# GUAM POWER AUTHORITY

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TRANSMISSION AND DISTRIBUTION

SPECIFICATION NO. E-028

FOR

## SCADA

## REMOTE TERMINAL UNITS

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## 1.0 General

This document contains the specifications for the remote terminal units (RTUs) to be supplied to the Guam Power Authority (Purchaser). Information concerning the Purchaser's objectives is presented in the form of acceptable design approaches. These suggested designs are not to be considered restrictive to the Contractor. Alternate designs which satisfy the Purchaser's functional requirements will be considered if clearly described by the Contractor.

The comparison of the functional requirements to the Contractor's standard hardware and firmware may cause the Contractor to conclude that there is a need for additional items not specifically mentioned in this specification. The Contractor shall supply all such items and propose a design which best meets the Purchaser's functional requirements.

## 1.1 Scope

The RTUs to be purchased under this specification shall acquire substation data used for power system monitoring and accounting purposes. The RTUs will also be used to transmit control actions to substation equipment including circuit breakers, tap-changing transformers, and interposing relays. The RTUs shall operate with the existing TRW SCADA system using the TRW communication protocol (RTU Model 2990, Message Format 9550).

## 1.2 RTU Subcontractor Relationship

The Contractor shall be responsible for providing the complete RTUs. Should the Contractor elect to subcontract manufacturing of any part of the RTUs, it shall remain the Contractor's responsibility to manage the RTU procurement as the RTU Contractor. All RTU procurement correspondence shall be between the Contractor's project manager and the Purchaser's project manager.

## 2.0 Remote Terminal Unit Functions

This section describes the functions to be performed by the RTUs. Each function is presented in sufficient detail to provide the Contractor with as much insight as possible into both the initial and future requirements of the RTUs. All functions described herein shall be provided by the Contractor even if the RTU is not initially equipped. It is the Purchaser's intent that the Contractor use as much standard hardware and firmware as possible; however, all of the functional requirements of this specification must be satisfied.

## 2.1 Data Acquisition

Power system analog and discrete input data shall be collected by the RTUs. Data will be retrieved from the RTUs as collections of points referred to as scan groups. Each scan group will consist of discrete inputs, analog inputs, or a mixture thereof. Momentary change detection (MCD) points shall also return an indication of multiple operations. The Contractor shall provide a convenient and flexible scheme for assigning points in the RTU to scan groups. The Contractor shall provide all special equipment necessary to assign points to the RTU database and scan groups (such as jumper plugs or PROM programmers).

## 2.2 Sequence-of-Events Reporting

The RTU shall be capable of sequence of events (SOE) data collection at a time resolution less than the operating speeds of the power system devices. The time resolution will enable the Purchaser's operating and engineering personnel to determine the cause and effect relationship of the device state changes throughout normal and abnormal operations.

Any discrete hardware input point in the RTU may be assigned, programmably, as an SOE point.

## 2.3 Device Control

The RTU shall provide the capability for the SCADA system to select and control specified discrete outputs. Device control will be used to control the following devices:

(a) Two-state Devices - Momentary control of circuit breakers, auto/manual switches, motor-operated disconnects, relay disable, and other two-state devices

(b) Multi-state Devices - Jog raise/lower control of load-tap-changers (LTC), and other multi-state devices

(c) AGC Raise/Lower Control - Pulse-duration control of generation MW levels through variable duration raise and lower pulses (future)

(d) AGC Setpoint Control - Setpoint output control of generation MW levels through an analog output signal (future).

## 3.0 Remote Terminal Unit Characteristics

The Contractor shall supply RTUs for interfacing to remotely-located devices in the power system. Analog input, discrete input, and control output interfaces are required. Appendix A quantifies the input and output point complement required for each RTU. The Contractor's RTUs shall support all future requirements of this specification regardless of their exclusion from the initial RTUs procured.

## 3.1 Communication Interface

The Purchaser will supply communication channels between the RTUs and the master station. Use of dedicated or party-lined channels shall be supported. The communication interface shall support a communication rate at up to 4800 bits-per-second, initially at 1200 bits-per-second. The communication interface shall support the equivalent of unconditioned, 4-wire, full-duplex, voice-grade, Bell type 3002, leased telephone and power line carrier communication channels using the modems described below.

The RTU shall be capable of operation at up to 4800 bits-per-second using appropriate modems or RS-232C serial interface. For initial SCADA system operation the Contractor shall supply asynchronous FSK modems for operation at 1200 bits-per-second using the four-wire circuits for RTU communication with the SCADA system. The modems shall not require manual equalization and shall include self-test features such as manual mark/space keying, analog loop-back, and digital loop-back.

## 3.2 Communication Protocol

The Contractor shall provide the TRW RTU communication protocol for the RTU Model 2990, Message Format 9550.

### 3.2.1 Channel Control

The RTU shall perform as a slave on the communication channel. All communication shall be initiated by the master station. Where the RTU must notify the master station of an unusual condition at the RTU (such as an RTU malfunction), or must initiate the transfer of periodic data, the notification shall be accomplished within the framework of the periodic data acquisition exchanges.

### 3.2.2 Scan Groups

Analog and discrete input points (including points reported by exception) shall be assignable to scan groups (specified sets of data points which will be communicated to the master station when addressed by a scan command). Any input point shall be assignable to any scan group. The RTUs shall support at least sixteen scan groups including the following initial assignments:

(a) Status change detection every two (2) seconds

(b) Analog data for AGC every four (4) seconds (future)

(c) General substation analog data every ten (10) seconds

(d) Integrity scan of all data every ten (10) minutes.

### 3.2.3 Status Exception Reporting

The RTU shall report status changes by exception. That is, the reply to a scan command may consist of a flag bit (or group of flag bits) indicating the presence or absence of a change of the points represented by the flag bit(s). The master station can then demand-scan the changed points. The flag bit(s) shall be reset only after the master station acknowledges successful receipt of the data represented by the flag(s). The protocol shall allow the master station to demand scan status data even if the data has not changed.

