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USACE / NAVFAC / AFCEA / NASA UFGS-26 09 13 (April 2006)  
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Preparing Activity: USACE Replacing without change  
UFGS-13451 (August 2004)

## UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated 19 March 2007

Latest change indicated by CHG tags

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#### SECTION 26 09 13

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04/06

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### SECTION 26 09 13

#### POWER MONITORING SYSTEM 04/06

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NOTE: This guide specification covers the requirements for power monitoring systems.

Edit this guide specification for project specific requirements by adding, deleting, or revising text. For bracketed items, choose applicable items(s) or insert appropriate information.

Remove information and requirements not required in respective project, whether or not brackets are present.

Comments and suggestions on this guide specification are welcome and should be directed to the technical proponent of the specification. A listing of technical proponents, including their organization designation and telephone number, is on the Internet.

Recommended changes to a UFGS should be submitted as a Criteria Change Request (CCR).

NOTE: This section will be used in conjunction with Sections 02 41 00 {DEMOLITION} {AND} {DECONSTRUCTION}; 26 20 00 INTERIOR DISTRIBUTION SYSTEM; 33 71 01 OVERHEAD TRANSMISSION AND DISTRIBUTION; 33 70 02.00 10 ELECTRICAL DISTRIBUTION SYSTEM, UNDERGROUND; 27 21 10.00 10 FIBER OPTIC DATA TRANSMISSION SYSTEM; 27 15 19.00 10 WIRE LINE DATA TRANSMISSION SYSTEM; 33 82 01 INTERCOMMUNICATION SYSTEM; and any other guide specification sections required by this design.

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## PART 1 GENERAL

### 1.1 REFERENCES

\*\*\*\*\*

NOTE: This paragraph is used to list the publications cited in the text of the guide specification. The publications are referred to in the text by basic designation only and listed in this paragraph by organization, designation, date, and title.

Use the Reference Wizard's Check Reference feature when you add a RID outside of the Section's Reference Article to automatically place the reference in the Reference Article. Also use the Reference Wizard's Check Reference feature to update the issue dates.

References not used in the text will automatically be deleted from this section of the project specification when you choose to reconcile references in the publish print process.

\*\*\*\*\*

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

ANSI X3.64 (1979; R 1990) Additional Controls For Use With the American National Standard Code for Information Interchange

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE C37.90.1 (2002) Surge Withstand Capability (SWC) Tests for Relays and Relay Systems Associated with Electric Power Apparatus

IEEE C57.13 (1993; R 2003) Standard Requirements for Instrument Transformers

IEEE C62.41 (1991; R 1995) Recommended Practice for Surge Voltages in Low-Voltage AC Power Circuits

IEEE Std 802.3 (2005; R 2006) Standard for Information Technology Telecommunications and Information Exchange Between Systems Local and Metropolitan Area Networks Specific Requirements - Part 3: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications

INTERNATIONAL ELECTROTECHNICAL COMMISSION (IEC)

IEC 61000-4-5 (2005) Electromagnetic Compatibility (EMC) - Part 4-5: Testing and Measurement Techniques; Surge Immunity Test

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

|             |   |
|-------------|---|
| NEMA 250    | (2003) Enclosures for Electrical Equipment<br>(1000 Volts Maximum)  |
| NEMA C12.1  | (2001) Electric Meters; Code for<br>Electricity Metering  |
| NEMA C12.20 | (2002) Electricity Meter - 0.2 and 0.5<br>Accuracy Classes  |
| NEMA C62.61 | (1993) Gas Tube Surge Arresters on Wire<br>Line Telephone Circuits  |
| NEMA ICS 1  | (2000; R 2005) Industrial Control and<br>Systems: General Requirements                                    |
| NEMA WC 74  | (2000) 5-46 kV Shielded Power Cable for<br>Use in the Transmission and Distribution<br>of Electric Energy |

TELECOMMUNICATIONS INDUSTRY ASSOCIATION (TIA)

|                 |   |
|-----------------|---|
| TIA-232-F       | (1997; R 2002) Interface Between Data<br>Terminal Equipment and Data<br>Circuit-Terminating Equipment Employing<br>Serial Binary Data Interchange   |
| TIA-485-A       | (1998; R 2003) Electrical Characteristics<br>of Generators and Receivers for Use in<br>Balanced Digital Multipoint System                           |
| TIA/EIA-568-B.1 | (2001 Addendums 2001, 2003, 2003, 2003,<br>2004, 2007) Commercial Building<br>Telecommunications Cabling Standard - Part<br>1: General Requirements |

U.S. NATIONAL ARCHIVES AND RECORDS ADMINISTRATION (NARA)

|           |                         |
|-----------|-------------------------|
| 47 CFR 15 | Radio Frequency Devices |
|-----------|-------------------------|

1.2 SYSTEM DESCRIPTION

\*\*\*\*\*  
NOTE: Designer will add location and site specific  
requirements, and select a single workstation or  
multiple workstation system as described under  
paragraph Communications.  
\*\*\*\*\*

1.2.1 System Requirements

The power monitoring system, consisting of commercial, off-the-shelf intelligent electronic devices (IEDs), communication channels, and PC-based workstation equipment, will be used by [\_\_\_\_\_] to monitor the operation of [\_\_\_\_\_] at [\_\_\_\_\_]. The power monitoring system shall be a [single] [multiple] workstation system utilizing an Ethernet local area network (LAN). The power monitoring system workstation[s] will be located at [\_\_\_\_\_].

### 1.2.2 System Response Times

- a. Any new display shall begin to update the workstation monitor within 2 seconds after being requested. Preformatted displays shall be completely presented within 5 seconds after the request.
- b. All calculated values shall be updated from the database, when displayed at the workstation, at least every 15 seconds.
- c. Digital status indications, when displayed at the workstation, shall be updated within 15 seconds from the IED.
- d. Analog values, when displayed at the workstation shall be updated within 15 seconds from the IED.

