การไฟฟ้าส่วนภูมิภาค

PROVINCIAL ELECTRICITY AUTHORITY

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จ้างจัดหาพร้อมติดตั้ง Hardware และ Software ระบบศูนย์สั่งการจ่ายไฟ (SCADA/TDMS)

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DISTRIBUTION SYSTEM DISPATCHING CENTER IMPROVEMENT PROJECT

(DISTRIBUTION DISPATCHING CENTER)

เล่มที่ 3

บทที่ 10: Technical Specifications

Part A : Project Overview

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1. Introduction

The main objective of the Distribution Dispatching Center Improvement Project (DDIP) is to enhance the ability of the Provincial Electricity Authority of Thailand (otherwise referred to as the “Authority”) to supply electric power to customers throughout its service territory reliably, safely, and economically.

This Part A of the DDIP Technical Specifications serves as a project overview. It provides relevant background information including some key characteristics concerning the Authority’s service territory and a description of the Authority’s existing facilities used to support power system network monitoring and control. The existing facilities include a SCADA/EMS/DMS system, thirteen SCADA/DMS systems, numerous substation and feeder field device interfaces, and a communications infrastructure.

Part A also describes the basic concepts and requirements that relate to overall project scope and implementation. The scope of work is presented in terms of the contracts that will be awarded to implement the project. This includes the general responsibilities and interdependencies of the different contractors and the project’s overall schedule requirements.

2. Background

There are three (3) Ministry of Interior state enterprises in Thailand that collaborate and share responsibility for electricity supply. They are briefly identified as follows:

1) Electricity Generating Authority of Thailand (EGAT) - Responsible for generation and transmission of bulk electricity for the entire country.

2) Metropolitan Electricity Authority of Thailand (MEA) - Responsible for electricity distribution in the Bangkok metropolitan area and two (2) adjoining provinces.

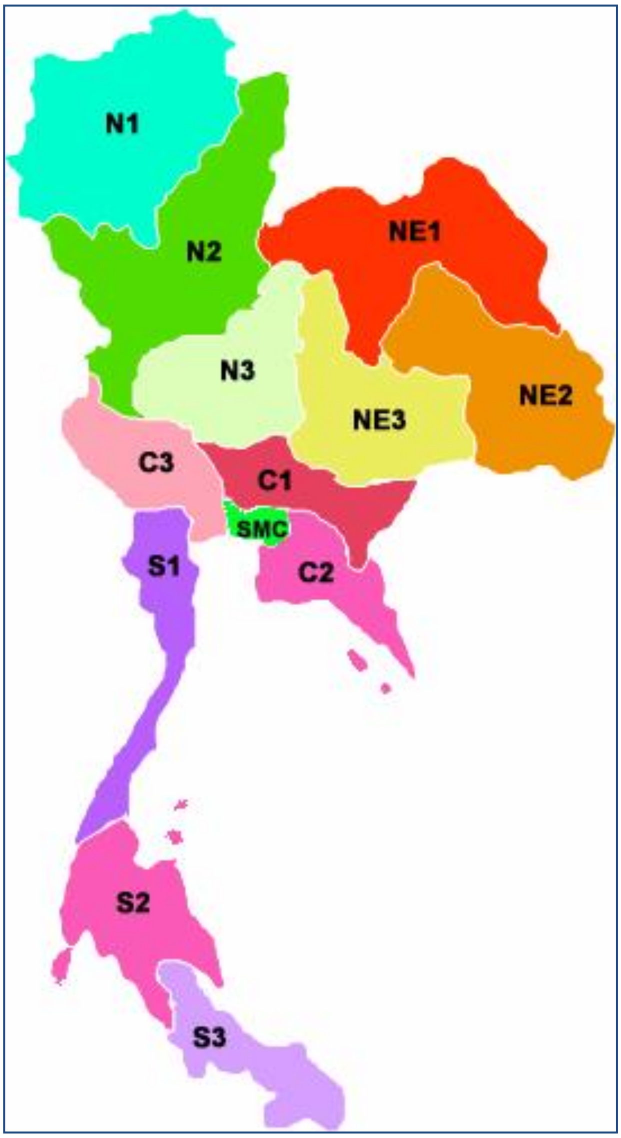
3) Provincial Electricity Authority of Thailand (PEA) - Responsible for electricity distribution throughout the country except for those areas served by MEA.