### 3.2.4 Control Security

Operation of control outputs (as defined in Section 3.6) shall be via a select-check-before-execute command sequence. The sequence shall operate as follows:

(a) The master station shall transmit a command message addressing the proper RTU and the control point within the RTU, and indicate the control action desired (such as trip).

(b) The RTU shall initialize its control logic, reassemble the command message, and transmit the reassembled message to the master station. The message sent to the master station shall be generated by the RTUs point selection logic; it shall not be a simple repeat of the master station's transmission.

(c) The master station shall check the returned message for validity and, if valid, shall issue an execute message to the RTU.

(d) The RTU shall only operate the control point selected, and only after the execute command has been received.

The control action shall be executed only if the check-before-execute sequence is performed without error or interruption by other messages. The RTU shall reset its control logic upon any error in the sequence or if the execute message is not received within 10 seconds of the command message.

### 3.2.5 Message Security

Each message transmitted shall include an error code, the use of which shall result in a very low probability of an erroneous message being accepted as valid.

## 3.3 Analog Inputs

The analog input accuracy, as defined in ANSI MC8.1, shall be 99.9% or better at 25°C ambient temperature. Mean accuracy, also defined in ANSI MC8.1, shall drift no more than 0.002% per °C within the temperature range of -20 to +60 °C. Determination of accuracy shall be made while the analog multiplexor is operating at rated speed. The analog-to-digital converter shall provide a minimum precision of 4096 counts (sign + 11 bits). The effect of common-mode voltage on the accuracy of differential inputs shall be less than 0.1% of full scale when tested at a common-mode voltage of 50 Vac peak-to-peak at 60 Hz. The effect of normal-mode voltage on accuracy shall be less than 0.1% of full scale when tested at a normal-mode voltage equal to the full scale input voltage at 60 Hz. Analog inputs shall be two-wire with a shield. Shield ground facility shall be provided for each input point.

The Contractor shall provide all appropriate signal level conversion and conditioning to allow full utilization of analog inputs and meaningful reasonability checking. Including signal conditioning components, the input impedance for voltage inputs shall not be less than 1 meg-ohm; the input impedance for current inputs shall not be greater than 5 kilo-ohm. Input scaling shall allow for 50% overrange.

The analog input shall be current inputs: isolated, unipolar or bipolar, 2-wire ungrounded differential signals with a range of 0 to +1 ma. Shield ground facilities shall be provided.

### 3.4 Discrete Inputs

The discrete input interface shall be capable of accepting isolated wet or dry contact status inputs. The Contractor shall supply the necessary sensing voltage, current limiting, optical isolators, and debounce filtering. The sensing voltage shall not exceed 24 Vdc and shall be supplied from a source separate from that of the RTU's logic power supplies such that application of a short circuit across the sensing power supply's output terminals shall not disrupt operation of the RTU (except for the shorted discrete inputs).

The following discrete input types shall be accommodated by the RTUs where any state of the input may represent a state of the device:

(a) Status Points - Detection of slower operating two-state status points. The status point input shall be from a form "A" or "B" contact. The RTU shall be initially set to capture contact operations of 20 ms or more duration. Operations of less than 20 ms duration shall be considered no change (contact bounce). The duration used to determine change vs. bounce shall be adjustable from 4 to 25 ms.

(b) Momentary Change Detection (MCD) Status Points - Detection of multiple operations of some two-state devices where the multiple operations will occur between RTU scans. The MCD status points shall be initially set to capture operations of 8 ms duration. Operations of less than 8 ms shall be considered no change (contact bounce). The duration used to determine change vs. bounce shall be adjustable from 4 to 25 ms.

(c) Accumulator Pulse (future) - A facility for counting and storing the number of contact closures generated by a device external to the RTU. The device will supply an isolated Form A, B, or C contact. The accumulator shall be incremented one count for each transition of the contact (operation of either open or closed contact). Each counter shall be capable of counting at least 4096 input operations before rolling over. The accumulator shall be capable of accepting counts at a rate of ten

counts per second. Similarly, a capability to reset (to zero) accumulator inputs from the master station, by local contact input, or on power-up of the RTU shall be provided.

(d) RTU Local Control Disable - To indicate that the control output capability has been disabled locally at the RTU. This point is not included in the point count provided in Appendix A.

### 3.5 Sequence-of-Events Reporting

Selected discrete input points, in addition to being scanned as status indication points, shall be classified as Sequence-of-Events (SOE) points. An event, for SOE, is defined as a state change, such as a breaker going from open to closed. Multiple transitions of a device, such as the tripping and subsequent reclosing of a breaker, shall be considered as a series of separate events. Each time an event is detected, the RTU shall time-tag the event and store a description and the time-tag of the event in a SOE buffer. The buffer shall be sized to store as a minimum a number of events equal to twice the number of SOE points in the RTU.

The time-tag recorded with each event shall be generated from a clock internal to the RTU. The clock shall generate time codes to a resolution of one millisecond (1 ms). The RTU shall synchronize its internal clock with a SCADA system clock located at the master station. The synchronization shall be coordinated so that the time-tags in each RTU shall be within eight milliseconds (8 ms) accuracy between the RTUs. Periodic updates shall assure that the system-wide accuracy is maintained. The updates shall not interfere with the normal RTU periodic scanning nor shall the procedure add significantly to the communication channel usage.

When commanded, the RTU shall transmit the SOE data stored in its buffer to the master station. An acknowledgement of receipt by the master station shall be made prior to the loss of any data in the RTU SOE buffer. Retransmission of data not received at the master station shall be provided. An indication that event storage at an RTU is approaching capacity shall be transmitted to the master station so that a priority can be set to retrieve the SOE data. An additional indication shall provide the condition of RTU SOE data buffer overflow.

