การไฟฟ้าส่วนภูมิภาค
PROVINCIAL ELECTRICITY AUTHORITY

รายละเอียดและขอบเขตของงาน
ประกวดราคาเลขที่ PEA-SMC-CM-07-2022
งานจัดหาพร้อมติดตั้งอุปกรณ์ควบคุมในระบบจำหน่ายเพื่อเพิ่มประสิทธิภาพ
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การไฟฟ้าส่วนภูมิภาค

ศูนย์สั่งการระบบไฟฟ้า

200 ถนนงามวงศ์วาน จตุจักร กรุงเทพมหานคร 10900

เล่มที่ 2

Technical Specification : Feeder Device Interface

PROVINCIAL ELECTRICITY AUTHORITY
SYSTEM MANAGEMENT CENTER
200 NGAM WONG WAN ROAD, CHATUCHAK,
BANGKOK 10900, THAILAND
www.pea.co.th
TEL. 0-2590-9506
FAX NO. 0-2590-9509

Technical Specifications
Part B: Feeder Device Interfaces

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1. Common Requirements

This clause describes the Authority's common requirements that apply to the FDI equipment.

1.1 Standards

With respect to installation procedures and associated accessories (such as power cables, ground cables, surge arrestors, etc.), the standards of the Engineering Institute of Thailand shall apply. Otherwise, the FDCU equipment shall be designed in accordance with applicable International Electrotechnical Commission (IEC) standards and comply, as may be necessary, to standards published by other organizations, such as the Institute of Electrical and Electronic Engineers (IEEE), American National Standards Institute (ANSI), National Equipment Manufacturers Association (NEMA), and Electronic Industries Alliance (EIA).

For conditions not covered by the referenced standards, other internationally recognized standards identified by the Contractor and approved by the Authority shall apply.

In all cases, the provisions of the latest current edition or revision of the referenced standard or code shall apply. If the initially referenced standard or code has been superseded, any such reference shall imply a reference to the new standard or code.

Within the context above, the Authority is particularly concerned with the end-to-end security of all data communications between the TDMS and FDCUs. Consequently, the Contractor's proposal shall have identified any cyber security related standards (such as IEEE 1686, IEEE 1815, IEEE 802.1X, IEC 62351, NERC CIP, or equivalent) with which the FDCUs comply along with any specific security measures that meet these standards and, on this basis, may be implemented in coordination with the security features of the TDMS and WRL communications system with which the FDCUs shall interface.

1.2 Service Conditions

The FDCU equipment shall be suitable for continuous outdoor operation in Thailand's tropical monsoon climate, which includes exposure to severe frequently occurring thunderstorms. It shall also be suitable for conditions where it will be exposed to heavy industrial pollution, salt-spray, and high levels of airborne dust. These exposure requirements shall apply to all accessories that may be vulnerable to such weather and environmental conditions as well. Thus, the Contractor's proposal shall have clearly clarified how the FDCU equipment and its accessories comply with such requirements. Otherwise, as may be necessary, conformal coating (Class 2 in accordance with IEC 60870-2-2 or Class 3K7 in accordance with IEC 60721) shall apply to all components that are prone to misoperation and/or damage from such exposure.

In addition, the equipment shall have been type tested for continuous operation under specific conditions as follows:

1) ***Temperature:*** 0°C to 70°C (IEC 60068-2-1, 2 or equivalent)

2) ***Temperature Gradient:*** Up to 30°C (IEC 60068-2-14, or equivalent)

3) ***Relative Humidity:*** Up to 95% at 40°C (IEC 60068-2-30 or 38, or equivalent)

4) ***Cyclic Damp Heat:*** 40°C to 25°C at 95% Relative Humidity (IEC 60068-2-3 or 78, or equivalent)

5) ***Vibration (sinusoidal):*** 2g acceleration, 9 to 350Hz (IEC 60068-2-6, or equivalent)

6) ***Shock:*** 15g, 11ms test (IEC 60068-2-27, or equivalent)

7) ***Tilted Pole:*** Up to 10 degrees from vertical in any direction

8) ***Altitude:*** Up to 1,000 meters.

The required type tests shall have been carried out by suitably accredited test laboratories that are independent of the manufacturer and Contractor. Certified copies of all type test certificate and test results shall have been included as part of the Contractor's proposal.[1]

1.3 Fail Safe Design

The FDCUs shall be designed to prevent false control actions being executed and erroneous data being transmitted. In this respect, they shall incorporate the following fail-safe design criteria in their control output logic:

1) No false output shall result from a single point of failure in any FDCU.

2) No false output shall result during FDCU power up or power down.

3) ~~No false output shall result from inadvertently inserting a circuit card into a wrong slot within the FDCU~~.

1.4 Maintainability

The Authority prefers FDCU equipment designs that do not require periodic preventive maintenance and inspection. If periodic maintenance is required, it shall be possible to perform all such work in the field without dismounting the equipment and without requiring that the associated power system circuit be de-energized.

Within this context, the FDCU hardware shall:

1) Be designed to minimize or eliminate the need for periodic maintenance.

2) Be assembled from modules to facilitate troubleshooting on a module basis.

[1] *In general, all type test requirements, as referenced here and elsewhere in the Technical Specifications, apply to Contractor standard products. In case customization or prototyping is necessary during project implementation, supplementary type testing shall apply.*

3) Be configured to simplify the removal and replacement of modules or component parts with minimum effort.

4) Include module interfaces that minimize opportunities for damage due to removal and replacement of modules and plugging and unplugging cables within the control cabinet.

5) Include graphic placard warnings of hazardous and potentially damaging actions.

The FDCU software, including firmware and firmware parameters where applicable, shall:

1) Include a mechanism to locally display the operating software and firmware versions.