2.1 Authority Service Territory

The Authority’s service territory is divided into four (4) regions, namely, the Northern, North Eastern, Central, and Southern regions, and each region is divided into three (3) administrative areas (refer to Exhibit 2-1). The service territory covers 510,000 square kilometers (approximately 99% of Thailand’s total area). The degree of electrification in terms of the number of communities within the Authority’s service territory is about 99%. Further information is summarized as follows:

- Number of Customers: 19.42 million
- Maximum Demand: 19,720 MW
- Annual Energy Sales: 129,782 GWh
- Substations: 700 (includes EGAT substations where Authority owns and operates the 22 and 33 kV switchgear)
- Medium Voltage (22 and 33 kV) Lines: 312,717 circuit km (80% at 22 kV)
- High Voltage (115 and 69 kV) Lines: 12,620 circuit km

Exhibit 2-1: Authority Administrative Areas



The Authority purchases electricity at 22, 33, and 115 kV from EGAT. The Authority also purchases power at Distributed Generator (DG) points of connection to the Authority's High Voltage (HV) and Medium Voltage (MV) circuits. DGs of capacity greater than 10 MW are owned and operated by Small Power Producers (SPPs). DGs of capacity less than 10 MW are owned and operated by Very Small Power Producers (VSPPs). The DGs include PV-Solar and Wind-Turbine units.

The adopted standard for MV power distribution in the Northern, Northeastern, Central, and upper section of the Southern region is 22 kV. For the lower section of the Southern region, it is 33 kV. The 115 kV and 69 kV voltages are used by the Authority's HV sub-transmission system, where 115 kV is mostly used in those areas where several large industrial customers are located. Mostly meshed circuit interconnections apply at the HV network level, whereas MV circuits are operated as open-loop (radial) feeders entirely.

For Volt/Var control, HV/MV transformer taps, line regulators (automatic voltage regulators), and capacitor banks are deployed.

MV feeder protection equipment includes circuit breakers at substations, line reclosers for main lines, and dropout fuse cutouts for branch lines. The radial feeders in their open-loop configurations include manually controlled group operating switches and remotely controlled load break switches that, as normally open tie points, allow for MV network re-configuration when necessary. The feeders also include remotely controlled load break switches and line reclosers as well as manually controlled group operating switches that together with remotely controlled substation circuit breakers or line reclosers are used to sectionalize feeders.

2.2 Existing Facilities

Authority HV/MV power system operations currently utilize a SCADA/EMS/DMS at the Bangkok control center known as the System Management Center (SMC), a SCADA/DMS at each of twelve (12) other control centers, known as Area Distribution Dispatching Centers (ADDCs), and another SCADA/DMS at one (1) control center known as the Phuket Distribution Dispatching Center (PDDC).

The SCADA/DMS at the SMC along with those at five (5) ADDCs were commissioned in 2004 as part of the Authority's Distribution Dispatching Center Project 1st Stage (DDC1). Subsequently, in 2008, the SCADA/DMS at the SMC was upgraded to a SCADA/EMS/DMS system by adding a suite of HV functions. The locations of these control centers are identified as follows:

1) SMC at Authority Headquarters (Bangkok)
2) ADDC-C1 in Central Region Area 1 (Ayutthaya)
3) ADDC-C2 in Central Region Area 2 (Chon Buri)
4) ADDC-C3 in Central Region Area 3 (Nakhon Pathom)
5) ADDC-S1 in Southern Region Area 1 (Phetcha Buri)
6) ADDC-N3 in Northern Region Area 3 (Lop Buri)

The main functions resulting from the DDC1 project are listed as follows:

- SCADA
- Data Exchange
- Switching Management System
- HV State Estimation
- HV Contingency Analysis
- HV Power Flow
- MV Demand Estimation
- MV Power Flow (3-phase unbalanced)
- Short-Circuit Analysis
- Load Forecast
- Fault Isolation and System Restoration
- Load Shed and Restore (fixed and rotating)
- Volt/Var Control
- Historical Information System

A Dispatcher Training Simulator (DTS) was also provided.

The Distribution Dispatching Center Project 2nd Stage (DDC2) then led to the 2012 commissioning of SCADA/DMS systems at the following seven (7) ADDCs:

1) ADDC-N1 in Northern Region Area 1 (Lamphun)
2) ADDC-N2 in Northern Region Area 2 (Phitsanulok)
3) ADDC-NE1 in North Eastern Region Area 1 (Udonthani)
4) ADDC-NE2 in North Eastern Region Area 2 (Ubon Ratchathani)
5) ADDC-NE3 in North Eastern Region Area 3 (Nakhon Ratchasima)
6) ADDC-S2 in Southern Region Area 2 (Nakhon Sri Thammarat)
7) ADDC-S3 in Southern Region Area 3 (Songkhla)

The main functions corresponding to DDC2 are listed as follows:

- MV State Estimation
- MV Power Flow (3-phase unbalanced)
- Short-Circuit Analysis
- Load Forecast
- Fault Isolation and System Restoration
- Load Shed and Restore (fixed and rotating)
- Integrated Voltage/Var Control
- Historical Information System.
- Data Exchange
- Access to the HV functions hosted by the SCADA/EMS/DMS at the SMC

An additional SCADA/DMS was commissioned in 2014. Installed at the PDDC, it supports Authority power system operations throughout the island of Phuket. It falls within the responsibilities of ADDC-S2 and, for DDIP purposes, the PDDC is considered as another DDC2 control center.

