding tags in the SCADA are configured correctly. The entire loop from field to PLC to SCADA and vice-versa shall be tested for all hardwired signals.

12.2.2. PLC Testing

PLC testing shall involve the following tests:

- a. Hardware configuration testing – This testing involves checking dipswitch settings, test of CPU diagnostic and I/O module diagnostic alarms coming to SCADA in the live environment, check of CPU scan time, CPU loading and CPU memory size. In case of redundancy, the hardware configuration testing shall also involve testing of CPU redundancy, testing of fibre optic ring network for remote I/O drops in single cut and double cut scenarios and testing of single or redundant OPC communication between PLC and SCADA systems.
- b. PLC Module testing – Testing to check whether CPU, backplane, power supply modules, communication card, analog and digital cards are healthy and no module level faults exist in the PLC.
- c. PLC Software testing – Check whether the entire PLC configuration is loaded. None of the control blocks, functions and function blocks shall be in simulation mode during the SAT. In fact all the simulation code (SIM variable tables, SIM logic, any simulated or forced analog or digital values) shall be deleted from the PLC code.
- d. UPS tests – This involves testing of UPS and battery alarms coming to SCADA in the live environment, testing of the healthiness of UPS and batteries, autonomy time tests, i.e. run time tests on batteries, testing of switchover from Mains to UPS and vice-versa, testing of UPS redundancy (if applicable). To test the autonomy time of the batteries, dummy loads are connected to the battery banks and then time is recorded for the battery to completely discharge.
- e. Power failure test – PLC system shall automatically recover and restart after a power failure without the need for any manual intervention such as resets or program restarts. Control system resumption time during power supply switchover shall also be recorded.
- f. Testing of temperature rise of panels (control cabinets, network cabinets and/or switchboard) – To perform this testing, the installed load within the panel shall be powered on and the internal temperature shall be allowed to reach stable equilibrium. The internal temperature of the panel is then measured to determine whether it crosses the maximum rated temperature of any of the equipment installed within the panel.

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12.2.3. SCADA Testing

SCADA testing shall involve the following tests:

- a. Hardware configuration testing – This involves checking the utilization of SCADA server and client machines and testing of the RAID architecture of the server machine (if applicable) in live environment
- b. SCADA Software testing – Test to ensure that SCADA configuration (including graphics, database, OPC software) is properly loaded
- c. License & drivers verification in SCADA servers
- d. Communications testing – SCADA Server communication testing with single or multiple Clients, SCADA server communication testing with the I/O server, SCADA server communication testing with peripheral devices like VSD or power meters (in case directly connected to SCADA)
- e. Redundancy changeover test – between redundant SCADA servers and/or redundant SCADA clients (if applicable)
- f. Auto back-up function testing of the SCADA servers to back-up the SCADA program (if auto back-up function is existing)
- g. SCADA application software testing – Following elements of application software shall be tested in the live environment
 - i. Graphics (including main graphics, face plates and pop-ups)
 - ii. SCADA security
 - iii. SCADA Trending
 - iv. SCADA Alarming
 - v. Events and Indications
 - vi. SCADA report generation
- h. Alarm Notification System Support-test
- i. Confirm hard disk space utilisation
- j. Database back up and reload test
- k. UPS tests – This testing is applicable if there are dedicated UPS used for SCADA servers. This involves testing of UPS and battery alarms coming to SCADA in the live environment, testing of the healthiness of UPS and batteries, autonomy time tests, i.e. run time tests on batteries, testing of switchover from Mains to UPS and vice-versa, testing of UPS redundancy (if applicable)
- l. Power failure test – SCADA system shall automatically recover and restart after a power failure without the need for any manual intervention such as resets or program restarts. In case of redundant servers, they shall be synchronized automatically after the power fail over

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12.2.4. Network Testing

Network testing shall involve the following tests:

- a. Testing of the ring network – Healing time shall be recorded in a single cut as well as double cut scenario
- b. System interface to other systems
- c. Testing of firewall & VPN (if applicable)
- d. Testing of network bandwidth
- e. Testing of remote access connectivity of system for programming & troubleshooting
- f. Testing loss of power to network equipment and successful recovery (if applicable)

12.2.5. Dry Commissioning

The purpose of testing during dry commissioning is to ensure that equipment is operational, reliable and ready to go into the production environment once the testing is completed. Dry commissioning is done without the introduction of water or any process fluids in the process system.