2) Be remotely downloadable and upgradeable in an encrypted from FDCU Test System to assure a secure and complete download. (also refer to Clause 2.3.3).

3) Be downloaded into parallel memory for error check and decryption before being loaded into operating memory.

4) Be stored locally as a previous version before new software and firmware is executed and, on this basis, be available for restoration.

5) Employ watchdog timers to detect FDCU failure and generate a restart.

6) Be supported by operation and maintenance information in the FDCU user manual.

1.5 Immunity to Electrical Stress and Disturbance

The electrical and electronic components of the FDCUs shall satisfy the requirements for insulation, isolation, and immunity from electromagnetic interference, radiated disturbance, and electrostatic discharge by complying with relevant international standards. In this respect, the standards with which the FDCUs comply shall be identified by the Contractor for Authority approval and shall have been verified by type tests carried out by suitably accredited test laboratories that are independent of the Contractor and/or manufacturer of the FDCU components. Certified copies of all relevant test certificates and test results shall have been included as part of the Contractor's proposal.

1.5.1 Minimum Insulation of Equipment

The following classes of exposure to electrical interference shall be used in interpreting the insulation requirements of all components and wiring as installed:

1) ***Exposed Equipment*** - Exposed equipment terminals may be interconnected without special protection of the insulation. Equipment terminals shall be considered exposed if they are galvanically connected to current or potential transformer secondary circuits.

2) ***Controlled Exposure Equipment*** - Controlled exposure equipment terminals may be interconnected when relevant conditions are satisfied. Equipment terminals shall be considered controlled exposure terminals when the following criteria are met:

a) The rated voltage of the associated circuit does not exceed 32 Vac or 48 Vdc.

b) Direct galvanic connections to exposed equipment terminals are made using a suitable barrier device that has the isolation ratings required for exposed equipment.

Exposed equipment terminals shall be intrinsically designed to meet the insulation requirements. The provision of externally mounted "add-on" circuitry, including devices such as auxiliary relays, isolating transformers, and electronic or gas suppressors, solely for compliance with the insulation requirements shall not be permitted.

Within the context above, the FDCUs shall meet or exceed the minimum insulation requirements listed in

Exhibit 1-1.

Exhibit 1-1: Minimum Insulation Requirements

Requirements	Test Standard	Specified Details	
		Exposed Equipment	Controlled Exposure Equipment
Rated Insulation Voltage	IEC 60255-5 Table I	500 V	60 V
Dielectric Test Voltage	IEC 60255-5 Table I Series B (Clause 6)	2.0 kV rms	1.0 kV rms
Insulation Resistance Test	IEC 60255-5 (Clause 7)	Required	Required
Impulse Voltage Test	IEC 60255-5 (Clause 8)	5 kV 1.2/50 µs 0.5 J	5 kV 1.2/50µs 0.5 J

1.5.2 Immunity from EMI, Radiated Disturbance, and Electrostatic Discharge

The FDCUs shall be designed for safe operation in harsh environments subject to high voltages. Their data communication ports shall be designed to withstand disturbance testing without permanent corruption of data and subsequent delay of data transfer. Within this context, they shall conform to the immunity, susceptibility, and interference requirements shown in

Exhibit 1-2.

Exhibit 1-2: Immunity, Susceptibility, and Interference Requirements

Requirements	Test Standard	Class or Level	Specified Details
High Voltage Impulse	IEC 60060-1	-	5 kV, 0.5 J
Electrical Disturbances (1 MHz Burst)	IEC 60255-22-1 IEC 60255-22-1	Class 3 Class 3	2.5 kV CM 1.0 kV DM
Electrostatic Discharge Immunity	IEC 61000-4-2 IEC 61000-4-2	Level 3 Level 4	8 kV air 8 kV direct
Radiated Immunity	IEC 61000-4-3	Level 3	80 MHz-1 GHz
Fast Transient/Burst Immunity	IEC 61000-4-4 IEC 60255-22-4 ANSI/IEEE C37.90.1	Level 4 Class 4 -	4 kV 4 kV 4-5 kV
Surge Immunity	IEC 61000-4-5	Level 4	2 kV/4 kV
Conducted Immunity	IEC 61000-4-6	Level 3	10 V
Harmonics Emissions	IEC 61000-4-7	-	Required for ac powered systems
Power Frequency Magnetic Field Immunity	IEC 61000-4-8	Level 4	30 A/m
Pulse Magnetic Field Immunity	IEC 61000-4-9	Level 5	1000 A/m
Damped Oscillatory Magnetic Field Immunity	IEC 61000-4-10	Level 4	30 A/m
Oscillatory Transient Immunity	IEC 61000-4-12 IEC 61000-4-12	Level 3	Ring Wave Damped Oscillatory 2.0 kV

1.6 Control Inhibit Switch

Control Inhibit Switch shall be qualified as following;

- Standard: IEC60947-3or equivalent
- Type: 2 positions, 90°, CAM switch
- Nameplate: Control inhibit switch
- Current rating: at least 10 A
- Voltage rating: at least 400V
- Contacts: 4NO/4NC

– Handle:	Short handle

2. FDCU Functional Requirements

This clause describes FDCU functional requirements from the perspective of remote monitoring and control of the Authority's remote-controlled switches. Required FDCU configuration, maintenance, and diagnostic features are also described.

2.1 TDMS Interface

Each FDCU shall support two-way communications with at least four Front-End Processors (FEPs), which have specific IP Address for each of FEPs, located at two Authority data centers. These FEPs and other servers will comprise the central computer platforms for DDIP's new Transmission and Distribution Management System (TDMS). The TDMS computer platforms will host the SCADA and EMS/DMS applications that will support remote power system operations from multiple Authority control centers and, in this respect, the computer platforms and control centers will provide backup for each other. The FDCUs shall communicate with the FEPs at both data centers using the secure authentication of the DNP 3.0 protocol over IP and shall confirm to the DNP3 Device Profile used in the TDMS.