SCADA as hosted by the existing systems supports interoperation with field device interfaces using the DNP3.0 (serial) data communications protocol. The field device interfaces include:

1) Substation RTUs (SRTUs)

2) Computer-Based Substation Control Systems (CSCSs)

3) Feeder RTUs (FRTUs) at the following pole-top sites:

    a) Remote Controlled Switch (RCS)[1] sites

    b) Line Recloser (LRC) sites

    c) Line Recloser/Regulator (LRR) sites

    d) Switched Capacitor Bank (SCB) sites

Communication with SRTUs and CSCSs uses serial channels over the Authority's extensive Optical Fiber Backbone (OFB) communications system. The OFB communications system is based on Synchronous Digital Hierarchical (SDH) technology, providing point-to-point communications over

[1] Used throughout the Technical Specifications, Remote Controlled Switch (RCS) is used by the Authority to denote a remotely controlled Load Break Switch (LBS).

Dense Wavelength Division Multiplexing (DWDM) core channels, Synchronous Transport Module (STM) core channels, and STM access channels. These channels operate over Optical Line Termination Equipment (OLTE) and, in general, ITU G.655 and G.652 All-Dielectric Self-Supporting **(**ADSS) optical fiber cable.

To reach most feeder sites beyond substation perimeters, Multiple Address Radio System (MARS) networks augmenting the OFB communications system are deployed. They consist of master, repeater, and remote radios that operate in cells within the UHF band of 450 MHz. The master radios are installed at Authority substation and electric office sites. Communications with FRTUs at SCB sites utilize third-party mobile telephone services. The MARS networks are also referred to as Wireless (WRL) networks.

The Data Exchange function hosted by the existing systems supports interfaces with the Authority's Outage Management System (OMS). The main OMS servers are located at Authority headquarters in Bangkok. They are accessible via the Corporate Wide Area Network (WAN).

Data Exchange also supports the SMC system's data exchange with the EGAT SCADA/EMS and each ADDC system. These data exchanges, over the Authority's OFB communications system, use the ICCP (TASE.2) protocol.

The DDC1 and DDC2 systems use data from the Authority's GIS to maintain their database and displays. The GIS is a hierarchical system having a server at Authority headquarters as well as servers in each of the Authority's administrative areas. Each area server is located on the Corporate WAN. Currently, however, on-line data exchange links between the GIS and the DDC1 and DDC2 systems are not utilized.

2.3 Operational Context

Currently, dispatcher responsibilities at the SMC and ADDCs are such that:

1) Dispatchers, at ADDCs provided as part of DDC1, monitor and control the HV and MV power system networks within their specific areas of responsibility. However, as they only have access to their local SCADA/DMS functions, they need to closely coordinate their HV operations with SMC dispatchers, who have access to EMS functions as well as SCADA/DMS functions.

2) Dispatchers, at ADDCs provided as part of DDC2, also monitor and control the HV and MV power system networks within their specific areas of responsibility. In this case, they have remote access to the EMS functions at the SMC as well, so that they can execute functions such as the HV power flow and contingency analysis functions independently of the SMC dispatchers.

3) SMC dispatchers can monitor MV networks and, if necessary, send controls to operate MV network devices. They can also execute the SMC system's DMS functions. Their primary concern, however, lies with monitoring and controlling the HV network and, in this regard, make use of the SMC system's EMS functions. Other related activities include:

a) Monitoring, coordinating, and supervising ADDC dispatcher control of the HV power system network.

b) Maintaining HV and MV load forecasts for each area as well as for the overall service territory.

c) In response to EGAT requests to shed load, deciding how much load should be shed in each area and then directing ADDC dispatchers to shed and ultimately restore load accordingly.

To support dispatcher responsibilities, SCADA at each ADDC collects real-time data from its field device interfaces and sends any required control commands to power system devices via these same interfaces. SCADA at the SMC has similar functionality, but the collection of real-time data and the sending of control commands is implemented indirectly via SCADA at the ADDCs, i.e., the SMC does not communicate with field device interfaces directly.

3. DDIP Overview

3.1 Objectives and Goals

As already stated, the main objective of the Distribution Dispatching Center Improvement Project (DDIP) is to enhance the ability of the Authority to supply electric power to customers throughout its service territory reliably, safely, and economically. Improvement is based on:

1) Replacement of all DDC1 systems because they have become difficult and costly to maintain and are largely obsolete.