### 1.2.3 System Accuracy and Display

\*\*\*\*\*  
**NOTE: Designer will include THD and K-Factor only when Enhanced IEDs are specified, and will add requirements for additional site specific measurements, including range and accuracy, for any special application not listed.**  
\*\*\*\*\*

The system shall maintain the specified end-to-end accuracy from sensor to all workstation displays, including the effects of transmitters, transducers, and engineering units conversions, for one year for the applications specified and shall report and display changes in sensed values as specified. The system accuracy and display requirements are as follows:

- a. Current: with a range for the specific application  $\pm 1.0\%$  of reading; display and print to nearest ampere.
- b. Voltage: with a range for the specific application  $\pm 1.0\%$  of reading; display and print to nearest volt.
- c. Power Factor: 1.0% of reading; display and print to nearest hundredth.
- d. kWh: with a range for the specific application  $\pm 1.0\%$  of reading; display and print to nearest kWh.
- e. KW: with a range for the specific application  $\pm 1.0\%$  of readings.
- f. KVA: with a range for the specific application  $\pm 1.0\%$  of reading; display and print to nearest KVA.
- g. KVAR: with a range for the specific application  $\pm 1.0\%$  of reading; display and print to nearest KVAR.
- h. Frequency:  $\pm 0.05$  Hz; display and print to nearest 0.1 Hz.
- i. Total Harmonic Distortion (THD) in percent for current and voltage, each phase.
- j. K-Factor (dimensionless ratio based on harmonic content of current

waveform).

- k. Special application(s) added by the designer, as needed.

#### 1.2.4 Environmental Requirements

\*\*\*\*\*  
NOTE: Designer will include sufficient air conditioning and/or heating to maintain the Workstation Equipment room temperature between 18 degrees C (65 degrees F) and 23 degrees C (75 degrees F), including allowance for Workstation Equipment and personnel cooling loads.  
\*\*\*\*\*

- a. Workstation and associated equipment shall operate without damage or degradation under the following ambient conditions, unless otherwise noted.

- (1) Operating Temperature: 16 to 29 degrees C 60 to 85 degrees F.

- (2) Operating Humidity: 20 to 80 %, non-condensing.

- b. All field equipment shall operate without damage or degradation under the following ambient conditions, unless otherwise noted.

- (1) Operating Temperature: 0 to 50 degrees C 32 to 122 degrees F.

- (2) Operating Humidity: 10 to 90 %, non-condensing.

#### 1.2.5 Electrical Transients and Electromagnetic Interference

##### 1.2.5.1 Power Line Surge Protection

Workstation equipment connected to ac circuits shall be protected from power line surges and meet the requirements of IEEE C62.41 location category A3, while equipment is operating. In addition, all IEDs shall be protected to meet the requirements of IEEE C37.90.1 or the requirements of IEC 61000-4-5, test level 4, while the equipment is operating. Fuses shall not be used for surge protection.

##### 1.2.5.2 Sensor Wiring Surge Protection

All digital and analog inputs of all IEDs shall be protected against surges induced on sensor wiring to meet the requirements of IEEE C37.90.1 or the requirements of IEC 61000-4-5, test level 4, while the equipment is operating. Fuses shall not be used for surge protection.

##### 1.2.5.3 Communications Channels Surge Protection

Communications equipment shall be protected against surges induced on its communications channels. Communication interfaces to all field equipment shall be protected to meet the requirements of IEEE C37.90.1 or the requirements of IEC 61000-4-5, test level 4, while the equipment is operating. Fuses shall not be used for surge protection. Metallic cables and conductors which serve as communications channels between buildings shall have surge protection installed at equipment and additional triple electrode gas surge protectors rated for the application installed at each end, within three feet of the building cable entrance. Surge protectors



shall meet the requirements of NEMA C62.61.

#### 1.2.6 Workstation Equipment Power Source

\*\*\*\*\*  
NOTE: The designer will show uninterruptible power supply (UPS) location and power requirements on the project drawings. UPS power will be required for the workstation, laser printer, and gateways.  
\*\*\*\*\*

Workstation equipment shall be powered from an uninterruptible power supply (UPS) as shown. The UPS shall provide 15 minutes of normal operation for all connected equipment.

#### 1.2.7 Communications

\*\*\*\*\*  
NOTE: The designer will select the minimum number of communication channels required for the project, based on site layout, and IED counts. The designer will not exceed 30 IEDs per communication channel.  
  
The designer will utilize the first bracketed paragraph when the system requirements do not exceed 4 communication channels. A single workstation system will be specified.  
  
The designer will utilize the second bracketed paragraph when the system requirements exceed 4 communication channels. A multiple workstation system utilizing a LAN will be specified.  
\*\*\*\*\*

[The Workstation shall be configured to accept a minimum of 4 TIA-232-F or TIA-485-A data communications channels by way of communication interface converters. Each communication channel shall support communication with at least 30 IEDs and shall meet the performance requirements as specified.]  
[The Workstations and associated local area network shall be configured to accept a minimum of 32 TIA-232-F or TIA-485-A data communications channels by way of Ethernet gateways. Each communication channel shall support communication with at least 30 IEDs and shall meet the performance requirements as specified.]

#### 1.2.8 Expansion Requirements

\*\*\*\*\*  
NOTE: The designer will select 120 IEDs for systems not exceeding 4 communication channels, and 960 IEDs for systems exceeding 4 communication channels.  
\*\*\*\*\*

The Contractor shall provide Workstation hardware and software to accommodate a total of [120] [960] IEDs.

#### 1.2.9 Protocols

The workstation equipment shall include software allowing it to communicate with field equipment using any of the following protocols:

- a. A published open protocol.
- b. MODBUS RTU/ASCII.

#### 1.2.10 Utility Demand Interval Synchronization

\*\*\*\*\*  
NOTE: If demand interval synchronization is required, coordinate with the utility to determine if utility demand synchronization signals are available. If the signals are available, include this paragraph and show the signal interfaces to the workstation computer; otherwise, delete this paragraph.  
\*\*\*\*\*

An interface for utility demand interval synchronization signals shall be provided as shown. The synchronization signal shall be used in calculating and displaying demand.