Within this context, each FDCU shall use the co-located UHF radio supplied and installed by Contractor to transmit data over the air to a master radio, installation by others, such that the data can be received by both data centers simultaneously. It shall be possible for the data to be sent under the following DNP 3.0 defined modes of operation:

1) During a Class 0, 1, 2, and/or 3 polls by the TDMS. This shall include:

    a) Integrity and report by exception polling.

    b) Sending selected status or analog points on demand.

2) During an unsolicited (spontaneous) Class 1, 2, and/or 3 FDCU response to a power system event. This shall include sending an analog or status point value in the event:

    a) An analog value exceeds an individually configurable dead band around its previously reported value.

    b) An analog value exceeds an individually configurable Threshold.

    c) A status point changes state.

The FDCU shall include the capability to receive and implement DNP 3.0 control commands as sent from any SCADA server that is a part of the two TDMS data center platforms.

The capability to configure the FDCU remotely using a secured and/or encrypted TCP/IP protocol like "https" shall also be supported.

2.2 Input/Output Points

The FDCU shall include facilities for handling all required analog input, status input, and control output points. The requirements for each type of I/O point are described in the following sub-clauses. Also, refer

to Appendix A where an example of the I/O points currently handled by existing FRTUs at some of the project RCS sites are identified. The FDCU shall handle similar points. However, all points to be handled will be confirmed during project implementation, i.e., during the initial design phase. Within this context, the Contractor's proposal shall have referenced the standards to which the FDCU complies such as IEC 61557-12, IEC 61000-4-30 Class S, or equivalent.

2.2.1 Analog Inputs

The FDCU shall:

1) Acquire analog inputs directly without transducers from each of three power system voltage and current terminals in the existing or Contactor-provided RCS control cabinets.

2) Apply suitable filtering to eliminate the risk of signal aliasing.

3) Use voltage and current inputs for calculations that support TDMS acquisition of the following data as a minimum:

    a) Line-to-line voltages.

    b) Phase current magnitudes and phase angles.

    c) Real and reactive powers (three-phase kW and kVar totals with sign).

    d) Power factor.

4) Accept ac voltage input signals with a normal input level of 110 V.

5) Employ analog to digital converters with minimum of 16-bit resolution for a bipolar input signal.

6) Accurately resolve ac voltage input signal levels from 0 to 150 V.

7) Accurately resolve ac current input signals with normal ranges of 0 to 5 A or 0 to 1 A.

8) Include the capability to report all analog values that have changed by more than their programmable dead bands from their last values successfully reported to the TDMS.

9) Record maximum rms fault current signals, over a period of at least one (1) second, up to 20 times normal (100 A) within a maximum error of 2.5% of Full-Scale Deflection (FSD).

10) Not impose a total analog input burden of more than 0.5 VA for all current and voltage inputs.

11) Demonstrate an overall analog input error of no more than ±0.2% of 1.2 times normal FSD over the temperature range 0 to 70 °C.

12) Demonstrate an analog input linearity better than ±0.05%.

13) Reject common mode ac (50 Hz) voltages up to 150 V.

2.2.2 Status Inputs

As a minimum, the FDCU shall accept isolated wet and dry single contact two-state status inputs and two-state status inputs with memory, i.e., Momentary Change Detection (MCD) inputs. Input change of state shall be timestamped to a precision of 1 millisecond.

Within this context:

1) All necessary wetting voltage, current limiting, input isolation, and bounce filtering shall be provided.

2) Contact de-bounce time periods shall be individually configurable.

3) The input circuits shall be optically isolated from the external signal.

4) Unless the FDCU can provide its own self-supplied wetting voltages, input contact wetting voltages shall be 24 Vdc as obtained from the dc power supply in the existing or Contactor-provided RCS control cabinets.

5) Each wetting voltage circuit shall be protected with its own circuit breaker.

2.2.3 Control Outputs

The FDCU shall support the following control output features:

1) A Select-CheckBack-Before-Operate (SCBO) procedure for all control operations. In this respect, the following concepts shall apply:

    a) On receipt of a control point select command, the FDCU shall check that no other point is selected, select the requested point, acknowledge the select command, and start a Command Receipt Timer.

    b) Control point selection shall be canceled if the subsequent operate command is not received within the Control Receipt Timer's programmable time-out period, which shall be adjustable from five (5) to thirty (30) seconds.

    c) On receipt of the operate command, if the control point has remained selected and no other point has become selected, the FDCU shall then initiate the requested control action.

    d) The SCBO procedure shall be canceled automatically on completion of the control action or if not completed within the Control Receipt Timer's programmable time-out period as per sub-clause b).

    e) Any further attempt at control shall require a new SCBO procedure.

2) RCS opening and closing by sending commands to a complimentary pair of contact outputs such that:

a) One command activates the contact used to open the switch.

b) The other command activates the contact used to close the switch.

c) Only one contact output in a complimentary pair can be activated at a time.

3) Momentary control where each output provides a contact closure pulse having an individually programmable duration from 1 to 60 seconds in increments of 1 second.

The following requirements shall also apply:

1) The FDCU shall be capable of direct control of the RCS.

2) The voltage rating of the control output contacts shall be 24 Vdc.

3) All control power shall be obtained from the existing or Contractor supplied 24 Vdc power supply.

4) FDCU control outputs shall be able to drive loads of at least six (6) amps.

5) Output relays shall be designed for 10^6 (one million) mechanical operations.