2) Replacement of all DDC2 systems, not because they are obsolete, but to take the opportunity to provide upgraded facilities in alignment with the more functional architecture that the new DDC1 and DDC2 systems will support.

Within this context, some key project goals include:

1) Provision of a disaster recovery/control center backup capability, which currently is not supported.

2) Deployment of more powerful physical servers that allow the benefits of virtual machine technology to be realized.

3) Deployment of enhanced cyber security measures based on latest security standards and practices.

4) Replacement of systems and no-longer viable RCS field device interfaces such that the benefits of using Ethernet/IP rather than serial data communications can also be realized.

5) Deployment of new RCS field device interfaces in existing or new RCS control cabinets, these new field device interfaces in the form of a Field Device Control Unit (FDCU) will provide integrated FRTU/RCS controller functionality.

6) Utilization of DNP 3.0 (Secure Authentication) over IP as the data communications protocol in place of the presently utilized DNP 3.0 profile, which does not include secure authentication and is used for serial communications.

7) Future proofing such that the new RCS field device interfaces can also support IEC 61850.

8) Enhanced system integration support via capabilities and features allowing the DDIP systems to interface with Authority GIS, OMS, MDMS, AMS, and substation CCTV systems via an enterprise service bus utilizing standards such as the Common Information Model (CIM).

9) Enhanced support for external users on the Authority's Corporate WAN, including field crew use of mobile devices such as tablets and smart phones.

10) Replacement of the existing MARS networks by UHF radio equipment comprising modern WRL networks supporting higher data rates, Ethernet/IP communications, and necessary security features.

11) Replacement of DDC1 video display walls to take advantage of the latest technology available.

12) Installation of Terminal Servers to convert existing CSCS and SRTU connections to the Authority's OFB network from Serial to Ethernet, thereby supporting IP-based communications with the TDMS.

3.2 Required System Architecture

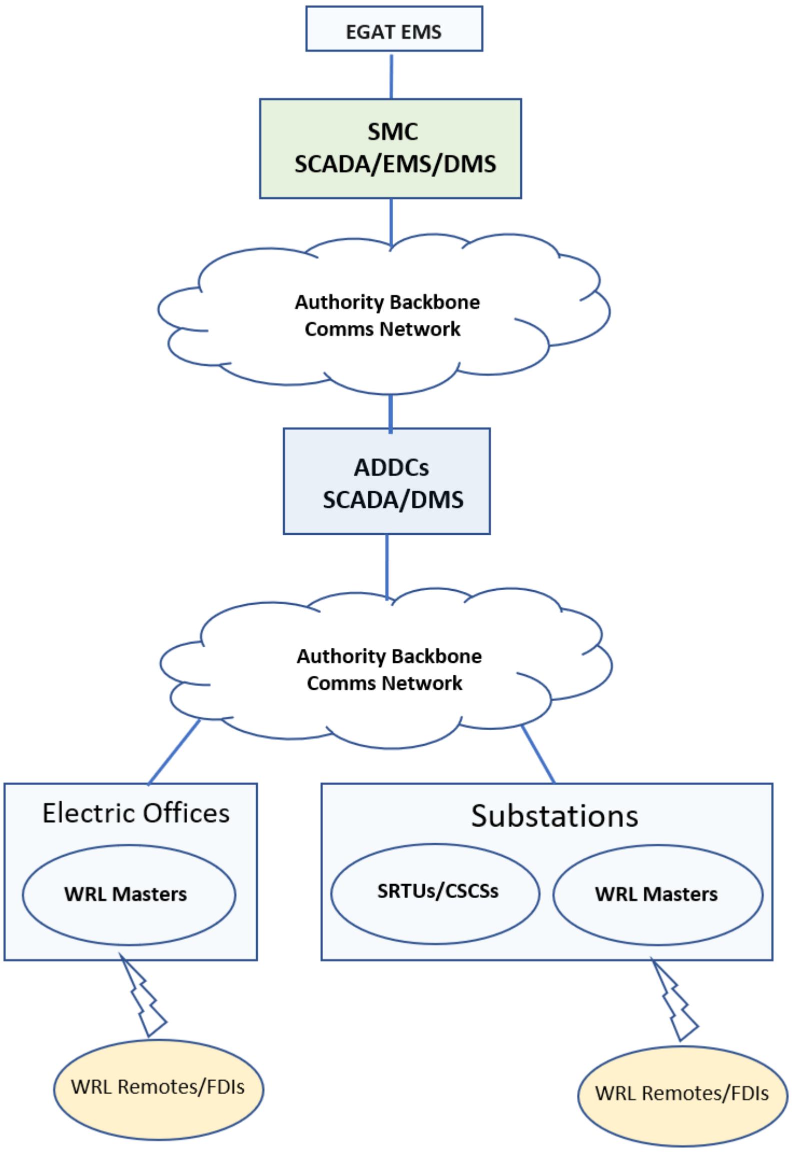
Compared to the existing DDC1/DDC2 architecture, which consists of individual SCADA/EMS/DMS or SCADA/DMS systems at 14 Authority control centers, the required architecture for DDIP is designed to provide a new SCADA/EMS/DMS capable of serving as a centralized common resource for these same 14 control centers. On this basis, to access the functional capabilities and features of the new SCADA/EMS/DMS, referred to hereafter as the Transmission and Distribution Management System (TDMS), the dispatchers at all control centers will be provided with remote client workstations. This avoids the need for individual SCADA/EMS/DMS or SCADA/DMS systems at the control centers.