### 1.3 DELIVERY OF TECHNICAL DATA AND COMPUTER SOFTWARE

#### 1.3.1 Data, Drawings, CD-ROMs, and Manuals

\*\*\*\*\*  
NOTE: The designer will coordinate with the installation to determine if MicroStation or AutoCAD file format is required.  
\*\*\*\*\*

All items of software and technical data (including technical data which relates to computer software), which is specifically identified in this specification shall be delivered strictly in accordance with the CONTRACT CLAUSES and the Contract Data Requirements List, DD Form 1423. All data delivered shall be identified by reference to the particular specification paragraph against which it is furnished. All drawings submitted shall be in DXF and [MicroStation v5.0] [AutoCAD v14] file structure. Five sets of CD-ROMs shall be provided after final drawings are approved. Manuals provided shall contain the minimum content specified, although varied packaging and formats are acceptable. The Contractor may submit standard manuals with additions as necessary to conform to the requirements listed below.

#### 1.3.2 Technical Data Package 1 - Existing Conditions Report

The data package shall include the existing conditions report as specified in Paragraph: Existing Conditions Survey, and associated documentation as specified.

#### 1.3.3 Technical Data Package 2 - System Data

##### 1.3.3.1 System and Installation Drawings

- a. Power monitoring system block diagram.
- b. Layout plans showing equipment locations and cable routing.
- c. Field equipment installation drawings including dimensional

drawings of any existing enclosures showing equipment cutouts and mounting locations, and indicating adequate clearance from existing wiring and devices per manufacturer's recommendations.

d. Instrument transformer wiring and installation drawings.

#### 1.3.3.2 Equipment Data

A complete data package shall be delivered for all materials and equipment as specified, including the following:

- a. Catalog data for workstation equipment demonstrating compliance with specified requirements.
- b. Catalog data for field equipment indicating outline and mounting dimensions and schematic external wiring arrangement, and
- c. Catalog data for instrument transformers demonstrating compliance with specified requirements.

#### 1.3.3.3 Installation, Setup and Operation Guides

The data package shall include the manufacturer's standard installation, setup and operation guides for workstation equipment and field equipment, and shall include details of the published open protocol for communications.

#### 1.3.3.4 User's Guides

The data package shall include the manufacturer's standard user's guides for all software provided with the system.

#### 1.3.3.5 Certifications

The Contractor shall provide written certifications that system components meet the requirements specified including:

- a. 47 CFR 15
- b. IEEE C62.41
- c. NEMA C12.1
- d. NEMA C62.61
- e. IEEE C37.90.1 or IEC 61000-4-5.

#### 1.3.4 Technical Data Package 3 - Training Data

Lesson plans and training manuals for the training phases, including type of training to be provided and with a list of reference material shall be submitted for approval as specified.

#### 1.3.5 Technical Data Package 4 - Performance Verification Testing Procedures

The Contractor shall submit test procedures for the Performance Verification Test (PVT). The test procedures shall explain in detail, step-by-step actions and expected results to demonstrate compliance with the requirements of this specification. The Contractor shall submit the PVT procedures for approval.

#### 1.3.6 Technical Data Package 5 - Performance Verification Testing Data

The Contractor shall submit the performance verification test data to the

Government after the Government approves the performance verification test.

#### 1.3.7 Technical Data Package 6 - Operation and Maintenance Manuals

\*\*\*\*\*  
**NOTE: The designer will consult with the  
installation to determine the quantity of manuals  
required.**  
\*\*\*\*\*

The operation and maintenance manuals shall consist of a resubmission of all technical data identified as Technical Data Package 2, bound in three-ring binder, with as-built corrections and revisions and with addenda/appendices as necessary to identify any special characteristics or operations not covered in the manufacturer's standard documentation. The Contractor shall submit [6] [\_\_\_\_\_] copies of the operation and maintenance manuals within 30 days following successful completion of the PVT.

#### 1.4 TESTING

##### 1.4.1 General Requirements for Testing

The Contractor shall perform testing of the workstation and field equipment, at the site, including adjustments of the completed system as specified. The Contractor shall provide all personnel, test equipment, instrumentation, and supplies necessary to perform all testing. Written notification shall be given to the Government at least 21 days prior to the PVT, and in no case shall notice be given until after the Contractor has received written Government approval of the specific testing procedures.

##### 1.4.2 Test Procedures and Reports

The procedures shall consist of detailed instructions for test setup, execution, and evaluation of test results. The test reports shall be used to document results of the tests. Reports shall be delivered to the Government within 7 days after completion of test.

#### 1.5 MAINTENANCE AND SERVICE

##### 1.5.1 General Requirements

The Contractor shall provide all maintenance services required and equipment necessary to maintain the entire system operational, as specified, for a period of 1 year after system acceptance. Maintenance shall include preventive maintenance in addition to repairs, replacements, and adjustments and software updates. Written permission shall be obtained from the Government prior to performing any service work or adjustments which have any impact on facility operations.

##### 1.5.2 Description of Work

The adjustment and repair of the system includes all workstation equipment and field equipment including software updates. Contractor shall perform each manufacturer's required adjustments and all other work necessary for proper operation as specified.

##### 1.5.3 Service Calls

The Government will initiate service calls when the system is not

functioning properly. The Government shall be furnished with a telephone number where the service supervisor can be reached at all times. Service personnel shall be at the site within three working days after receiving a request for service. The system shall be restored to proper operating condition within seven working days after receiving a request for service.

#### 1.5.4 Records and Logs

The Contractor shall keep records and logs of each maintenance and service task, and shall organize cumulative records for each major component, and for the complete system chronologically. A continuous log shall be maintained for all devices on a site-by-site basis. The log shall contain all initial analog span and zero calibration values and testing of all digital points. Complete logs shall be kept and shall be available for inspection onsite, demonstrating that planned and systematic adjustments and repairs have been accomplished for the system. The Contractor shall provide the Government with a summary report of the maintenance and service performed during each previous month.

#### 1.5.5 System Modifications

The Contractor shall make any recommendations for system modification as part of maintenance and service in writing to the Government. No system modifications, including operating parameters and control settings, shall be made without prior approval of the Government. Any modifications made to the system shall be incorporated into the system documentation including drawings and manuals.

#### 1.5.6 Software

The Contractor shall provide notices of all software updates and verify operation in the system, if the Government chooses to incorporate the update. These updates shall be accomplished in a timely manner, fully coordinated with system operators, and shall be incorporated into the manuals and software documentation. The Contractor shall install and validate the latest released version of the software, upon receiving written approval by the Government.