### 3.6 Control Outputs

The RTUs shall provide control outputs as described in the following sections. All discrete control outputs shall be form "A" contacts driving interposing relays rated at 12 amps, 240 VAC.

The operation of control output relays shall be current limited such that only one control output may be "on" at a time. Each control output point shall provide two outputs (e.g. trip and close, raise and lower, etc.).

#### 3.6.1 AGC Raise/Lower (future)

When commanded from the master station, the appropriate raise or lower output shall operate for the timed interval specified by the command message received. Each raise/lower output shall have an operation interval variable over a range of 0.1 to 2.0 seconds, in a minimum of eight equal increments.

#### 3.6.2 Momentary and Jog Control

Each momentary and jog control output shall drive the Purchaser's equipment. When commanded from the master station, the appropriate contact shall be operated for a preset time period. The operation period for all outputs within the RTU (as a group) shall be adjustable from 0.1 to 2 seconds. The operation period shall be initially set at 425 ms.

#### 3.6.3 Control Security

The point selection logic for the control output shall be designed to preclude operation of an unselected output under single component failure conditions. That is, no single component shall be capable of selecting, arming and operating an output point by itself.

#### 3.6.4 Control Disable

The local I/O shall be equipped with a manual switch to disable all control outputs. The outputs shall be disabled by breaking the power supply connection to the control output. An auxiliary contact on the switch shall be wired to a contact input in the RTU to report the control disable switch's status to the master station processor. This contact input is not included in Appendix A.

### 3.7 Analog Output (future)

Analog outputs shall be provided to drive the Purchaser's external equipment. The analog outputs shall have an accuracy, as defined in ANSI MC8.1, of 99.75% of full scale at an ambient temperature of 25°C. Mean accuracy, also as defined in ANSI MC8.1, shall drift no more than 0.01% per °C over a temperature range of -20 to +60 °C. Outputs of 0 to 1 ma, ±1 ma, ±5 Vdc, and 0 to 10 Vdc shall be available. Current outputs shall be capable of driving into a 5,000 ohm load and voltage outputs into a 1,000 ohm load.

### 3.8 Overload Protection

Connection of high-voltage sources to input and output terminals may occur during the life of the equipment. No damage shall occur to any input or output due to continuous normal mode overload of up to 120 Vdc or 120 Vac peak at 60 Hz, or due to imposition of up to 300 Vdc or 300 Vac peak at 60 Hz, between any terminal and ground. Recovery from either type of overload to nominal accuracy shall require less than 5 minutes. The effect on analog accuracy of either type of overload on any adjacent analog channel shall be less than 0.1% of full scale. Input overload response characteristics shall be tested as described in ANSI MC8.1.

Overloads greater than specified above, but less than 600 Vdc or 600 Vac peak may damage some components but shall not result in propagation of any damage beyond the single input, output, or communications circuit at which the overload has occurred.

### 3.9 Surge Withstand Capability

The RTUs shall be able to successfully undergo the tests described in ANSI C37.90a, Guide for Surge Withstand Capability (SWC) Tests. Application of the SWC wave form to any input or output, including the power input and communication channel connections, shall not result in the loss of data from any input or output other than the input or output being tested. The RTU shall not reset or restart its internal logic as a result of SWC wave form application, nor shall the contents of any internal memory be affected by the SWC testing.

### 3.10 Support Facilities

The Purchaser intends to be self-reliant for both RTU hardware and firmware maintenance. To this end, the Contractor shall provide the support hardware, software, firmware, and documentation necessary to repair, configure, and document the RTU. This shall include, but not be limited to, card extensions, test cables, PROM programmer,

maintenance manuals, RTU database compiler, firmware listings, RTU configuration listings, or other support facilities as they are applicable to the Contractor's RTU design.

### 3.11 Environmental Requirements

The RTUs will be installed in control houses initially and possibly outdoors in the future. The RTUs shall be capable of operating in temperatures from -20 to +60 °C and relative humidities from 10 to 95%, non-condensing.

For the RTUs located in a control house, the control houses are equipped with supplemental air conditioning, while no humidity or temperature control is provided. The Contractor shall supply heaters in any outdoor RTUs, as necessary, to meet the above environmental requirements above.

### 3.12 Power Supply

The Purchaser will provide nominal 128 Vdc ±10% (as specified in Appendix A), in compliance with ANSI C37.1-1979, as the power source for the RTUs. The Contractor shall supply any hardware required to convert battery voltage to the required internal voltages for the RTU hardware. The RTUs shall be capable of operating with ungrounded or grounded (either polarity) input power; however, the RTU shall not place a ground on the input power.

Each RTU shall have the capability of automatic startup and initialization following restoration of power after an outage without need of master station intervention. All restarts shall be reported to the master station.

### 3.13 Noise Level

The audible noise generated by the RTU equipment shall not exceed the values for noise criteria curve NC-45 as described in ANSI C37.1 (as extracted from MilSTD-1472).

### 3.14 Assembly and Component Identification

Each assembly (to the level of printed circuit cards) shall be clearly marked with the manufacturer's part number, serial number, and the revision level of the component. Changes to assemblies shall be indicated by an unambiguous change to the marked revision level.

All electronic parts (such as capacitors, resistors, and integrated circuits) shall be marked either with the characteristics of the part or with an industry standard part number. Where custom parts are provided (such as read-only memories), the part shall be marked such as to specifically identify the part where similar parts may exist.

All printed circuit card cages and all slots within the cages shall be clearly labeled. Printed-circuit cards shall be keyed for proper insertion. It is desirable that printed-circuit cards be keyed to prevent insertion into incorrect locations.