Conceptually, the differences between the existing and new architectures are illustrated by comparing Exhibit 3-1 and ผิดพลาด! ไม่พบแหล่งการอ้างอิง.

In Exhibit 3-1, SMC personnel notwithstanding, the SCADA/DMS at each control center receives, processes, stores, and displays data for use by its own dispatcher and data engineering personnel. This is based on system data communications with its own set of Field Device Interfaces (FDIs), i.e., the FDIs located at the system's substation and feeder sites.

In contrast, as shown in ผิดพลาด! ไม่พบแหล่งการอ้างอิง, the new architecture leads to a situation in which the TDMS servers at two data centers communicate with the substation and feeder-located FDIs, where the two data centers represent ICT facilities that are to be built as part of a separate Authority project. By having TDMS servers at both data centers, the DDIP goal to provide disaster recovery capabilities are met, i.e., if one data center's TDMS functions are no longer available, dispatchers can continue working by accessing the same functions executing on the TDMS servers at the alternative (backup) data center. In addition, with all control centers having access to the same SCADA, EMS, and DMS functions, one or more control centers can serve as backup for any control centers that become non-functional. For example, if one control center goes down, dispatchers at other control centers can be assigned its Areas of Responsibility (AORs). Note that critical TDMS functions at any data center will also be backed up, i.e., these functions will be supported by redundant servers so that, if a server goes down, failover to the backup server will take place.

Exhibit 3-1: Existing DDC1/DDC2 Architecture (Conceptual)



3.3 Summary of Benefits

Some of the expected benefits of the new architecture resulting from DDIP are summarized as follows:

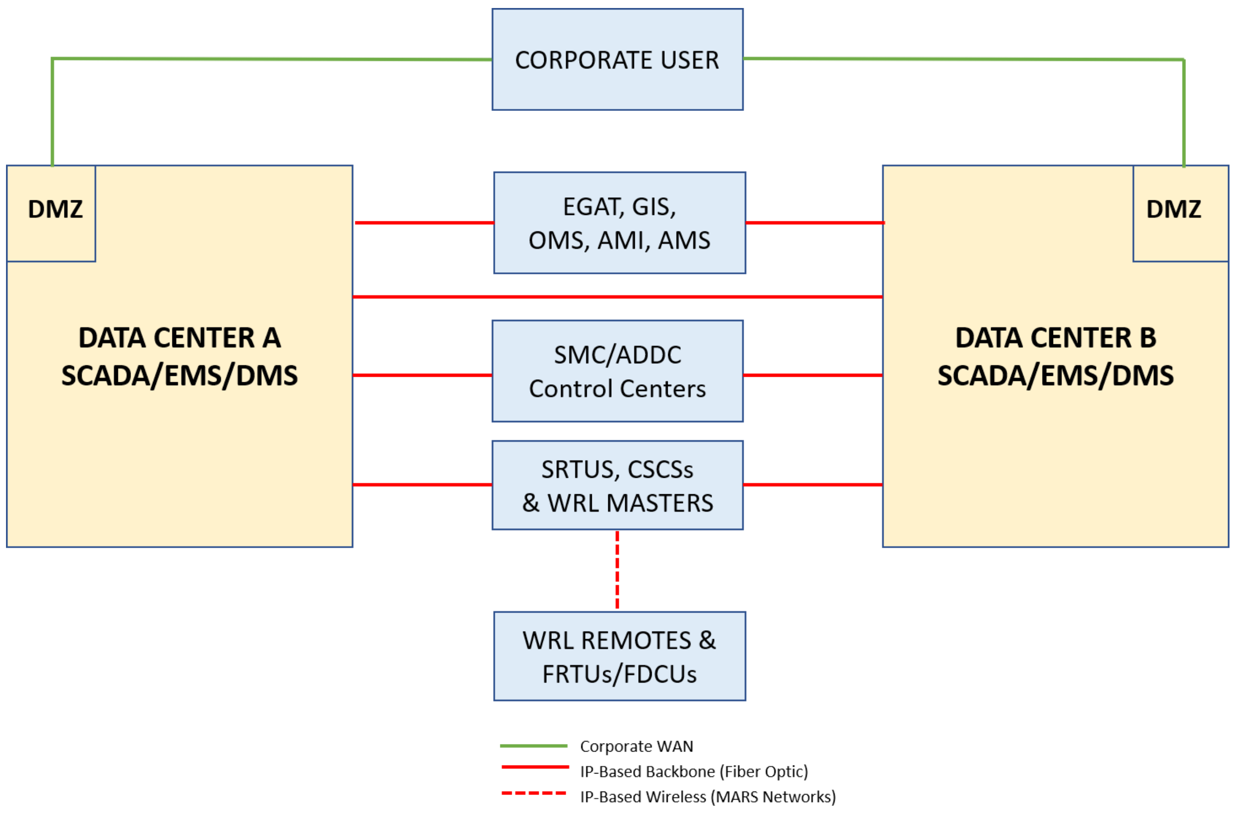
1) Less costly system procurement, implementation, and maintenance costs.