#### 1.5.7 Telephone Consultation

\*\*\*\*\*  
**NOTE: The designer will consult with the  
installation to determine if telephone consultation  
is to be required; if not, delete this paragraph.**  
\*\*\*\*\*

The Contractor shall provide up to 40 hours per year of telephone consultation to Government personnel. The Contractor shall keep a log by month, identifying caller, date and length of call, and results of call.

### PART 2 PRODUCTS

#### 2.1 MATERIALS AND EQUIPMENT

##### 2.1.1 General

Units of the same type of equipment shall be products of a single manufacturer. Each major component of equipment shall have the manufacturer's name and address, with model and serial number in a

conspicuous place. All materials and equipment shall be currently in production at time of delivery to the Government.

#### 2.1.2 Nameplates

Laminated plastic nameplates shall be provided for each equipment enclosure and device furnished. Laminated plastic shall be 3 mm 1/8 inch thick, white with black center core. Nameplates shall be a minimum of 25 by 75 mm 1 by 3 inches, with minimum 6 mm 1/4 inch high engraved block lettering. Nameplates for devices smaller than 25 by 75 mm 1 by 3 inches shall be attached by a non-ferrous metal chain. All other nameplates shall be attached to the device. The nameplate for each equipment enclosure or device shall include the designator or number as shown, and the site name. Site names shall be provided after order placement. Nameplates shall be attached to the equipment with stainless steel panhead screws.

#### 2.1.3 Field Wiring, Cabling, and Terminal Blocks

- a. Internal wiring in factory pre-wired enclosures shall be installed according to the Contractor's standard as to wire size, insulation, and method of termination on internal equipment. The individual conductors of the interconnecting cables shall meet the flame resisting test requirements of NEMA WC 74 [\_\_\_\_]. Each individual conductor in individual enclosures shall be uniquely identified in accordance with NEMA ICS 1. Splices shall not be permitted.
- b. Rail mounted compression clamp terminal blocks shall be provided for conductors requiring connection to circuits external to the specified equipment, and shall be suitable for up to 12 AWG wire. Terminal blocks for analog circuits shall be knife switch disconnecting type. Terminal blocks shall be grouped for easy accessibility unrestricted by interference from structural members and internal devices. Sufficient space shall be provided on each side of each terminal block to allow an orderly arrangement of all leads to be terminated on the block. Plastic wiring duct or other factory mounted cable support devices shall be provided to support cables for external circuit wiring.
- c. Terminal blocks, interposing relays, switches, or similar devices shall be readily accessible. The equipment shall be located in compartments, enclosures, or junction boxes in such arrangement that maintenance personnel shall have direct access to the equipment without removal of barriers, cover plates, or wiring. Grouped terminal blocks for all external connections shall be provided. All wiring leaving an enclosure shall leave from terminal blocks or prefabricated connectors and not from other devices in the enclosure. Terminal blocks and jumpers shall be permanently and uniquely marked in conformance with NEMA ICS 1.

#### 2.1.4 Power Supplies

\*\*\*\*\*  
NOTE: The designer will verify existing power source characteristics and circuit availability to provide a 120 Vac circuit to field equipment. Sources of power will be shown including transformers, if required.  
\*\*\*\*\*

Field equipment shall be powered from 120 Vac or shall derive power from the monitored circuit.

#### 2.1.5 Enclosures

\*\*\*\*\*  
**NOTE: The designer will coordinate number of keys  
with the installation.**  
\*\*\*\*\*

Enclosures shall conform to the requirements of NEMA 250 for the types specified. Damaged surfaces shall be repaired and refinished using original type finish. Enclosures installed outdoors shall be type 4X stainless steel, unless otherwise shown, and shall contain a thermostatically controlled space heater to maintain the enclosure above the dew point, if required by the equipment installed. Enclosures shall have removable hinged, key-locked front doors. All enclosure locks shall be keyed alike. A total of [5] [\_\_\_\_\_] keys shall be turned over to the Government.

#### 2.1.6 EMI/RFI Compliance

Equipment shall be designed to minimize the generation of electromagnetic and radio frequency interference. Workstation equipment shall be in compliance with 47 CFR 15, for Class B computing devices.

### 2.2 FIELD EQUIPMENT

#### 2.2.1 Basic Intelligent Electronic Device (IED)

##### 2.2.1.1 Basic IED

Basic IEDs shall be microprocessor based devices providing multiple measurements for 60 Hz single phase or three phase electric systems as shown. Basic IEDs shall utilize a communication protocol in accordance with Paragraph: Protocols for display and transmission of the following parameters as specified plus other parameters as shown:

Voltage line-to-neutral plus or minus 0.5%  
Voltage line-to-line: plus or minus 1%  
Current: plus or minus 0.5%  
kVA: plus or minus 1%  
kVAR: plus or minus 1.5%  
Power factor: plus or minus 1%  
kW: plus or minus 1.5%  
kWh: plus or minus 1.5% of reading

##### 2.2.1.2 Mounting

Basic IEDs shall accommodate mounting in or on switchgear enclosures as required for the installation.

##### 2.2.1.3 Communications

- a. Basic IED to workstation: Communications interfaces shall be provided for each Basic IED to the communications channels for data transfer between Basic IED and workstation.

- b. Each Basic IED shall have ports and modems or line drivers to perform the specified functions.

#### 2.2.1.4 KWH Value Retention

Basic IEDs shall retain the accumulated KWH value for 72 hours minimum during power outages.

#### 2.2.2 IED Communication Equipment

\*\*\*\*\*

NOTE: The designer will include Enhanced IEDs in the project only if required by the installation. Enhanced IEDs will typically be applied to main service feeders and feeders to sensitive or critical loads. Show Enhanced IEDs where required. The designer will show requirements for any additional parameters to be displayed by a table on the project drawings. The designer will check technical literature for several manufacturers, and additional parameters will not exceed those listed in manufacturers' literature.

\*\*\*\*\*

Repeaters shall be provided where required for extension of communication channel physical media.