### 3.15 Enclosures

The Contractor shall provide enclosures meeting the following requirements:

(a) Finished inside and out. All cabinet metal shall be thoroughly cleaned and sanded, and welds chipped to obtain a clean, smooth finish. All surfaces shall be treated to resist rust and to form a bond between the metal and the paint. RTU enclosures shall be finished a semi-gloss medium gray color.

(b) Freestanding-floor mounted and shall not exceed 96 inches in height, 22 inches in width, or 32 inches in depth.

(c) Maintenance access to the hardware and wiring through lockable, full height, front and rear doors.

(d) Provisions for top and bottom cable entry.

(e) Suitable signal and safety ground networks within the enclosure. The safety ground shall be isolated from the signal ground and shall connect to the ground wire of the power input. The signal ground shall terminate at a separate stud connection sized for connection of a lugged 2/0 ground wire. Each ground network shall be a copper bus bar, braid, or cable. Use of the enclosure frame, skins, or chassis mounting hardware for the ground network is not acceptable.

(f) Supplied with 120 Vac 60 Hz, three-wire duplex, isolated neutral, convenience outlets and a maintenance lamp.

(g) All enclosure doors shall be provided with a key lock to control entry.

(h) All enclosures provided shall be used indoors and shall meet NEMA 12 specifications.

### 3.16 Interconnections

All cabling between component units of the RTU shall be supplied by the Contractor and shall be shown on Contractor supplied drawings. Plug-type connectors with captive fasteners shall be used for all interconnections. The connectors shall be polarized to prevent improper assembly. Each end of interconnection cables shall be identified by a marker which includes the cable number and the identifying number and location of each of the cable's terminations; this information shall agree with the Contractor's drawings. All logic card and cable terminations shall be gold plated to prevent contamination in the high humidity of the Purchaser's environment.

Contractor wiring within enclosures shall be neatly arranged and shall not be directly fastened to the enclosure frame. All internal interconnection wiring and cables shall be routed separately from the Purchaser's field wiring to the RTU terminals. All wiring shall use copper conductors and have flame retardant insulation. PVC insulation is not acceptable. Conductors in multi-conductor cables shall be individually color coded.

The use of nonflammable, self-extinguishing, plastic wire troughs is permissible. Metal clamps must have insulating inserts between the clamps and the wiring. Wiring between stationary and movable components, such as wiring across door hinges or to components mounted on extension slides, shall allow for full movement of the component without binding or chafing of the wiring.

All connections between the RTUs and the Purchaser-supplied signal wiring shall be through barrier-terminal blocks with knife-switch isolation, mounted in the RTU enclosure. Terminal blocks shall be screw-type, with full depth insulating barriers. Terminal blocks for signal inputs shall accommodate #12 AWG wire and shall be rated for 15 amps at 1000 Vrms. Terminal blocks for input power and output signals shall accommodate #10 AWG wire and shall be rated for 30 amps at 2000 Vrms. All terminals and blocks shall be clearly labeled.

No more than two wires shall be connected to any terminal. Adequate space and hardware shall be provided for routing of the field wiring within the enclosures. The Contractor shall provide two input terminals and a shield termination for each analog input signal. Contact input and output signals shall require two terminals per point plus a shield termination for each group of signals.

### 3.17 Spare Parts and Test Equipment

The Contractor shall provide the optimum complement of spare parts and test equipment for the purchased RTUs. Spare parts and test equipment shall be included in the price of the hardware. The Contractor shall itemize and price each item separately.

### 3.18 Portable Test Set

The Contractor shall supply one (1) portable RTU test set for testing RTU operation and communication. The test set shall be capable of emulating both the master station and the RTU. The test set shall have the capability of interfacing to either the analog or digital side of the modem.

The test set shall be capable of receiving single and repeated messages. Each received message shall be checked for validity, including the check code. The test set shall maintain and display error counters so that the number of errors during a period of unattended testing can be accurately determined. The test set shall be capable of formatting and transmitting, both as one-time and periodic transmissions, any master station-to-RTU command. It shall also be possible to prepare illegal messages, such as messages having invalid check codes, for transmission. After the test set has received or transmitted a message, it shall be possible to immediately "turn around" and transmit or receive a response message.

The test set shall also be capable of passively monitoring all communication traffic on a channel without interfering with channel operation. Channel traffic captured in the active or passive modes of test set operation shall be displayed. All fields of a message, excluding only the pre-transmission mark and the soft carrier turnoff, shall be displayed. A pass/fail indication for the check code shall be included with each code displayed.

### 3.19 Availability

The RTUs will perform data acquisition and control of important equipment necessary for the operation of the Purchaser's power system. Any failure of an RTU to perform its functions will adversely affect power system operations. An availability of 99.9% is required exclusive of communication channel availability. An RTU shall be considered unavailable when:

(a) Any function is lost for all points of a single type

(b) One entire data scan group fails

(c) More than one input card or output card of the same type fails

(d) One input card or output card of each type fails.

### 3.20 Maintainability

The RTU design shall facilitate isolation and correction of all failures. The following features which promote rapid problem isolation and replacement of failed components shall be provided:

(a) Self-diagnostic capabilities within each RTU which can be initiated from the master station and at the RTU site

(b) On-line error detection capabilities within the RTU and detailed reporting to the master station of detected errors

(c) Local indication of RTU failures.

### 3.21 Life Span

Each RTU shall have a design life of 20 years from the date of final acceptance. The Contractor shall make available at no cost to the Purchaser the manufacturing drawings and rights to manufacture those subassemblies which the manufacturer will not support or discontinues support for during this life span. For each subassembly, the specific parts supplied shall be identified and referenced in supplied documentation.

## 4.0 Firmware Requirements

The RTUs shall meet the following characteristics of the firmware provided to support the functions of the RTUs. The term firmware, as used in this specification, will mean PROM based software which may be provided to satisfy the Purchaser's requirements. The Contractor shall use standard firmware as much as possible.