2) Server platforms located in ICT Data Center environments with already built-in facilities such as reliable power supplies, air-conditioning, enclosures, and physical security procedures.

3) Disaster Recovery capability at the SMC/ADDC as well as Data Center levels.

4) Only one integrated HV/MV power system network model to maintain, thereby supporting centralized, more reliable and efficient, creation and incremental update procedures for not only the model, but also displays associated with the model. This also provides for a more reliable and efficient process for testing model and display updates and then sending and checking them out in the system's on-line production environment.

Exhibit 3-2: New DDIP Architecture (Conceptual)



5) Despite centralization of the TDMS servers, data engineering still capable of being supported remotely from the 14 control centers.

6) Centralized and hence more efficient approach to installing, testing, and applying software patches and upgrades including security patches.

7) Less complex deployment of cyber security measures.

8) Much reduced hardware and software to maintain at control centers where essentially only dispatcher consoles are required.

9) Via virtualization, server consolidation, increased utilization, less rack space, and faster failure recovery times.

10) Less complex system integration requirements from the perspective of interfacing the TDMS with Authority GIS, OMS, MDMS, AMS, and substation CCTV systems.

4. DDIP Scope of Work

The scope of work for DDIP concerns three (3) main components as follows:

1) Procurement, development, testing, delivery, installation, and commissioning of new SCADA, EMS, and DMS hardware and software in the form of the Transmission and Distribution Management System (TDMS). This includes the TDMS servers to be located at the Authority's two new data centers, remote workstations to be located at the 14 control centers, new video walls at the six (6) DDC1 control centers, and all other hardware, software, deliverables, and services to meet the Authority requirements as described in Technical Specifications, Part B: TDMS Replacement of Existing Systems.

2) Procurement, development, testing, delivery, installation, and commissioning of Field Device Interfaces (FDIs) in the form of numerous Field Device Control Units (FDCUs) for existing pole-top located Remote-Control Switches (RCSs). This includes all other hardware, software, deliverables, and services to meet the Authority requirements as described in Technical Specifications, Part B: Field Device Interfaces.

3) Procurement, development, testing, delivery, installation, and commissioning of UHF radio equipment in the form of numerous master/remote radio cells supporting TDMS communications with not only the FDCUs, as referenced above, but also the existing FDIs that serve as FRTUs for pole-top located Line Reclosers (LRCs) and Line Recloser/Regulators (LRRs). This includes all other hardware, software, deliverables, and services to meet the Authority requirements as described in Technical Specifications, Part C: Wireless Communications System.

5. Award of Contracts

To carry out the work described in Clause 4 above, five (5) separate but interrelated contracts will be awarded. These contracts are listed as follows:

1) Contract No. 1: To undertake the TDMS scope of work.

2) Contract No. 2A: To undertake the Field Device Control Unit (FDCU) and Wireless Communications System (WRL) scope of work as applicable to the Authority's Northern (N) region.

3) Contract No. 2B: To undertake the FDCU and WRL scope of work as applicable to the Authority's North Eastern (NE) region.

4) Contract No. 2C: To undertake the FDCU and WRL scope of work as applicable to the Authority's Central (C) region.

5) Contract No. 2D: To undertake the FDCU and WRL scope of work as applicable to the Authority's Southern (S) region.