#### 2.2.3 Enhanced IED

Enhanced IEDs shall provide all functions specified for Basic IEDs, and shall provide the following additional functions:

- Frequency: Plus or minus 0.05 Hz
- THD in percent, for current and voltage, each phase
- K Factor (dimensionless ratio based on harmonic content of current waveform)
- Sag/Swell Detection
- Waveform Capture

Enhanced IEDs shall maintain the ten most recent captured waveforms in memory and shall retain captured waveforms for 72 hours minimum during power outages. Enhanced IEDs shall be certified to meet the accuracy requirements of NEMA C12.20 for utility revenue metering.

### 2.3 INSTRUMENT TRANSFORMERS

#### 2.3.1 Potential Transformers

Potential transformers shall be compatible with IEDs furnished. The Contractor shall be responsible for determining the actual voltage ratio of each transformer. Potential transformers shall conform to IEEE C57.13 and the following requirements.

- Type: indoor, dry type, of two-winding construction
- Frequency: Nominal 60Hz
- Accuracy: plus or minus 0.3% at 60Hz



### 2.3.2 Multi-Ratio Current Transformers

Current transformers shall be compatible with the IEDs furnished. Current transformers shall conform to IEEE C57.13 and the following requirements.

Insulation Class: BIL rating shall be equal or greater than the equipment being connected to.

Frequency: Nominal 60Hz

Accuracy: plus or minus 0.3% at 60Hz

Burden: Burden class shall be selected for the load

Phase Angle Range: 0 to 60 degrees

## 2.4 WORKSTATION EQUIPMENT

### 2.4.1 Workstation Computer

#### 2.4.1.1 Digital Computer

The workstation computer shall function as the overall system coordinator, perform automated functions, and perform calculations associated with operator interactions, alarm reporting, and logging of events. Each workstation computer shall be a single manufacturer's standard unmodified digital computer of modular design. The workstation computers shall not include any hardware precluding the purchase of a standard maintenance and service contract from the computer manufacturer. Each workstation computer shall have at least a 400 MHz processor and a 32 bit data and address bus:

#### 2.4.1.2 Memory

Each workstation computer shall be provided with 128 megabytes RAM as a minimum, expandable to 512 megabytes.

#### 2.4.1.3 Hard Disk Drive Data Storage

Each workstation shall be provided with a hard disk drive system. Each hard disk drive system shall include at least one drive and controller. Formatted drive capacity shall be not less than 8 gigabytes, and average access time shall not be greater than 10 milliseconds. Automatic read-after-write checking shall be provided.

#### 2.4.1.4 Floppy Disk Drive

Each workstation computer shall have a 1.44 megabyte 89 mm 3-1/2 inch floppy disk drive and controller.

#### 2.4.1.5 CD-ROM Drive

A 32X CD-ROM drive having a nominal storage capacity of 650 megabytes and a minimum 128 kilobyte cache memory shall be provided for each workstation computer.

#### 2.4.1.6 Workstation Computer Magnetic Tape Drive

Each workstation computer shall have a 4 mm 3/16 inch Magnetic Tape Drive with a formatted uncompressed storage capacity of 4 gigabytes and formatted compressed storage of 8 gigabytes.

#### 2.4.1.7 Workstation Color Monitors

- a. Workstations shall include a color monitor with a tilt/swivel base and local controls for contrast, brightness, focus, vertical size, horizontal size, vertical position, and horizontal position.
- b. A graphics adapter shall be furnished, with four megabyte (minimum) of video memory, supporting all video modes and resolutions specified.
- c. The color monitors shall be nominal 508 mm (20 inch) 20 inch, with 0.26 to 0.28 mm 0.0104 to 0.0112 inch dot pitch.

#### 2.4.1.8 Keyboard

Each workstation shall have a keyboard provided with the system. The keyboard shall comply with the ANSI X3.64 standard and shall include a typewriter arrangement of alphanumeric symbols, vertical and horizontal tab keys, a standard numeric pad, cursor direction controls with a home key, and 10 user assignable push-button keys.

#### 2.4.1.9 Mouse

The Contractor shall provide a standard mouse with each workstation. Mouse speed and resolution shall be adjustable.

#### 2.4.1.10 Audible Alarm

Each workstation shall include an audible alarm, actuated by the on-line workstation computer.

#### 2.4.1.11 Laser Printer

Each workstation shall be provided with a laser printer. Resolution shall be a minimum of 600 dots per inch and there shall be a minimum of 2 megabytes RAM. Printing speed shall be a minimum of eight pages per minute, with a 100-sheet minimum paper cassette and with manual feed. A parallel interface shall be provided for connection to the workstation computer.

#### 2.4.2 Communications

\*\*\*\*\*

NOTE: The designer will utilize the first bracketed paragraph when the system requirements do not exceed 4 communication channels and the installation does not require multiple workstations. A single workstation system will be specified.

The designer will utilize the second bracketed paragraph when the system requirements exceed 4 communication channels, or the installation requires multiple workstations. A multiple workstation system will be specified.

\*\*\*\*\*

[Communications channels for the IEDs shall be provided as shown. The workstation shall include communication channels as required, expandable as

specified with additional cards. Data transfer shall be set at 9600 bps per channel. Repeaters and modems shall be provided as shown or required.] [Each Workstation computer shall be supplied with an internal network interface card for connection to IEEE Std 802.3 BASE-T twisted pair Ethernet LANs. Interface cards shall be supplied with an on-board transceiver for direct connection to the LAN, and with an AUI port for performing diagnostics. Interface cards shall also have an on-board buffer memory to prevent loss of data packets. The LAN shall interconnect and service system local and remote components. The network transmission media shall be Category 5 twisted pair cable as defined by TIA/EIA-568-B.1. All cabling, patch panels, patch cables, and accessories shall be provided as required to implement a complete wiring system for the LANs. Connector type shall be Category 5 rated. A minimum of one AUI port shall be provided per twisted pair module. Ethernet gateways shall be provided for interface of IED communication channels to the LAN. Ethernet gateways shall accept data from field equipment at the full speed of the field equipment communication channel.]

## 2.5 SYSTEM SOFTWARE

The standard system software supplied by the computer system manufacturer shall not be modified in any way that would preclude purchase of a standard maintenance and service contract from the computer manufacturer. A currently available and supported windowing disk operating system and graphical user interface shall be utilized.