6) The FDCU shall monitor all operations and local status information and give warnings or advisory messages when any wrong operational sequence is requested.

7) Abnormal conditions shall inhibit control operations, e.g., low gas-pressure lockout of an RCS.

2.2.4 Feeder Fault Current Detection

The FDCU shall be able to detect and report the passage of momentary as well as sustained feeder fault currents. Within this context, sensitive earth fault as well as all other fault type detection shall be supported. It shall also be able to detect and report loss of power system voltage and a return-to-normal feeder energized state. In this respect, the following functional requirements shall be met:

1) Fault passage detection shall be based on checking if a current set point value has been exceeded. If such a condition is detected and continues for a specified time duration, the detection logic shall result in a Fault Event being registered and reported to the TDMS.

2) Fault passage detection shall include reporting features for the different types of fault that can occur. In this respect, for example, the fault detection features associated with such relays as follows shall be incorporated, where equivalent IEC 60617 codes as well as the referenced ANSI codes may apply:

a) Overcurrent (ANSI 50/51, 50G/51G)

b) Sensitive earth fault (ANSI 50SEF)

c) Directional relay (ANSI 67)

d) Broken conductor (ANSI 46BC or ANSI 47BC)

e) Negative sequence voltage (ANSI 47)

3) Detection of a return-to-normal state shall be based on recognizing that the voltage level has been above a configurable set point for a specified time, in which case a Fault Cleared Event shall be registered, reported to the TDMS, and used to reset the FDCU so it is ready to detect any subsequent fault.

4) The FDCU shall support TDMS downloading and uploading of the set points and time periods that correspond to Fault Events and Fault Clearance Events using the DNP 3.0 protocol.

5) The FDCU's feeder fault detection function shall:

a) Work properly for all possible configurations of the power system circuit where the FDCU is installed.

b) Prevent miss-operation due to magnetizing inrush currents and other transient no-fault conditions.

c) Report the fault current level with time stamp to the TDMS and reset the fault current register to zero.

d) Report Fault Event, Fault Direction, and Fault Clearance Event details as time-stamped Sequence of Events (SOEs).

e) Save the last 128 Fault Events along with their corresponding Fault Direction and associated Fault Clearance Event details and, on demand, report them to the TDMS.

f) Support a configurable format for local fault record reporting including the Comma Separated Variable (CSV) format for use in a spreadsheet and the COMTRADE (IEEE C37.111-1999) format for use with a commercial COMTRADE viewer.

2.2.5 Point Counts

The FDCU shall be equipped to handle the I/O list described in the relevant tables shown in the Input/Output point for FDCU-RCS Interface table. They shall also include spare I/O points fully configured and available for immediate use by the Authority. In this respect, at least 5% of the number of status points, and 5% of the control output point in each as-built distributed I/O module shall be spare.

The spare status and control output points shall be wired from the FDCU I/O card to the associated terminal strips in the associated control cabinet. Additional I/O point on the I/O card beyond those needed to satisfy the requirement for spare points need not be wired.

2.3 FDCU Architecture

The FDCU shall incorporate a programming capability within an architecture that supports convenient installation, maintenance, and expansion features. The architecture shall include a central processing module, I/O module, control module, communications module, and time and date module. Associated

equipment such as dc power supply and local control panel are described elsewhere in the Technical Specifications.

2.3.1 Central Processing Module

The Central Processing Module (CPM) shall:

1) Support a high-level language processing capability per the open IEC-61131-3 standard for programmable logic controllers.

2) Support management of the FDCU database from the FDCU Test Systems.

3) Implement the DNP 3.0 Secure Authentication protocol interface with the TDMS.

4) Control data acquisition from the RCS and the sending of control commands to the RCS using an I/O module.

5) In accepting commands from the TDMS:

    a) Perform address recognition.

    b) Assemble response messages in accordance with the received command messages.

    c) Transmit these messages to the TDMS.

6) Provide interfaces for a time standard set-and the FDCU Test System.

7) Manage communications between all other functional modules of the FDCU.

8) Determine the integrity of the FDCU.

9) Provide diagnostic information in the message structure that the TDMS shall monitor.

10) Set a flag if the FDCU performs a restart for any reason including power failure.

11) Include a watch-dog timer that is reset regularly by FDCU software. If the software fails to reset the watch-dog timer (e.g., because of a software error causing the software to "loop" or "hang"), then the timer shall expire causing the CPM to reset and restart.

2.3.2 I/O Module

I/O module requirements include the following capabilities and features:

1) Capability to accept analog and status inputs and send control outputs. This shall include fault current measurements.

2) Capability of being replaced without reprogramming, redefinition of configuration parameters, or rewiring.

3) A Control Switch (CS) that, if not in its normal control position, inhibits RCS control from the TDMS or test set.

4) A status input contact so that the TDMS or test set can monitor if the position of the CS is in its normal control position.

5) Capability to report the position of the Local/Remote (L/R) switch supplied with the RCS. For the CS to be effective, the L/R switch must be in "Remote." Otherwise, with the L/R switch in "Local", remote control from the TDMS or test set shall be disabled irrespective of the CS position.

2.3.3 Communications Interface

The FDCU shall be provided with a communications interface including necessary and sufficient numbers and types of port that can be used to support:

1) Remote data communications with external systems and devices over an Ethernet/IP network using the latest secure DNP 3.0 communications protocol. This shall include data communications with multiple masters, as in the TDMS systems at the Authority's two data centers, and the DAC Simulator (or equivalent standard DNP3 Test Set, such as ASE2000).

2) Local and remote configuration with a static IP address.

3) The fully implemented message security features of the DNP 3.0 protocol running over TCP/IP. This capability shall be demonstrated successfully as part of factory acceptance testing.