Some manufactures do not recommend to dry test certain types of pumps and valves. They require fluid in the pump or valve to prevent damage when being operated. It is Contractor's responsibility to check the pumps and valves datasheet before planning any activity related to dry commissioning of equipment. In case the Contractor identifies any such equipment, it shall be bought to Principal's notice and Principal reserves the right to exclude this equipment from dry commissioning.

The following control systems activities are completed during dry commissioning in accordance with the Test Sheets:

- a. Device testing
- b. Interlock testing for all control units
- c. Control modes testing
- d. Testing of duty/standby changeover of equipment
- e. Extended motor runs with loads (belts) disconnected and measurement of motor No Load operating parameters as appropriate
- f. Testing of PID closed loop controls
- g. Sequence testing of start-up and shutdown sequences during normal mode of operation and abnormal mode of operation (refer to section 11.6).
- h. Testing of Supervisory controllers (part of cause and effect testing, refer to section 11.7).
- i. Final calibration of instruments & tuning control system parameters (on delay and off delay timers, engineering range of analog points etc.)
- j. Completion of test sheets as per Test & Inspection Report
- k. Collection, recording and verification of operating parameters (valve travel time, pump ramp time etc.)

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12.2.6. Wet Commissioning

Control systems testing during wet commissioning shall be carried out in two stages:

- i. In the first stage, the water is purged into the process system to check for any leakages and to ensure the integrity of the process lines.
- ii. In the second stage, chemicals are mixed with water or sometimes pure chemicals are introduced in the process system.

Equipment functionality and safety checks shall be performed during these two stages of wet commissioning until the requirements for acceptance tests are met. The following control system activities are completed during this stage of commissioning:

- a. Operation of all the major equipment (valves, drives etc.) by issuing start/stop commands or open/close command
- b. Revisiting analog loops – PID tuning of closed loop controls shall be carried out in wet commissioning
- c. Commissioning of digital controls – testing of valve travel times, ramp up and ramp down times for soft starters and VSDs
- d. Tuning of sequences – Start and stop timers, on-delay and off-delay timers etc.

12.2.7. Testing during Plant Start-up

In case of start-up of a process area, cut-over may be required to integrate the new process area with the existing plant or a new PLC to the existing control systems. The test plan document shall describe the details of cut-over requirements at the time of commissioning.

The test plan document shall also describe any specific control systems tests that are required during the plant start-up. The contractor shall visualise the integration requirements of the new process area with the existing plant while creating specific test sheets for the control system during plant start-up.

12.3. Completion of Site Acceptance Test

- a. Contractor shall submit the following documents to the Principal as proof of completion of SAT. The timeline requirements are specified in *B-SPE-STD-003 Commissioning Requirements*.
 - i. SAT ITRs duly completed, signed and commented
 - ii. Duly signed and completed test sheets
 - iii. Duly signed and completed defect
- b. Default values are to be set at the end of commissioning, and an “as commissioned” setpoint backup is to be taken and provided to the Principal.
- c. Contractor shall correct the defects and re-test the system (or part of the system) affected by that change at their own expense until the tests are satisfactorily passed. Tests shall be re-witnessed by the Principal unless agreed otherwise.
- d. The successful completion of control systems SAT shall be a hold point as per *B- SPE-STD-003 Commissioning Requirements*.
- e. Site Acceptance Test shall be deemed complete after the successful completion of the following items:

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- i. SAT ITRs and test sheets duly signed-off by the Principal
- ii. All high and medium priority defects, and the non-compliance listed in the SAT Test & Inspection report are closed by the contractor
- f. Control systems with intermittent, unintentional or unrepeatable warnings, errors or failures shall not be accepted
- g. The contractor may include any suggested improvements that may arise during the SAT process in the defects register for handover to the Principal. No action is required to be taken by the Contractor for these items.

13. POPT for Control Systems

Proof of Performance Testing (POPT) is described in detail in *B-SPE-STD-003 Commissioning Requirements*. After the successful introduction of water, the plant will be operated at a continuous rate to ensure smooth ramp up to design capacity production. Once the plant has achieved stable operation, the agreed acceptance testing shall be undertaken to test the process functionality and reliability against the performance guarantees specified in the project.