## 2.6 COMMAND SOFTWARE

### 2.6.1 General Features

Command software shall be provided and shall request, receive, and process all real-time values acquired from periodic scans of field equipment and manual data and command entries from operator workstations. The software shall effectively coordinate the field equipment scanning and database updating with the workstation interface, report and event software, and other related calculation and data processing software.

### 2.6.2 Database Management

#### 2.6.2.1 Real-Time Database

- a. A real-time database shall be provided to store and manage the most current calculated, and scanned values.
- b. The real-time database shall be designed to handle the total number of IEDs specified in paragraph EXPANSION REQUIREMENTS.

#### 2.6.2.2 Database Editor

The database editor shall enable the operator to add, modify, and delete system IED's via interactive procedures. The editing software shall dynamically resize tables and files as IEDs are added or deleted. The system shall provide "fill-in-the-blank" displays for editing.

#### 2.6.2.3 Calculated Value

This value shall be created by calculating it from any combination of monitored values and parameters, and other data. The results of the calculation will be a value having all the properties of monitored values

without the associated hardware. The calculated point shall be available for use in any display or report.

#### 2.6.3 Scanning

- a. The software shall provide the message exchange sequence for scanning, generate necessary commands to retrieve monitored values and parameters, and perform all required error checking to ensure validity of received data, and/or proper completion of the scan sequence. All system malfunctions, including no response from field equipment, incomplete data, or invalid data, shall be reported.
- b. The Workstation shall communicate with IEDs on a sequential continuous scan basis.
- c. Inclusion or exclusion of any IED from the scanning sequence shall be accomplished from any Workstation.

#### 2.6.4 Error Detection and Retransmission

An error detection algorithm shall be used for data between IED and workstation which shall detect all single and double bit errors, all burst errors of eight bits or less, and at least 99% of all multi-bit and burst error conditions. A message shall be in error if one bit is received incorrectly. The system shall retransmit all messages with detected errors.

#### 2.6.5 User Interface Software

##### 2.6.5.1 General Display Requirements

Displays shall be provided as specified and shown. All displays shall be uniquely labeled. All displays shall include time and date. Displays shall contain any combination of graphic and tabular information. A display shall contain any combination of monitored data from all IEDs, and all displayed data shall be updated as specified in Paragraph: System Response Times.

##### 2.6.5.2 Display Editor

The display editor shall enable an operator with proper password to create, modify, and delete displays. The primary use shall be for adding and modifying one-line diagrams, station status displays, system summaries, and system directories, as field equipment or new data are added.

##### 2.6.5.3 Specific Displays

\*\*\*\*\*  
NOTE: The designer will show one-line diagrams and other project-specific graphics on the project drawings.  
  
Specify waveform displays (item e. below) only if Enhanced IEDs are specified.  
\*\*\*\*\*

The Contractor shall provide the following graphic and tabular displays:

- a. System Menu (menu of all tabular, reports, graphical displays,

active trends, and other displays provided on the system). Hot buttons shall be provided to allow an operator with an appropriate password, to select and go to any display from this index.

- b. Station Index (a list of all IEDs). Hot buttons shall be provided to allow an operator to select and go to the graphic displays and tabular displays for the selected IED.
- c. Site index (a list of sites such as substations or switching stations). Hot button shall be provided to allow an operator to select and go to the graphic displays and tabular displays for the selected site.
- d. Graphic displays based on the information shown.
- e. Waveform displays with adjustable time and magnitude scales and graphical means to analyze data at any point in the captured waveform.

#### 2.6.6 System Access Control

A minimum of 32 passwords shall be usable with the system software. The system shall include software security provisions to prevent inadvertent or unauthorized change of the password. The password shall not be displayed or printed.

#### 2.6.7 Trending

##### 2.6.7.1 Software General Requirements

- a. The trending software shall maintain data files for a minimum of 64 data trends. Any monitored or calculated value shall be trendable. Each data trend file shall retain a minimum of 500 data samples. The time rate of sampling shall be selectable on an individual trend basis. The data files shall be maintained with new data "pushed" in and the oldest data overwritten.
- b. The monitor shall display at least four trend values per window with separately selectable amplitude scales and time scales for each window. The time line programming shall allow for time scale references to be presented in a visual format that is representative of the application. As each new data line is written on the display, all previous entries shall be advanced to the next sequential element position. Time lines shall automatically move with each data point such that the time reference is always correct.
- c. An operator shall be able to enter upper and lower limits for each trend.
- d. The system shall provide for dynamic line and bar graphs, illustrating an analog value through a horizontal or vertical bar. The color of the bar graph shall be user-specified.
- e. The trending software shall allow at least eight colors to be used for different trends.
- f. The trending system shall include indication of alarm conditions.

- g. The system shall support the presentation of data with time on the X-axis (horizontal) and amplitude on the Y-axis (vertical). A minimum of 24 1-hour divisions and 31 1-day divisions shall be displayed on the X-axis. The start and end date/time shall be operator definable.

#### 2.6.7.2 Trend Description Fields

Each trend display shall include the following trend user-definable description fields.

- a. Variable name
- b. Amplitude scale
- c. Amplitude designation (engineering units)
- d. Time units per division

#### 2.6.7.3 Trend Functions

The trending system software shall support the following trend functions.

- a. Trend data from history file without active update.
- b. Trend data with active update and trend history from time of request to present (no prior history).
- c. Trend data with active update and with prior history from a trend history file.

#### 2.6.7.4 Storage of Trend Files

A user shall be able to select any combination of trend files for storage on hard disk. The files shall be automatically saved after a user-selectable number of trend values.

#### 2.6.8 Report Generator

##### 2.6.8.1 Required Software Features

Software shall be provided with commands to generate and format both tabular and graphical reports (including bar charts, pie charts and curve plots) for displaying, printing, and storing on hard disk. Reports shall be stored by type, date, and time. The destination of each report shall be selectable by the user. Reports shall use database dynamic values and parameters, values calculated using the database, and reports stored on disk or tape. Reports shall be spooled allowing the printing of one report to be complete before the printing of another report commences. Parameters used in reports shall be assignable by the user. Reports shall be processed to avoid interference with normal workstation computer tasks. The report shall contain the time and date when the sample was taken, and the time and date when the report was printed. Reports shall be user-definable to show information in the system database. The system shall allow for the operator to request an immediate printout of any report at any time.