4) Communications that is not degraded by simultaneous activity in other parts of the FDCU.

5) Temporary connection of laptops, such as the DAC Simulator (or equivalent standard DNP3 Test Set, such as ASE2000, etc.) or Contractor supplied test set for local installation, maintenance, diagnostic, and test purposes for all configurations and data access functions associated with the FDCU.

6) SCP/SSH with respect to downloading, for example, FDCU configuration parameters and firmware updates.

7) Features such as HTTPS for web server functionality (refer to Clause 2.3.5).

8) Blocking or disabling of ports to prevent unauthorized access.

9) MAC and IP filtering so that Ethernet traffic is limited to a configurable "whitelist" of network device MAC and IP addresses.

10) Access control using a secure log-in procedure. As a minimum, this shall include user authentication based on a unique username and password.

11) System logging (syslog) at a device or system level. Syslog alerts shall include remote user access activity including successful and unsuccessful login attempts.

12) Manual configuration of a routing table with different metrics so that networks may be reached using locally entered alternative paths (IP redundant paths for example).

2.3.4 Time and Date Function

The FDCU's time and date function shall:

1) Include an internal time-of-day clock for data collection coordination. The time resolution of the internal clock shall be one (1) ms or better and, without synchronization, the time shall drift by no more than 5 ms per hour.

2) Use the existing or Contractor-provided RCS control cabinet's 24 Vdc power supply as the only source of power for the internal clock, i.e., no other source such as an internal (on-board) battery shall be used.

3) Synchronize the internal clock whenever the FDCU is powered up. This shall not prevent the FDCU from immediately registering inputs even before the time and date reference signal has been received. Any such inputs shall be reported to the TDMS with the appropriate time and date, i.e., use of an arbitrary default time and date is not acceptable.

4) Be able to receive a DNP 3.0 compliant time and date message that contains a Greenwich Mean Time (GMT) reference signal, generated by the TDMS in long format and in such a way as to properly account for communication path delays.

5) Be able to synchronize the internal clock to the GMT time and date received from the TDMS.

6) Be able to synchronize to an optional Global Positioning System (GPS) receiver as described in the Contractor's proposal. The GPS antenna shall be of low profile type for secure and moisture-resistant mounting on top of the FDCU enclosure. The receiver shall be used to synchronize the internal clock to the correct GMT time and date within a time resolution of at least 1 millisecond.

7) The equipment shall support internal clock time retention in the event of a power supply failure. In this respect, the use of an on-board battery is not acceptable (also refer to Clause 2.3.4, Sub-clause 2). The mechanism for internal clock retention shall not require periodic maintenance.

The time and date facility shall be accomplished by all necessary devices, equipment, and software provided and installed by the Contractor. This shall include full cooperation with the TDMS contractor to ensure correct functionality from an overall system perspective.

2.3.5 Web Browser connection

The FDCU shall be accessible through a secure HTTPS connection both locally and remotely by means of not only the FDCU test set (refer to Clause 4), but also a standard laptop PC, tablet, or smartphone (if supported). Access shall be password protected and allow for different permissions based on defined user roles. Passwords and roles shall be defined during project implementation. As a minimum, the facilities of the web server module shall include:

1) Maintenance features that include the capability to upgrade and configure FDCU firmware.

2) The capability to set FDCU communication parameters such as DNP3 Source Address, Destination Address, Timeouts, Retries, Frame Size, etc.

3) The capability to set FDCU clock time, time synchronization, and fault detection features.

4) Display and clearance of historical logs and the capability to export logs in CSV format.

5) MMI features such as mimic and graphic displays supporting for example RCS monitoring and control, visualization of site location details, and presentation of voltage and current measurements.

6) An FDCU field testing feature that allows a locally entered data point (simulating for example a power system voltage measurement) to be sent to the TDMS via DNP 3.0 along with an appropriate data quality code.

2.4 DC Power Supply

The FDCU equipment shall powered from a 24 Vdc power supply of existing enclosure.

2.5 Software/Firmware

The term "software" is used in these Technical Specifications to mean software or software implemented through firmware. All software shall be implemented per the Contractor's established design and coding standards. Complete and comprehensive documentation shall be provided for all software.

2.5.1 Operating System

The FDCU operating system shall:

1) Be a real-time non-proprietary operating system.

2) Manage and support all FDCU applications.

3) Support editing and customization by the Authority as needed to maintain FDCU operation.

4) Provide automatic restarts of the FDCU on power restoration, memory parity errors, hardware failures, and manual request.

5) Initialize the FDCU on power-up and begin execution of the FDCU functions without intervention by the TDMS.

6) Report all restarts to the TDMS.

2.5.2 Operating Software

The FDCU operating software shall be:

1) Prepared in a high-level language such as the IEC61131 programming suite.

2) Documented in detail.

3) Free of additional licensing charges or license agreements.

4) Supported by protocol, configuration, and application data contained in easily programmable non-volatile memory such as Flash EPROM.

5) Independent of any data communications protocol that would impose restrictions on the flexibility or functionality of the FDCU. In this respect, protocol changes shall be capable of being accomplished by locally and remotely implemented software/firmware changes only.

2.5.3 Diagnostic Software

FDCU diagnostic software shall:

1) Continuously monitor operation of the FDCU.

2) Report FDCU hardware errors to the TDMS.

3) Check for memory, processor, and input/output errors and failures.

4) Be sufficiently detailed to detect malfunctions to the level of the smallest replaceable component.

5) Facilitate isolation and correction of all failures.

6) Include features promoting rapid fault isolation and component replacement.

7) Include integrated on-line diagnostic functions in all functional module nodes.

8) Report diagnostic results to the CPM for store and forward to the TDMS.