13.1. Minimum Test Requirements for Control System

Following tests shall be conducted under the Proof of Performance testing for Control systems.

- a. Control System Availability Testing (refer to section 13.2).
- b. Successful automatic plant/process group start-up and shutdown without manual intervention. Alarm inhibit function shall work for automatic plant start-up and shutdown for configured alarms.
- c. Successful alarm notification and acknowledgement through to SCADA and successful escalation of alarms.
- d. Report Accuracy – Daily, weekly and monthly log reports shall be checked to ensure accuracy of historical data being displayed in the reports.
- e. Testing of response time of I/O points from field to SCADA via PLC and vice- versa.
- f. Testing of the response time between peer to peer communications of the PLC controllers.
- g. Testing of communication response time of peripheral devices (VSD, soft starters, power meters etc.) to the PLC system.

13.2. Control Systems Availability Testing

The purpose of the control systems availability test is to demonstrate system reliability, performance and functionality under actual process conditions. Unless otherwise defined in the project scope of work, the general requirements for the availability tests are:

- a. A control system availability test shall be carried out for the complete as-installed system under normal plant operating conditions. The duration of this test shall be a minimum of thirty (30) days unless alternatively specified in the scope of work document of the project.

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- b. The control Systems availability shall be determined using the following formula:

$$\text{Availability} = \frac{[(\text{Total test time} - \text{Down Time}) \times 100]}{[\text{Total test time}]}$$

Where:
 Total test time = Total time in test period of operation (hours)
 Down time = Down time in test period of operation (hours)

- c. For calculating downtime, the following shall be taken into considerations:
- i. All the single points of failures identified in the FTA or RBD during the detailed design. Single points of failures can be the faults/failure in the PLC CPU, SCADA servers, remote I/O drops, Ethernet switches, FOBOT, power supply modules, UPS etc.
 - ii. All conditions which resulted in partial loss or full loss of production
 - iii. Failure in the duty/standby equipment or redundant equipment of control systems shall be recorded and considered for availability testing. For example, if there are redundant PLC CPU's and the secondary CPU fails three times during the POPT testing. Then CPU MTBF (mean time between failures) is calculated for the POPT period and if it is more than the manufacture recommended MTBF, then that particular piece of control system equipment does not meet the required availability.

If the calculated availability achieved during the availability test period is less than the Principal's performance guarantee specified in the scope of work document, corrective action shall be implemented and the availability test shall be performed again.

Recurrent failures may require the use of sophisticated hardware failure analysis techniques or software simulation by the Contractor. All such analysis shall be completed by the Contractor resources at no additional cost to Principal.

14. System Handover

The minimum acceptance criteria for hand-over of the System (Practical Completion) are specified in B-SPE-STD-003 Commissioning Requirements. In addition to the minimum acceptance criteria, the Contractor shall also comply with the below requirements for the control systems handover. These shall include, but not be limited to:

- a. All the defects (high, medium and low priority defects) found during FAT, SAT & POPT shall be documented, rectified and closed by the Contractor. When the defects are rectified, the correct operation shall be verified by the Principal.
- b. All relevant programming software on servers, clients, and/or engineering workstations installed.
- c. Issue of all relevant Test and Inspection report and completed test sheets.
- d. Successful completion of Site Acceptance Test and Proof of Performance Test.
- e. Submission of final Operation and Maintenance Manuals.
- f. Submission of RPEQ signed "As Constructed drawings" in AutoCAD and .pdf formats.
- g. Submission of all software design and support documentation.
- h. Submission of all source codes (PLC & SCADA programs, VSD configuration files, etc.) including user credentials for protected source code & data sheets for site specific applications.

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- i. Completion of operator and technical (where required) training as per the scope of work document.
- j. Spares and supporting tools as described in the scope of work document are to be provided.
- k. PLC, SCADA & VSD programming licenses and all software literature shall be handed to the Principal.
- l. Handover of control systems loose spares (including power supplies, CPU, communication processor modules, interface modules, I/O modules, Ethernet switches, Profinet communication cables, PLC programming cables etc.) as per the requirements specified in the scope of work document.
- m. Contractor should ensure labelling of Racks/IO card/Switches/FOBOT etc. and specified Ethernet cables colors (Table15-3 of I-SPE-STD-013) are used before handover.