### 4.1 Design Characteristics

All firmware shall be completely and consistently documented. It shall not be necessary to perform modification to firmware, logic, or data for expansion within the sizing parameters defined for the RTU.

At the time the RTU is accepted, all firmware delivered must be up to date and in final form, including all standard firmware changes and field changes initiated by the Contractor or the Contractor's suppliers prior to acceptance. The firmware documentation must reflect these changes.

### 4.2 Initialization/Restart Program

Firmware shall be provided to enable the RTU to restart itself automatically for power restoration, memory parity errors, hardware failures, and upon manual request. The firmware shall initialize the RTU and begin execution of the RTU functions without intervention by the master station. All restarts shall be reported to the master station.

### 4.3 RTU Operations Monitoring Firmware

Firmware shall be provided to continuously monitor operation of the RTU and report RTU hardware errors to the master station. The firmware shall check for memory, CPU, and input/output errors and failures.

### 4.4 Database Maintenance

The Contractor shall supply software to configure and document each RTU's database. A compiler shall be provided to completely generate or modify the database of the RTUs. The database compiler shall provide error detection services and shall produce a printed listing of the input data and the resulting RTU configuration.

### 4.5 Diagnostic Firmware

The Contractor shall supply diagnostic firmware with self-diagnostic capability built into the RTU.

## 5.0 Inspection and Test

All RTU materials, hardware, and firmware to be furnished and all work to be performed under this specification shall be subject to inspections and tests. No RTUs shall

be shipped until all required inspections and tests have been made, demonstrating that the equipment conforms to the specification and that the hardware and firmware have been approved for shipment by the Purchaser.

Approval of RTU inspection and test results, acceptance of hardware and firmware, or the waiving of inspection and tests thereof, shall in no way relieve the Contractor of the responsibility for furnishing equipment which meets the requirements of this specification, nor shall such actions invalidate any claim which the Purchaser may make because of defective or unsatisfactory hardware and firmware. The Purchaser reserves the right to request additional tests on the RTUs at no extra charge on any work the Purchaser determines not to be in accordance with this specification.

Whenever the results of any inspections or tests performed or requested by the Purchaser in accordance with the requirements of this section indicate that specific hardware, firmware, or documentation does not meet the specification requirements, the Contractor shall replace, modify, or add, at no cost to the Purchaser, RTU hardware, firmware, or documentation as necessary to correct the noted deficiencies.

**5.1 Inspection**

Representatives of the Purchaser shall have free entry into the shops of the RTU manufacturer at any time while design, fabrication, or testing of the equipment is taking place and into any mill, shop, or factory where the hardware or firmware described in this specification is being produced.

The Contractor shall provide to the Purchaser representatives, free of cost, all reasonable facilities, equipment, and documentation necessary to satisfy the Purchaser's representatives that the RTUs are being fabricated in accordance with the specification. The inspection rights described above shall apply to the facilities of the Contractor or the Contractor's subcontractor where the RTUs are being manufactured. The inspection rights shall not apply to the facilities of subcontractors supplying unit components to the RTU manufacturer. Such items will be inspected and tested by the Purchaser's representatives at the manufacturing site.

Inspections by the Purchaser will include visual examination of the physical appearance of the RTU hardware, cable dressings, and equipment and cable labeling. Contractor documentation will also be examined to verify that it adequately identifies and describes all RTU hardware, firmware, and spare parts. The Purchaser shall have access to inspect the Contractor's and manufacturer's quality assurance standards, procedures, and records which are applicable to this RTU project. Inspection shall not relieve the

Contractor of the responsibility for furnishing material and equipment conforming to the requirements of the specification, nor shall such inspection invalidate any claim which the Purchaser may make because of defective or unsatisfactory RTU hardware or firmware.

**5.2 Test Procedures**

The Contractor shall submit the RTU test plans for approval four (4) weeks prior to the start of factory tests. Fully approved test procedures shall be submitted to the Purchaser at least two (2) weeks prior to the commencement of the tests. The Purchaser will only approve test procedures if they are inclusive, thoroughly testing each section of the equipment. The Contractor shall use ANSI MC8.1, "Recommended Practice, Hardware Testing of Digital Process Computers," as a guide in preparing the RTU test procedures. The test procedures shall include the following:

(a) The test schedule, including provision for eight hours of unstructured tests to be performed by the Purchaser

(b) The purpose of each test

(c) The function to be tested

(d) The plans/procedures to be followed

(e) Specific references to project documentation for correlation with the procedures and for verification of the documentation

(f) The test setup, equipment, and conditions for each part of the test

(g) All test inputs and outputs

(h) Test firmware descriptions and listings

(i) A copy of any certified test data to be used in lieu of testing

(j) Expected results

(k) The acceptance criteria

(l) A procedure for handling the variances that are identified during testing.

### 5.3 Test Records

The Contractor shall maintain a complete record of the results of all tests. This record shall be keyed to the steps enumerated in the previously approved test plan. The record shall include the following items:

(a) Reference to the appropriate section of the test plan

(b) Description of any special test conditions or special action taken

(c) Test results, passed/failed.

A copy of the test records shall be delivered to the Purchaser at the conclusion of the tests.