2.6 Interlocking

The FDCU shall include configurable interlock logic to prevent misoperation of the RCS. In addition to preventing RCS operation locally and/or remotely in accordance with the positions of the Local/Remote and Mechanical Lock/Free switches, the RCS control command shall be prohibited in the case of a low SF_6 gas alarm. The interlock information shall be sent to the TDMS via the DNP 3.0 protocol.

3. Existing Enclosures

Existing enclosures shall be utilized at RCS sites where existing control circuits and dc power supply modules are still functional, i.e., the FDCU shall be installed on the FDCU steel plate, that provided by the Contractor. And the FDCU steel plate with FDCU and UHF radio shall be installed to existing RCS control cabinets and wired as necessary to support TDMS monitoring and control of the different RCS models that are deployed by the Authority at such sites. As a minimum, this shall require the FDCU to be connected in the field to existing I/O terminal points and the existing 24 Vdc power supply. Connections to each site's UHF radio shall be coordinated with the existing relevant WRL communications system. All necessary FDCU mounting hardware, cables, and connectors shall be provided.

Within this context, the characteristics of the existing RCS control cabinets are presented in Appendix B.

4. FDCU Test Systems

Contractor FDCU test sets shall be supplied. They shall include all necessary hardware and software to support compliance with the following requirements:

1) Each test system shall support all maintenance aspects such as verifying proper operation, troubleshooting, reconfiguring, and setting operational parameters for the FDCU.

2) The test systems shall support all functional capabilities of the FDCU including functions that are not explicitly required in these Technical Specifications as well as functions that may not be included in the delivered FDCUs.

3) It shall be possible to use a test system locally at the site of the FDCU under test and remotely wherever access can be obtained to the FDCU communication channels.

4) DHCP shall be supported to provide a TCP/IP address for each FDCU.

5) If applicable, serial data rates shall be easily selectable.

6) It shall be possible to use the test systems to monitor communications between the TDMS and the FDCU by selecting specific data streams, or portions of such data streams, both to and from an FDCU. The data shall be displayed in a form that is easy for the user to interpret.

7) It shall be possible to connect the test system directly to the FDCU and use the test system to:

    a) Perform all necessary FDCU management and expansion functions.

    b) Monitor all stored data.

    c) Monitor FDCU inputs including fault currents.

    d) Exercise FDCU outputs.

    e) Diagnose and troubleshoot the FDCU.

8) The test system shall support access and utilization of the FDCU's web server module.

9) No programming skills shall be required to use the test systems. Interactive procedures relying mostly on pull down menus shall be used. The user shall not be required to type in commands and shall be prompted when data entry is needed.

10) Each test system shall include Ethernet, Serial, and USB ports and all necessary interface connectors and cables to allow direct on-site connection of the test system to the appropriate FDCU communication ports used for normal TDMS operations as well as diagnostic and configuration activities.

11) As a minimum, the test system shall be equipped to support DNP 3.0 and DNP 3.0 over IP. This shall include DNP's secure authentication feature as specified in the latest published version of IEEE 1815.

12) The software used by the test system shall be able to provide the functional capabilities and features associated with commercially available test systems such as ASE2000, or equivalent.

13) The test system shall:

    a) Consist of a notebook PC representing the latest available technology.

    b) Be delivered with a case sufficiently sized to contain and safely protect all its components.

    c) Be sufficiently rugged to withstand frequent transportation and use under typical field conditions.

    d) Include all accessories, such as cables and connectors, and all documentation associated with its operation.

    e) Store all accessories and documentation within the test system package or in suitable separate containers.

Within the context above, each FDCU test set in the form of a notebook PC.

5. Documentation

5.1 Hardware Operation and Maintenance Manuals

5.1.1 Equipment Manuals

Equipment manuals shall contain the following:

1) A description of equipment function.

2) Installation, setup, and operating instructions.

3) A block diagram showing the logical and physical interconnections among the major modules and components.

4) Expansion and upgrade capabilities and instructions.

5) Preventive maintenance instructions.

6) Detailed functional, logical, electrical, and mechanical characteristics of all interfaces to the equipment including protocol descriptions.

7) Troubleshooting and repair guides, including descriptions and instructions for the diagnostics furnished.

5.1.2 Hardware Maintenance Manuals

The hardware maintenance manuals shall describe the preventive and corrective maintenance procedures required to maintain the FDCU equipment in good operating condition. The information in the manuals shall include:

1) ***Operating details*** – This information shall include:

   a) A detailed description of how the equipment operates and a block diagram illustrating each major assembly in the equipment.

   b) Descriptions of external data transfers with other equipment, including data patterns, security check-codes, and transfer sequences.

   c) Detailed logic diagrams shall also be provided as necessary for troubleshooting analysis and field repair actions.

2) ***Preventive maintenance instructions*** – These instructions shall include:

   a) All applicable visual examinations, hardware testing and diagnostic routines, and the adjustments necessary for periodic preventive maintenance of the equipment.

   b) Instructions on how to load and use any test and diagnostic program and any special or standard test equipment.

3) ***Corrective maintenance instructions*** – These instructions shall include:

   a) Procedures for locating malfunctions down to the field-replaceable module level.

   b) Adequate details for quickly and efficiently locating the source of an equipment malfunction.

   c) Explanations for the adjustment or replacement of all items, including printed circuit cards.

   d) Schematic diagrams of electrical, mechanical, and electronic circuits, parts-location illustrations, photographs, cable routing diagrams, and sectional views giving details of mechanical assemblies as necessary to replace faulty equipment.

   e) Information on tolerances, clearances, wear limits, and maximum bolt-down torque for mechanical items requiring field repair.

   f) Information on the loading and use of special off-line diagnostic programs, tools, and test equipment, as well as any cautions or warnings that must be observed to protect personnel and equipment.