All documents that are handed over shall be signed for as received by the Principal. This confirmation of receipt does not indicate that the content is accepted as final. Review comments on handover documents shall be accommodated. The format for handover of the above documents shall be agreed between Principal and Contractor as electronic and/or hardcopies.

As per [FRA-00048](#) Operational Technology Assurance and Controls Framework, a new or altered system is defined as 'operational' at the conclusion of the change management system used. Commonly, the point in time of 'operational' will correspond to 'handover' but designated point in time milestones may not always correspond.

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15. Changes from previous version

This Standard Specification will be regularly reviewed and updated, including the consideration of requested alterations, in accordance with Seqwater Procedure X- PRO-STD-004 [Development and Review of Asset Standards](#).

Section Number	Change
4	Additional details for improved clarity of assurance and controls activities.
5	Minor text updates to abbreviations list
6	Updated references with FRA-00048 Operational Technology Assurance and Controls Framework
10	Further specificity added for the first review cycles of both PLC and SCADA especially highlighting custom code and / or third party or propriety devices.
11.2.1	Added details on cabinet testing to ensure fit for purpose outcomes to the control systems design.
14	Included reference to 'Operational' definition from FRA-00048 Operational Technology Assurance and Controls Framework
16	Added details of sample checks as defined in FRA-00048 Operational Technology Assurance and Controls Framework

16. Verification

Compliance with this document may be verified by internal audit

In accordance with [FRA-00048](#) Operational Technology Assurance and Controls Framework, a sample of new or altered systems that are required to adhere to this standard will be checked for the correct application of this standard.

17. Further Information

For further information please contact the owner of this document.

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Appendix A – Requirement Checklist

Testing Compliance Requirements

Please complete the following testing compliance requirement checklists and if you have answered 'No' to any of the following items, contact [CSM](#) principals for further advice

Requirements	Section	Yes	No	N/A
Test Plan documentation completed	8.2	☒	☐	☐
Cut Over plan documented	8.3	☐	☐	☐
Roll back and migration plan documented and tested successfully	8.4	☐	☐	☐
General Requirements of Test plan document	8.5	☐	☐	☐
Test & Inspection Report completed	8.6	☐	☐	☐
Notice and Witness of Control System Tests completed.	8.7	☐	☐	☐
Pre-Fat verification of PLC program completed successfully	10.1	☐	☐	☐
Pre-FAT verification SCADA Program completed successfully	10.2	☐	☐	☐
Hardware FAT completed successfully	11.2.1	☐	☐	☐
Software FAT completed successfully	11.2.2	☐	☐	☐
System FAT completed successfully	11.2.3	☐	☐	☐
Test Equipment for conduction of FAT checked	11.3	☐	☐	☐
PLC & SCADA Configuration Inspection completed	11.4.1	☐	☐	☐
Device testing completed successfully	11.5	☐	☐	☐
Sequence testing completed successfully	11.6	☐	☐	☐

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Requirements	Section	Yes	No	N/A
Software function completed successfully	11.7	☐	☐	☐
Peer to Peer communication testing completed successfully	11.8	☐	☐	☐
Control system equipment testing completed successfully	11.9	☐	☐	☐
Factory Acceptance Testing completed successfully	11.10	☐	☐	☐
SAT General requirement checked	12.1	☐	☐	☐
SAT Point to Point testing completed successfully	12.2.1	☐	☐	☐
SAT PLC test completed successfully	12.2.2	☐	☐	☐
SAT SCADA test completed successfully	12.2.3	☐	☐	☐
SAT network test completed successfully	12.2.4	☐	☐	☐
SAT dry commissioning test completed successfully	12.2.5	☐	☐	☐
SAT wet commissioning test completed successfully	12.2.6	☐	☐	☐
Testing during plant start-up completed successfully	12.2.7	☐	☐	☐
SAT completed successfully	12.3	☐	☐	☐
POPT minimum test requirement checked	13.1	☐	☐	☐
POPT control system availability testing completed successfully	13.2	☐	☐	☐
System handover completed successfully	14	☐	☐	☐

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