### 5.4 Factory Tests

All RTU shall successfully pass a complete test before being accepted. In the event the RTUs are delivered in stages (more than one delivery date), the Purchaser shall have the option to require complete testing on the early delivery RTUs. This complete testing shall include, but not be limited to, all of the following functional performance tests:

(a) Inventory check and inspection for general appearance, cabling, drawing conformance, and labeling

(b) Checks of proper functioning of all hardware and firmware by a thorough exercising of all RTU functions, both individually and collectively

(c) Simulation of inputs, including noise and transient conditions, using convenient test panels which allow each input to be varied over its entire range via individual setters

(d) Checks of power supply voltage margins, ripple levels, and short-circuit protection

(e) Test of all discrete input points

(f) Test of all control outputs

(g) Checks of analog accuracy, temperature coefficient, noise rejection, and over-voltage protection on 10% of all analog point

(h) Test of power failure and reeovery

(i) Tests of communications

(j) Test of equipment spares through substitution

(k) Checks to verify the accuracy of hardware and firmware documentation

(l) Demonstration of techniques and methods for modifying the database, including point additions and deletions

(m) Tests conducted to verify the test set capabilities and operations. All on- and off-line diagnostic features and equipment shall be tested

(n) Test under full-power and simulated operation for a minimum of 48 hours. Twelve hours of this test shall be at the specified high temperature limit. The RTU shall demonstrate continuous operation without any failures. This operation shall include periodic scanning of all points and demonstration that all RTU functions operate properly.

**5.5 Field Performance Tests**

The field performance tests shall consist of the Purchaser's personnel installing, starting, and checking the performance of the equipment at the field location. All hardware will be aligned and adjusted, interfaces to all inputs and outputs established, operation verified, and all test readings recorded in accordance with the Contractor's recommended procedures. The field performance test will exercise all functions of the RTUs and duplicate selected factory acceptance tests to the extent possible. This testing will include, but not be limited to, the following conditions:

(a) RTU initialization

(b) Diagnostics

(c) Checks of proper functioning of hardware and firmware by exercising of selected RTU functions

(d) RTU communications interface including failure modes

(e) Database modifications, including point changes and any RTU down-load capability if applicable.

## 6.0 Training and Support Services

The Contractor shall provide the training and support services to create the Purchaser's in-house maintenance and support capabilities for the RTU hardware. The training program shall be comprehensive and provide for interdisciplinary training of hardware and firmware. The required training of the Purchaser's personnel shall be conducted by the Contractor.

### 6.1 RTU Maintenance Training

The Contractor shall provide RTU maintenance training. The course shall familiarize the Purchaser's course participants with RTU installation, component level troubleshooting and repair procedures, and the recommended preventive maintenance procedures for the RTU equipment. Course coverage shall include the use of the RTU test set or diagnostic terminal and shall demonstrate all facets of their operation. The course shall include hands-on experience with the RTUs supplied by the Contractor and shall cover any special equipment required for maintenance. Use of the actual RTUs to be supplied shall be required.

#### 6.1.1 Attendance

The Purchaser plans for up to 2 participants to attend RTU maintenance training courses.

#### 6.1.2 Training Schedule

The training schedule shall coincide with the delivery of the RTUs to the Purchaser.

#### 6.1.3 Training Location and Classrooms

The RTU maintenance courses shall be given at the Contractor's facility, or optionally at the Purchaser's facility.

### 6.2 Manuals, Equipment and Audio/Video Recordings

Training manuals shall be prepared by the Contractor and submitted to the Purchaser. It is desirable that the manuals used for training be prepared for use as training aids. The use of maintenance or reference manuals as the only training manual is unsatisfactory, although their use as supplementary material is encouraged.

Each course participant shall receive an individual copy of the training manuals and other pertinent material. One master of all training manuals and materials shall be provided to the Purchaser in addition to the individual participant's copies. The master copy shall be suitable for reproduction by the Purchaser. All training manuals and supplemental material shall be provided prior to commencement of the training courses. Upon completion of each course, training manuals shall become the property of the Purchaser.

The Contractor may utilize prerecorded lectures as supplemental training material. These lectures shall not serve as a replacement for the classroom instructor or as a primary training material. A copy of any course material on audio or video tape shall be provided by the Contractor to the Purchaser for retention, playback, and reference documentation.

The Contractor shall provide all special tools, equipment, training aids, and any other material required to train the students effectively. The number of special tools and other training equipment shall be adequate for the number of students attending the course.

### 6.3 Continuing Support Services

All training courses shall be available to the Purchaser from the Contractor for a minimum of ten years after RTU delivery. Subsequent to final acceptance, the Contractor shall provide continuing technical support of the RTUs for a minimum ten-year period. This requires that both consultation with knowledgeable Contractor technical personnel and support by trained field service personnel be readily available to assist the Purchaser engineers in correcting difficult RTU malfunctions.

## 7.0 Documentation

This section describes the requirements for design approval and documentation.

### 7.1 Documentation and Design Approval Process

To insure that the RTUs to be supplied conform to the specific provisions and general intent of the specification, the Contractor shall submit hardware and firmware documentation produced specifically for the Purchaser's RTUs to the Purchaser for approval. The Purchaser will document their approval or submit comments to the Contractor within 15 working days after receipt of the documents. The Contractor shall not proceed with implementation of any hardware or firmware which has not been approved until documentation submitted for it is corrected or the Purchaser grants written permission for the Contractor to proceed. Corrected documents must be resubmitted by the Contractor to the Purchaser for approval as soon as possible. The Purchaser will review the resubmitted documents and record their approval or submit additional comments to the Contractor within 15 working days after receipt of the document. No schedule relief is to be implied for documents requiring correction and resubmission to the Purchaser.

Documentation for the Contractor's standard hardware and standard firmware shall be furnished to the Purchaser for review, but approval by the Purchaser will not be required. The Purchaser, however, reserves the right to determine that this standard hardware and standard firmware is in full conformance with the specification, that it is consistent with other hardware and firmware being provided, and that the documentation is complete and correct in all respects.

In cases where the Contractor's standard hardware or standard firmware does not conform to the requirements of this specification and modifications are required, the standard documentation along with documentation of the modification shall be submitted for the Purchaser's approval.

Any purchasing, manufacturing, or programming implementation initiated prior to the Purchaser's approval of the relevant documents or drawings shall be performed at the Contractor's risk. The Purchaser shall have the right to request additional support documents, and require the Contractor to make any necessary changes to construct the RTUs in conformance with the provisions and intent of the specification without additional cost to the Purchaser. Review and approval by the Purchaser does not relieve the Contractor of the overall responsibilities to satisfy specification requirements.