4) ***Parts information*** – This information shall include:

   a) Identification of each replaceable or field-repairable module at a level of detail sufficient for procuring any repairable or replaceable part.

   b) Cross-references between Contractor and OEM part numbers.

5.2 Software Documentation

The following documents shall be provided for all software (and/or firmware where applicable):

1) List of Deliverable Software.

2) Database definition documents.

3) Software functional description documents.

4) Installation images and source code.

5) Detailed design documents.

6) Software maintenance manuals.

5.2.1 List of Deliverable Software

The list of deliverable software shall itemize each software item and include version and any applicable license information. The distribution media for each software item shall be identified. The list shall also indicate for each item whether source code is supplied.

5.2.2 Database Definition

The database definition shall identify the characteristics of the FDI database. It shall include, but shall not be limited, to the following:

1) The name or identification of the database.

2) A description of the intended use of the database.

3) A description of the organization of the database (the database schema or model).

4) A description of each field of each data item.

5) Instructions for generating and populating the database.

6) Details of programming interfaces including Application Programming Interfaces (APIs). This shall encompass access methods, address schemes, and read, write, and modify actions.

7) Initialization description (how, or by what software, data is initialized and to what values).

8) Details of maintenance actions.

The Authority encourages the use of "self-documenting" database technology, where the database definition is developed and stored with the data. The resulting documentation shall be printable.

5.2.3 Software Functional Descriptions

The functions of each FDCU software module shall be described from the standpoint of a user. Such software functional descriptions are also referred to as user guides. In this respect, the FDCU's functional operation shall be clearly described so that it can be understood without understanding the detailed operation of each software module.

The software functional descriptions shall include the following minimum content:

1) ***Functional description*** – A narrative description of the software including algorithms where applicable.

2) ***Performance requirements*** – The execution periodicity, processing capacity, and tuning and execution parameters that control or limit the capabilities of the software.

3) ***Resource requirement*** – The expected minimum requirements for main memory, auxiliary memory, processor capacity, and other resources required by the software.

4) ***User interface*** – A description of the interface used to control the software, including all user inputs and the corresponding software response to these inputs.

5) ***Software interface requirements*** – A description of the logical interfaces with other software.

6) ***Data requirements*** – A description of all data and databases accessed by the software, including execution parameters.

7) ***Error messages*** – A concise description of all error messages and possible corrective actions.

8) ***Diagnostic messages*** – The messages the software generates as a record of its internal operations.

9) ***Maintenance and expansion procedures*** – A description of the steps required to maintain and/or expand the software (as in modifying the software or adding new functionality).

5.2.4 Installation Images and Source Code

The software shall be delivered in three forms:

1) As fully operational software already installed in the FDCUs.

2) As distribution images, suitable for installation.

3) As source code including libraries, compilers, and linkers for building the software.

The distribution images shall include all operating system, platform software, application software, and the code management library of modifications incorporated into the delivered software. All standard software shall be supplied on the original installation media used by the Contractor to build the system. The Authority prefers CD-ROM as this media. All customized software shall be supplied as part of the code management library or other distribution image against which the code changes are to be applied.

It shall be possible for the Authority to completely generate, build, install, and configure FDCU software from the distribution images and software utilities provided by the Contractor. To this end, "make files" or other compilation, generation, and installation tools, scripts, and directives shall be delivered.

For the purposes of this requirement, "software" shall specifically include the FDCU database, i.e., sufficient definition and content images shall be supplied such that the database can be created and installed in the FDCUs.

5.2.5 Detailed Design Documents

The detailed design documents are intended as a second level of detail to the software functional descriptions. In general, a detailed design document shall relate to a single software functional description.

For customized software, the Contractor shall first deliver a software functional description for approval by the Authority. After approval, the Contractor shall produce a detailed design document for approval. Production of the software shall then proceed after approval of the detailed design document.

The detailed software design documentation shall include, but shall not be limited to, the precise design information needed for planning, analysis, and implementation of the software. It shall show the divisions of the software design entities, a dependency description specifying the dependent entities, their coupling, and required resources, an interface description providing details of external and internal interfaces, and a detailed design description containing the internal details of each design entity.

The detailed software design documentation shall provide a detailed description of how the software will support the functions described in the software functional description. Detailed software design documentation shall include a diagram of the software indicating major modules and an overview of the operation of each module. It shall describe data structures and flow and a diagram or description of the way the modules interface with other modules.

5.2.6 Software Maintenance Manual

A software maintenance manual shall be provided for each FDCU. It shall describe all user procedures necessary to build, maintain, and configure the FDCU software. It shall also include detailed information on troubleshooting, describing the meaning of all software-generated error or informational messages, the recommended response to these messages, and the procedures required to restore normal operation following failure of the FDCU, such as directions to restore software as well as to restore configuration and operating data.

5.3 Operating Manuals

The Contractor shall submit, for review and approval, operating manuals providing FDCU operating instructions. It shall be provided in Thai and English.

Each manual shall be organized for quick access to each detailed description of the user procedures that are required to interact with the FDCU functions. This shall include the procedures, as required both remotely from the TDMS and DAC Simulator and locally from a Windows laptop computer (using the FDCU's USB port for example), to configure the FDCU, upload and down load the configuration, test and save the configuration, and restore the configuration should it become corrupted.

Each manual shall present in a clear and concise manner all information that a user needs to know to understand and operate the FDCU. It shall make abundant use of diagrams and/or photographs to help illustrate procedure utilization.