6. Contract Interdependencies

Whereas Contract No. 2A, 2B, 2C, and 2D could be carried out independently of each other, their common interdependencies with the work to be carried out under Contract No. 1 must be recognized. In this respect, the Contractors responsible for the FDCU/WRL scope of work shall cooperate closely in a comparable, compatible, and consistent way with Contractor No. 1 (the TDMS Contractor) to ensure that the Authority's functional, capacity, performance, and security requirements are met from an overall project perspective. To this end:

1) All contractors (including the suppliers of the TDMS, the different FDCUs, and the different UHF radio equipment) shall cooperate in early integration tests as part of a Joint Development program. The aim of the program is to demonstrate the ability of the TDMS to interoperate successfully with the FDCU and radio equipment via a common DNP 3.0 profile and thereby minimize potential problems during subsequent on-site point-to-point testing. The proposals of all contractors shall have described their suggested approach to the Joint Development program to help finalize and reach agreement on a detailed and comprehensive plan for the program as soon as possible after DDIP implementation begins.

2) Contractor No. 1 shall be responsible for helping the Authority coordinate the work of the other contractors. This shall include taking the lead in the above referenced Joint Development program as well as calling for meetings as may be necessary to identify and resolve common design, test, and schedule issues. It shall also include responsibility for proposing solutions to the technical problems that may arise during the process of integrating the FDCUs, including the WRL radio equipment, so that they interoperate with the TDMS successfully.

3) Contractor No. 2A, 2B, 2C, and 2D shall be responsible for ensuring that the FDCUs can interoperate with the TDMS in accordance with the DNP 3.0 and IEC 61850 profiles proposed by Contractor No. 1 provided these profiles are approved by the Authority. This includes responsibility for reaching a collective agreement with Contractor No. 1 with respect to the procedures for remote configuration, updating, and diagnostic testing of the FDCUs and WRL radio equipment from the TDMS.

4) Contractor No. 2A, 2B, 2C, and 2D shall provide Contractor No. 1 with representative FDCU and UHF radio equipment so that it can be used during factory development and testing of the TDMS. This will help determine if the equipment is interoperable and, if not, what steps should be taken to rectify the problem. Responsibility for returning the FDCU and UHF radio equipment undamaged and in good working order shall rest with Contactor No. 1.

5) Contractor No. 1 shall be responsible for providing several laptop test sets that simulate the SCADA functionality of the TDMS and can be used by the other 4 Contractors to help validate

the interoperability of their FDCUs during FDCU factory development and testing. These test sets, referred to as DAC Simulators, can also be used during FDCU on-site installation tests prior to point-to-point testing with the actual TDMS. The FDCU/WRL Contractors shall return the DAC Simulators undamaged and in good working order.

6) Contractor No. 1 shall take the lead during on-site point-to-point testing of the TDMS with respect to all FDCUs and FRTUs. These are the FRTUs already existing at LRC and LRR sites where the other 4 Contractors have the additional responsibility to install remote radios as part of their WRL communications system scope of work. To support all such point-to-point testing, the other 4 Contractors shall have personnel available to participate and help resolve any FDCU or WRL communication problems that may arise.

7. Project Schedule

Contractors shall have provided detailed project implementation plans in their proposals that are consistent with the Authority's overall schedule requirements. These plans shall have identified all major milestones, tasks, and the nature of all information and support expected from the Authority. Details shall have included relevant schedules for design, development, factory testing, delivery, documentation, training, local transportation, installation, site testing, acceptance testing, and all other activities, such as progress and design review meetings, as required to complete all tasks. In addition, during contract negotiations, these project plans will have been fine-tuned if necessary to ensure the goals of the project are met as effectively and efficiently as possible.

Otherwise, as a guide to completing the DDIP, the Authority's general requirements pertaining to implementation of the overall project within a 36-month schedule are presented, as follows in terms of specific milestone requirements, noting that, for the TDMS project, an additional 3 months for completing the system availability test is added. These requirements relate to "technical" milestones, which are not necessarily the same as "payment" milestones.

7.1 Contract No. 1

Following the effective date of contract, work shall begin immediately on all aspects of Contract No. 1. Subsequently, in completing the work, the following milestones shall be met where the specified times of completion are in months after the effective date of contract:

1) ***Milestone No. 1*** – Delivery of required Documentation Plan. (*1 month*)

2) ***Milestone No. 2*** – Early delivery, installation, and demonstration of the required Development System (DVS) and Quality Assessment System (QAS) comprising a preliminary form of the TDMS Pre-Production Environment (PPE), including relevant documentation such as functional design documents, display style guides, and user manuals. The early DVS and QAS in their final PPE configurations will be installed in one of the Authority's new Data Centers. On initial delivery, however, they may be temporarily installed and utilized in the SMC building. (*4 months*)

3) ***Milestone No. 3*** – Completion of all necessary training so that Authority personnel can use the DVS and QAS effectively to include, for example, the import of data from the Authority's new GIS (if available), the migration of data and displays from the Authority's existing systems, the building of new displays and dashboards, the creation of reports, the testing of databases, displays, and reports from a pre-production user interface perspective. (*6 months*)