##### 2.6.8.2 Creation of Reports

- a. Status Report: The system shall include software to produce reports on the current status of any equipment or parameters in the data base, including:

1. An individual IED.
  2. A list of equipment or monitored values, by category, such as substation, building, unit, and type of monitored value.
- b. Profile Reports: The software shall provide for generating profile reports by sampling and storing defined parameters on an operator assignable and selectable time interval basis such as an interval of 15 minutes for a period of 1 month and shall include:
1. Power consumption (value vs. time).
  2. Average power demand (value vs. time).
  3. Equipment subsystem profiles (value vs. value or value vs. time).
  4. Provide for 32 profile reports each having up to 1000 samples of up to 8 parameters.

#### 2.6.8.3 Standard Reports

\*\*\*\*\*  
**NOTE: Specify waveform reports (item f. below) only  
 if Enhanced IEDs are specified.**  
 \*\*\*\*\*

The following standard reports shall be provided:

- a. Electrical Power Utilization Report: An electrical power utilization summary, user selectable for individual meters or transducers, any group of meters or transducers, and all meters or transducers on a daily and a monthly basis. The report shall include:
- (1) Total daily kWh consumption.
  - (2) Total monthly kWh consumption for period beginning on user selectable day of the month.
  - (3) Demand interval kWh peak for the month and day, with time of occurrence.
  - (4) kWh consumption over each demand interval.
  - (5) Average kW demand during the interval containing the utility company's peak demand.
  - (6) Average kW demand during the interval containing the base's peak demand.
  - (7) Time-of-use peak, semi-peak, off-peak, or baseline total kWh consumption.
- b. Alarm Report: All current alarms or all alarms occurring within a user-specified period by IED, building, substation, installation, and the entire system, including time of occurrence.
- c. Analog Limit Report: An analog limit and differential summary selectable to describe a single analog value, all analog values within an IED, all analog values within a building, and all analog values for the project.
- (1) Analog value.
  - (2) Engineering units.

- (3) High limit.
- (4) Low limit.
- (5) Analog value change differentials.
- d. Static Database Reports: A listing of the values of fixed parameters and constraints defining the characteristics of the system. Provide operator commands to list the entire static database or to list an operator selected building, substation, unit, or IED. Each value listed shall be identified in English.
- e. Real-Time Database Reports: A list of the values of dynamic variables including all measured values and calculated values. These variables shall include year, month, day, hour, and minute on the report. Operator commands shall allow for listing the entire real-time database or to list a user selected building, substation, unit, or IED. Each value listed shall be identified in English.
- f. Waveform Reports: Graphical displays of captured waveform data, tagged by location (substation or IED), date and time.

#### 2.6.9 Alarm Processing

The alarm processing software shall recognize excursions of monitored or calculated values beyond operator assigned limits. Alarms shall be stored in the database and shall be retrieved for display or reporting as alarms.

#### 2.6.10 Historical Data Processing

##### 2.6.10.1 System General Requirements

The system shall process all real-time values and store user-selectable values for use at a later time. It shall store scanned values on a periodic basis, the maximum value for a point which occurred within a given time, or a calculated value. It shall generate reports using the historical data base processor and the reporting software. All historical information shall initially be stored. The tape drives shall store data in a form that allows historical reports to be readily prepared from the media. Historical trend files saved to the tape drives shall be recallable both as a trend file and as tabular data. All historical data shall be written to appropriately structured files on the workstation computer's hard drive, which shall function as a 30-day buffer. After the 30-day period is over, the system shall prompt the operator to archive the data to tape.

##### 2.6.10.2 DDE Data Export

Software shall be provided to implement Dynamic Data Exchange (DDE) for export of historical data to an Excel spreadsheet or other application. Data shall be stored in an Open Data Base Connectivity (ODBC) compliant format.

##### 2.6.10.3 Waveform Data Processing

\*\*\*\*\*  
**NOTE: Specify waveform data processing only if  
Enhanced IEDs are specified. Delete this paragraph**



if not required.

\*\*\*\*\*

The system shall store waveform data for display and printing.

## 2.7 FIELD EQUIPMENT SOFTWARE

The Contractor shall provide software necessary to accomplish the following functions, fully implemented and operational, within the field equipment.

- a. Scanning of inputs.
- b. Averaging or filtering of inputs.
- c. Display of values.
- d. Report to workstation of values.
- e. IED diagnostics.

## 2.8 INITIAL STOCKS

The Contractor shall furnish the stocks as specified below. All initial quantities shall be in addition to those needed for running the PVT.

- a. One box of 10-3.5" 1.44 MB diskettes for each Workstation.
- b. One toner cartridge for each laser printer.
- c. Ten new 4 mm formatted tapes with a capacity of 4 Gbytes before compression.

## 2.9 COMMUNICATIONS CHANNELS

The Contractor shall provide communications channels as shown between the IEDs and workstations as specified in Sections 27 21 10.00 10 FIBER OPTIC DATA TRANSMISSION SYSTEM and 27 15 19.00 10 WIRE LINE DATA TRANSMISSION SYSTEM. The Contractor shall use Government-furnished communications channels where shown.

## 2.10 LAN SOFTWARE

\*\*\*\*\*

**NOTE: The designer will include the following paragraph regarding LAN software for multiple workstation systems.**

\*\*\*\*\*

The LAN software shall provide for transparent communication with any node on the network. LAN software shall support operation of the system configured as shown. A network operating system shall be supplied as part of the LAN software. The network operating system shall support central and remote database maintenance, servers, file transfer, security, and job entry. A configured and operational shell menu interface shall be provided, and shall be user-configurable.

## PART 3 EXECUTION

### 3.1 INSTALLATION

The Contractor may start installation after Government acceptance of the Technical Data Packages 1 and 2.

### 3.1.1 Existing Condition Survey

The Contractor shall connect to and utilize existing devices as shown. Devices that are usable in their original configuration without modification may be reused. The Contractor shall perform a field survey, including inspection of all existing devices intended to be incorporated into the system and furnish an existing conditions report to the Government. The report shall identify those items considered nonfunctioning. The Contractor shall provide (with the report) specification sheets, or written functional requirements to support the findings and the estimated cost to correct the deficiency. If a device fails after the Contractor has commenced work on that device, the Contractor shall diagnose the failure and report the failure to the Government. The Contractor shall be held responsible for repair costs due to Contractor negligence or abuse of Government equipment.