### 7.2 Documentation

The Contractor shall provide complete documentation for the equipment as described in this section. The documentation requirements shall pertain to all documentation, including documentation produced by subcontractors. All documentation is subject to review and approval by the Purchaser.

#### 7.2.1 Hardware Documentation

The Contractor shall provide documentation for all hardware supplied to the Purchaser. Documentation describing the circuitry, operation of the circuitry, and troubleshooting and maintenance procedures shall indicate the revision level of the hardware to which the documentation applies. Generic manuals are not acceptable unless they clearly show what is supplied with the system. This documentation shall satisfy the following requirements:

(a) An inventory of the hardware to be supplied, including the manufacturer's name, model number, serial number, and other pertinent data.

(b) The physical planning/site preparation documents, containing detailed mechanical drawings of all cabinets and related hardware and indicating mounting details, clearance requirements, and environmental restrictions, as well as the electrical requirements of the hardware.

(c) The installation, wiring, and cabling diagrams. Terminations for the Purchaser's connections shall be clearly identified with adequate space for the Purchaser cable and wire identifiers. Any special precautions associated with cabling shall be identified on this drawing.

(d) The internal wiring diagram, oriented toward the input and output (typically two relays per point) field wiring terminal blocks.

The drawing shall include:

(1) The identification of the terminal block and pin numbers

(2) Point name (at least twenty characters)

(3) Point type

(4) The point's I/O card location

(5) The point's address within the protocol

(6) The point's signal conditioning (filtering, scaling, isolation, etc.) and the location of the conditioning (if not on the point's I/O card)

(7) All jumper/strap positions.

(e) The enclosure assembly drawings showing the location of the components, such as power supplies and printed-circuit card chassis, and the subassemblies comprising the components to the level of printed circuit cards .

The drawings shall identify each component and subassembly by part number and revision level. An individual drawing shall be produced for each enclosure's equipment and a copy of the appropriate drawing shall be stored inside each enclosure, preferably on the enclosure's door.

(f) All maintenance documentation, including manuals and other descriptive material, which will enable the Purchaser personnel to maintain all Contractor-supplied equipment.

The maintenance documentation shall include descriptions, specifications, theory of operation (including firmware listings where applicable), printed circuit module schematics and layout drawings showing components and position, mother-board schematics showing inter-module connections, back-panel and assembly wiring diagrams, pin lists, and other data on the electrical, electronic, and mechanical hardware. All schematic diagrams shall show signal sources and destinations by drawing number and area. All schematics (including back panel wiring) shall include a signal name list alphabetically listing each signal, its source, and all destinations.

Instructions shall be included for preventive maintenance procedures consisting of examinations, tests, adjustments, and cleaning that should be performed periodically under normal operating conditions for the purpose of preventing failure or impairment of the equipment.

The manuals shall provide guidelines for isolating the cause of a hardware malfunction. The discussions should contain concise information on how the hardware operates, troubleshooting guides for localizing faults, listings of possible sources of trouble, symptoms, probable causes, use of test equipment, use and interpretation of built-in RTU test functions, and instructions for remedying faults. User configuration options must be described as well as their normal position. Instructions shall be provided for the removal, repair, and replacement of all hardware.

Complete parts lists and breakdowns, and descriptions sufficient to identify each component and ordering information for these parts shall be provided in conjunction with maintenance manuals. Every component subassembly and assembly shall have a unique part number assigned to it. This part number shall coincide with the markings on the hardware itself and shall be used in the documentation whenever the hardware element is referenced. Where standard components are used, standard part numbers or the identification used by the component supplier shall be shown. Alternate sources and part numbers shall be supplied for non-standard components. Where applicable, the characteristics of a component shall also be shown to aid in obtaining substitute parts (such as the value and rating of resistors).

(g) A thorough description of the RTUs communication protocol. The data formats used and the relationship of I/O card locations/addresses to message fields must be clearly presented.

(h) Operation and maintenance documentation for the test set, similar in content and detail to the RTU documentation.

The Contractor shall describe by title and by a content outline the specific documents which will be provided to the Purchaser. The documentation described by items (a) through (e) above, shall be provided within three months after contract award. Documentation that will be required by the Purchaser for RTU installation shall be provided within two months after contract award. Final RTU documentation shall be delivered with the equipment.

### 7.2.2 Firmware Documentation

The Contractor shall supply documentation for all firmware provided with the RTUs. This documentation shall include the following data as a minimum:

(a) An inventory of all programs and modules to be provided and a cross referenced index to the firmware documentation

(b) A functional overview document which describes the firmware on a subsystem basis and includes a brief description of the hardware interfaces.

This document shall functionally describe all firmware to be provided with simplified block/flow diagrams. The relationship among each program, the database, and the SCADA system hardware shall be included. This document shall be provided within four months after contract award and prior to the issuance of any individual firmware documents.

(c) A firmware documentation standards manual which defines in detail the documentation format for items (d) and (e) below.
Within four months after the contract award, the Contractor shall provide the documentation standards for the Purchaser's review.

(d) Existing design documentation and user's manuals for the Contractor's standard firmware that satisfies the requirements of the specification submitted to the Purchaser in their existing form.

(e) Standard firmware which requires some modification to fulfill the Purchaser's requirements shall be subject to the Purchaser's review and approval. The standard documentation and the change documents shall be submitted prior to the implementation of the changes by the Contractor. All changes to the Contractor's standard firmware shall be identified.

### 7.2.3 Test Documentation

The Contractor shall provide documentation for all factory and field tests. Section 5.2 describes the test documentation requirements.