4) ***Milestone No. 4*** – Completion of the Joint Development program with all other contractors. (*12 months)*

5) ***Milestone No. 5*** – Delivery of DAC Simulators to Authority headquarters, including relevant documentation such as functional design and user manuals, and demonstration and training of Authority personnel in practical use of the simulators to test and verify that field device interfaces are SCADA ready. Within this period, DAC Simulators will be picked up for use by the FDCU/WRL Contractors. (13 *months*)

6) ***Milestone No. 6*** – Completion of databases, displays, and reports sufficient to support TDMS factory testing. (15 *months*)

7) ***Milestone No. 7*** – Completion of QAS training, including delivery of relevant documentation, such that Authority personnel can use the QAS to help perform field device interface and communications point-to-point testing as the field device interfaces and their communication facilities become available. (18 *months*)

8) ***Milestone No. 8*** – Delivery of all functional and detailed design documents, user manuals, test plans, and test procedures required to support TDMS factory testing. (21 *months*)

9) ***Milestone No. 9*** – Completion of the TDMS Factory Acceptance Test (FAT) and delivery of the FAT report and Contractor's finalized system cut-over plan. (*27 months*)

10) ***Milestone No. 10*** – Delivery, installation, and TDMS pre-commissioning including integration of the early Development System (upgraded in its final configuration), completion of all remote workstation and video wall display installations (including preliminary interoperability testing), and delivery of all remaining documentation. (33 *months)*

11) ***Milestone No. 11*** – Delivery of all required TDMS training including training materials. (33 months)

12) Milestone No. 12 – Completion of TDMS cut-over and commissioning. This includes completion of the TDMS Site Acceptance Test (SAT) to verify successful power system operations from all control centers, completion (ideally) of all FDI point-to-point testing, secure Corporate user access, and system integration testing, where system integration relates to TDMS interfaces with Authority GIS, OMS, MDMS, AMS, existing video wall, and substation CCTV systems, and with EGAT EMS systems. It also includes system vulnerability testing (an audit) to determine how successful the system's cyber security measures have been implemented. (*36 months*)

13) ***Milestone No. 13*** – Delivery of as-built drawings and completion of the TDMS availability test while running under typical operating conditions (39 *months*).

7.2 Contract No. 2A, 2B, 2C, and 2D

The milestones for the FDCU/WRL scope of work are listed as follows where again (as for Contract No. 1) the specified times of completion are in months after the effective date of contract:

1) ***Milestone No. 1*** – Delivery of required Documentation Plan. (*1 month*)

2) ***Milestone No. 2*** – Completion of full functional testing of prototype FDCU and UHF radio equipment including submission of any necessary type test certificates and test reports. (*6 months*)

3) ***Milestone No. 3*** – Completion of the UHF Study Report that, based on terrain and site surveys (including signal-level measurements and performance calculations), will be used to finalize WRL communications system design details. (6 *months*).

4) ***Milestone No. 4*** – Delivery of functional and detailed design documents, user manuals, test plans, and test procedures as required to support factory testing of FDCU and UHF radio equipment. (9 *months*)

5) ***Milestone No. 5*** – Delivery of representative FDCU and UHF radio equipment to the factory of Contractor No. 1 for use in TDMS development and testing. (9 *months*)

6) ***Milestone No***. 6 – Completion of the Joint Development program with Contractor No. 1. (*12 months*)

7) ***Milestone No. 7*** – Delivery of all required FDCU and WRL communications system training including training materials. (12 months)

8) ***Milestone No. 8*** – Completion of all FDCU and UHF communications testing in the form of formal Authority-witnessed factory testing (including utilization of the DAC Simulator provided by Contractor No. 1), routine production testing prior to shipment of the equipment, and delivery of corresponding test reports. (15 *months*)

9) ***Milestone No. 9*** – Delivery, installation, and unit testing of all FDCU and UHF radio equipment at their assigned sites, including interoperability testing via the DAC simulators provided by Contractor No. 1 and support for point-to-point testing with the Contract No. 1 QAS and TDMS. (*36 months*).

8. Software Licenses

Software licenses for contractor and/or third-party supplied software shall be irrevocable “enterprise-wide” licenses. These licenses shall also apply at no additional cost to all servers, workstations, and/or other equipment that the Authority may acquire from any source to upgrade or replace such equipment as initially delivered and commissioned by contractors to meet the Authority's Technical Specifications. Contractor proposals shall have clarified what extra licensing may be required in the event the upgrade or replacement leads to a greater number of servers, workstations, and/or other equipment (including a greater number of CPUs) executing the licensed software.