6. Test Requirements

6.1 Type Tests

As a minimum, the following type tests shall have been conducted:

1) Dielectric tests.
2) Impulse voltage withstand tests.
3) High frequency disturbance tests.
4) Thermal requirement tests.
5) Mechanical requirement tests.
6) Limiting dynamic value tests.
7) Contact performance tests.
8) Electromagnetic radiation susceptibility tests.
9) Electrostatic discharge susceptibility tests

The FDCU shall have passed type tests in accordance with IEC 60255-3, IEC 60255-6 to demonstrate that it complies with the ratings stated in these standards

6.2 Factory Acceptance Testing

This testing shall consist of two separate phases described as follows.

6.2.1 Full Functional Test

In this respect, the FFT shall verify that the prototype can meet such basic requirements as follows:

1) Fail safe design.
2) Transducerless acquisition of ac analogs, such as voltages and currents, within specified signal levels and with required accuracy and sampling rates.
3) Correct calculation of ac analogs such as kW, kVar, and power factor.
4) Detection of fault current amplitude and direction.
5) Acquisition of dc analogs corresponding to all specified types and signal levels.
6) Rejection of specified common mode voltage and normal mode noise levels.
7) Availability of at least one ac voltage reference signal of specified accuracy.

8) Ability to report analogs by exception using a programmable dead band on an individual point-by-point basis.

9) Ability to support de-bounce time periods individually configurable for each status input point.

10) Ability to accommodate the Authority's specified status input types.

11) Status input wetting at 24 Vdc.

12) Ability to issue all relevant control output types, e.g., on/off commands.

13) Ability to select the timeouts associated with control output commands.

14) Control outputs capable of driving loads of at least 6A at the primary control voltage, following a Select-Checkback-Before-Operate (SCBO) procedure, and properly accounting for applicable interlocking features.

15) Reporting of SOE records with specified capacity and time tag resolution.

16) Reporting of analog limit excursions with specified time tag resolution.

17) Equipped and capable of operating with each of the specified number of configurable communication ports.

18) Ability to communicate with external systems using the DNP 3.0 (Secure Authentication) over serial and IP protocols at the specified data rates.

19) Ability to support download and upload of FDI parameter and configuration data.

20) Availability and function of specified watch dog timer.

21) Availability and function of specified local and remote, control disable, and auto/manual switches.

22) Time and date facilities meeting specified time resolution and drift criteria and capable of being synchronized using time and date reference signals remotely from the TDMS as well as locally from an OEM GPS clock.

23) Batteries and battery chargers capable of meeting all specified capabilities and features including those associated with voltage limits, alarms, and discharge/recharge times.

24) Availability of specified diagnostic capabilities including the maintenance and test facilities associated with the FDCU's web browser connection.

25) Availability of specified programmable logic capabilities of IEC 61131 type.

At the end of each FFT, the Contractor shall submit a corresponding test report for Authority review and approval.

6.2.2 Factory Routine Test

To demonstrate that all component parts and functions of the FDCU equipment are in good working order and properly configured for field installation and subsequent integration with the TDMS, the FRT shall include the following tests as a minimum:

1) Visual tests to confirm that construction and physical sizing requirements have been met.

2) Verification that the interface software and firmware support FDCU sizing and expansion requirements.

3) Verification that the FDCU database is complete and properly mapped for use by the TDMS and test set.

4) Rigorous testing of each input and output function. This shall include the fault current detection functions as well as operation and performance of the time and date facilities. Suitable I/O panels and other equipment shall be provided to simulate appropriate test signals.

5) Verification of the ability to download and upload parameters and configuration data.

6) Testing for secure operation, including verification that:

    a) Communication errors are detected.

    b) SCBO procedures are properly performed for control outputs.

    c) No erroneous control operation occurs and no incorrect data is generated when power is turned on or off or when operating on low battery voltage.

6.3 Site Acceptance Testing

Within this context, the following requirements shall apply:

1) Unit testing by the Contractor at the time of installation shall be conducted to ensure all components can be powered up and are in good working order.

2) Site Acceptance Testing (SAT) shall be undertaken by the Contractor to demonstrate to the Authority that the FDCU equipment is fit for purpose and fully operational.

3) SAT shall be carried out by using the functional capabilities of the FDCU to monitor and control the site's associated RCS. This may require:

    a) RCS isolation in full coordination with the Authority's dispatchers.

    b) The monitoring of actual analog and status inputs but checking for control output signals at points that are temporarily isolated from the power system.

4) SAT shall also include a full demonstration of the FDCUs from the perspective of interoperating with the TDMS. In this respect, the Contractor shall make full use of the Test set (or perhaps the

full use of TDMS's QAS SCADA Functions Test). This shall include point-by-point checks to make sure that the FDCU database is properly mapped to the corresponding TDMS database.

No FDI installation shall be accepted as complete until the Authority is satisfied that all variances associated with an individual site have been corrected and that the FDI equipment is SCADA ready, i.e., can be considered fully available for integration with the SCADA/TDMS.

6.4 End-to-End Tests

The contractor will be responsible for overall commissioning of the SCADA/TDMS under typical field conditions, including the need to verify that it can interoperate successfully with the Contractor's installed FDCUs. Verification will be based on end-to-end tests concerned with:

1) Checking for correct database mapping between the SCADA/TDMS and the FDCUs.

2) Making sure that the SCADA/TDMS and FDCUs, working together as an integrated system, can meet the Authority's overall functional performance requirements.

In effect, the end-to-end tests shall serve as a means of commissioning the FDI equipment as well as the SCADA/TDMS. The Contractor, therefore, shall:

1) Support commissioning by having adequate Contractor personnel on hand to witness the end-to-end tests.

2) Resolve any FDI variances that may be raised. Variances specifically identified as FDI problems shall be taken care of as quickly as possible to avoid delays in commissioning of the FDIs and the beginning of their warranty period.