### 7.2.4 Final Documentation

Final documentation shall consist of the documents necessary to satisfy the requirements in Sections 7.2.1, 7.2.2, and 7.2.3 and the other documents described herein or requested by the Purchaser. The documents will be used by the Purchaser personnel for the RTUs operation and maintenance after their acceptance. Final documentation must be delivered within three weeks after the RTUs are shipped. The final hardware documentation shall include one set of mylar reproducible tracings of all RTU drawings, and external connection diagrams prepared specifically for the Purchaser.

Each document shall be identified by a Contractor document number. Additionally, each document shall have indicated the Purchaser's Job Order Number and Purchase Order Number. Where a document is revised due to a change in design (or for any other reason), each revision shall be indicated by a number, date, and subject in a revision block and some indication of approval by the Contractor's project manager. Additional notation shall be made on the document to permit rapid location of the revision. A final index of SCADA system documentation shall be provided. All final documentation supplied by the Contractor shall be easily reproducible by the Purchaser.

All drawings larger than B-size (280 mm x 430 mm) shall be supplied as mylar reproducible tracings in addition to the paper prints required in Section 7.2.5. Also, all drawings prepared specifically for the Purchaser shall be provided on floppy disk media in a AutoCAD, Revision 10, DXF format.

The Contractor shall be responsible for supplying documentation revisions or changes due to inaccuracies, installation requirements, omissions determined by usage, and design or production alterations to the RTUs. Changes shall be issued in the form of replacements for the affected drawings, diagrams, charts, graphs, tables, lists, and pages in the various manuals prior to the start of the field performance test.

### 7.2.5 Document Quantities

The quantity to be supplied for each document is shown in Table 1 below. Copies of documentation provided at training courses are in addition to these quantities. If the Contractor-supplied documentation differs from the items in this list, the proposal shall identify the specific differences.

| | Review or Approval | Final Documents |
|---|---|---|
| **HARDWARE DOCUMENTATION** | | |
| 1. Inventory of Hardware | | 3 |
| 2. Site Preparation Manual | 1 | 3 |
| 3. Installation, Wiring & Cabling Diagram | 1 | 3 + 1/RTU |
| 4. Internal Wiring Diagrams | 1 | 3 + 1/RTU |
| 5. Assembly Drawings | 1 | 3 + 1/RTU |
| 6. Maintenance Manuals for RTUs | 1 | 3 + 1/RTU |
| 7. Test Set Documentation | 1 | 3 |
| **FIRMWARE DOCUMENTATION** | | |
| 1. Inventory of Firmware | 1 | 3 |
| 2. RTU Functional Overview | 1 | 3 |
| 3. Firmware Documentation Standard | 1 | 3 |
| 4. Standard Software | 1 | 3 |
| 5. Modified Standard Software | 1 | 3 |
| **TEST DOCUMENTATION** | | |
| 1. Test Plan | 1 | 2 |
| 2. Test Records | - | 2 + 1/RTU |

**Table 1**
**RTU DOCUMENT QUANTITIES**

## Appendix A

## RTU Point Summary

| Equipped Points | | | Input | | | | Output | |
|---|---|---|---|---|---|---|---|---|
| RTU Name | Power Supply | Enclosure | Status | MCD | *SOE | Analog 0-1 ma | Momentary Control | Jog Control |
| Tumon | 128 Vdc | Indoor | 45 | 16 | 175 | 91 | 16 | 2 |
| Tamuning | 128 Vdc | Indoor | 45 | 16 | 175 | 90 | 16 | 2 |

**Appendix A**
**RTU Point Summary**

Appendix A Legend:

* = Future capability to be included in the RTUs (e.g. All racks, chassis, power supplies are to be included, but no SOE point cards). Points are assigned to Status and MCD for the interim.

Status = Two-state input status points.

MCD = Two-state input points with momentary-change-detection.

Analog 0-1ma = Analog inputs at 0 to 1 ma.

Momentary = Control output pairs for breaker Open/Close.

Jog Control = Control output pairs for LTC Raise/Lower.

SOE = Sequence of events points. Status or MCD points which are to have time tags for SOE. These SOE points are in addition to the Status and MCD point counts.

# TAMUNING SUBSTATION POINT COUNT

**Two-state Status**

| | |
|---|---|
| Breaker - Local/Remote | 16 |
| LTC - Manual/Automatic | 2 |
| LTC - Local/Remote | 2 |
| Relays and Alarms - Normal/Alarm | 25 |

**MCD Status**

| | |
|---|---|
| Breakers - Open/Closed | 16 |

**Momentary Control**

| | |
|---|---|
| Breakers - Open/Close | 16 |

**Jog Control**

| | |
|---|---|
| LTC - Raise/Lower | 2 |

**Analog**

| | |
|---|---|
| Watts | 21 |
| Vars | 6 |
| 3-phase Amps | 45 |
| 3-phase Volts | 12 |
| LTC - Position | 2 |
| Weather Data | 4 |

**SOE (Future)**

| | |
|---|---|
| Breakers - Open/Closed | 16 |
| Relays and Alarms - Normal/Alarm | 159 |

## TUMON SUBSTATION POINT COUNT

| | |
|---|---|
| **Two-state Status** | |
| Breaker - Local/Remote | 16 |
| LTC - Manual/Automatic | 2 |
| LTC - Local/Remote | 2 |
| Relays and Alarms - Normal/Alarm | 25 |
| **MCD Status** | |
| Breakers - Open/Closed | 16 |
| **Momentary Control** | |
| Breakers - Open/Close | 16 |
| **Jog Control** | |
| LTC - Raise/Lower | 2 |
| **Analog** | |
| Watts | 22 |
| Vars | 6 |
| 3-phase Amps | 45 |
| 3-phase Volts | 12 |
| LTC - Position | 2 |
| Weather Data | 4 |
| **SOE (Future)** | |
| Breakers - Open/Closed | 16 |
| Relays and Alarms - Normal/Alarm | 159 |