### 3.1.2 Scheduling of Work and Outages

The Contract Clauses shall govern regarding permission for power outages, scheduling of work, coordination with Government personnel, and special working conditions.

### 3.1.3 Demolition and Removal

Required work shall be in accordance with Section 02 41 00 [DEMOLITION] [AND] [DECONSTRUCTION] and the Contract Clauses.

### 3.1.4 Installation of Field Equipment

#### 3.1.4.1 Installation General Requirements

The Contractor shall install all field equipment as specified and required for a fully functional and operational system. The Contractor shall exercise caution when drilling holes in panels housing energized equipment.

When mounting field equipment, the Contractor shall not allow metal shavings to fall into energized equipment. All work related to power equipment, including installation of instrument transformers on high voltage equipment and feeders, shall be as required in Sections 33 71 01 OVERHEAD TRANSMISSION AND DISTRIBUTION, 33 70 02.00 10 ELECTRICAL DISTRIBUTION SYSTEM, UNDERGROUND, and 26 20 00 INTERIOR DISTRIBUTION SYSTEM.

#### 3.1.4.2 Grounding

The Contractor shall provide grounding in accordance with manufacturer's recommendations and as specified. The Contractor shall provide an adequate ground for all enclosure circuits and cable shields to prevent ground loops and electrical noise from adversely affecting operation of the system.

#### 3.1.4.3 Communications Equipment

The Contractor shall be responsible for installing and testing communications equipment.

### 3.1.5 Installation of Workstation Equipment

The Contractor shall install all Workstation and peripheral equipment as specified and shown for an operational system.

### 3.1.6 Installation of Current Transformers

Each terminal of each current transformer shall be connected to a short circuiting terminal block.

### 3.1.7 Installation of Software

#### 3.1.7.1 General

\*\*\*\*\*  
**NOTE: The designer will include installation of LAN software for multiple workstation systems.**  
\*\*\*\*\*

The Contractor shall install all software as specified and required for an operational system including databases, operational parameters, [LAN], system, command, application, and Workstation programs. Upon successful completion of the PVT, the Contractor shall provide original and backup copies of object modules for all accepted software including diagnostics, on each type of media utilized. The hard drive on each workstation shall be partitioned and formatted at the factory, and all workstation software shall be installed on the hard drive at the factory. The Contractor shall provide one master copy and one back-up copy of all software, including the operating system, on CD-ROM.

#### 3.1.7.2 Development of Database

The Contractor shall develop the entire system database, using data shown, and the Contractor shall supply all other data required for the database.

#### 3.1.7.3 Displays Required

The Contractor shall provide the displays specified and as shown. All real-time inputs for the displays shall be included. All graphics provided shall be in the format and meet the requirements of paragraph USER INTERFACE SOFTWARE.

### 3.1.8 Installation of LAN Equipment

\*\*\*\*\*  
**NOTE: The designer will include this paragraph regarding LAN equipment for multiple workstation systems. Delete this paragraph if not required.**  
\*\*\*\*\*

- a. The Contractor shall install all LAN equipment as specified for an operational system.
- b. LAN cable shall be prepared in accordance with the cable and connector manufacturer's instructions. Category 5 rated connectors, as defined by **TIA/EIA-568-B.1**, shall be used for direct connection to the cable. Cables shall be of sufficient length to allow equipment displacement of at least **2.5 m 8 feet** in any direction.

### 3.2 SITE TESTING

#### 3.2.1 General

The Contractor shall provide all personnel, equipment, instrumentation, and supplies necessary to perform all site testing. The Government will witness all PVT testing. Original copies of all data produced, including results of each test procedure, during the PVT shall be turned over to the Government prior to approval of the test.

#### 3.2.2 Field Testing

The Contractor shall test, adjust, and calibrate all field equipment and verify system communications before the system is placed on line. The Contractor shall verify operation of all systems as specified upon loss of power, and that all systems return to proper operation automatically upon resumption of power. The Contractor shall deliver a report describing results of functional tests, diagnostics, and system calibrations including written certification to the Government that the installed complete system has been tested, adjusted, and calibrated, and is ready to begin the PVT. The report shall also include a copy of the approved PVT procedure.

#### 3.2.3 PVT

The Contractor shall demonstrate compliance of the completed system with the contract documents. Using approved test procedures, all physical and functional requirements of the project shall be demonstrated and shown. The PVT as specified shall not be started until after receipt by the Contractor of written permission by the Government, based on the Contractor's written report including certification of successful completion of Contractor's Field Testing as specified, and upon successful completion of training as specified. The PVT shall be performed as an integrated test with the data transmission system, and with all equipment specified operating and exchanging actual data under fully loaded conditions.

### 3.3 TRAINING

\*\*\*\*\*  
**NOTE: The designer will coordinate the number of  
personnel to attend each training session with the  
installation.**  
\*\*\*\*\*

#### 3.3.1 General

The Contractor shall conduct training courses for designated personnel in the maintenance and operation of the system as specified. The training shall be oriented to the specific system being installed under this contract. Training manuals shall be delivered for each trainee with two additional copies delivered for archival at the project site. The Contractor shall furnish all audiovisual equipment and all other training materials and supplies. Where the Contractor presents portions of the course material by audiovisuals, copies of those audiovisuals shall be delivered to the Government either as a part of the printed training manuals or on the same media as that used during the training sessions. A training day is defined as eight hours of classroom instruction, including two 15-minute breaks and excluding lunchtime, Monday through Friday, during the daytime shift in effect at the training facility. For guidance in

planning the required instruction, the Contractor shall assume that attendees have a high school education or equivalent, and are familiar with utility systems. Approval of the planned training schedule shall be obtained from the Government at least 30 days prior to the training.

#### 3.3.2 Operator's Training I

The first course shall be taught at the project site for a period of two consecutive training days during or after the Contractor's field testing, but before commencing the PVT. A maximum of [6] [\_\_\_\_\_] personnel will attend the course. No part of the training given during this course shall be counted toward completion of the PVT. The course shall include instruction on the specific hardware configuration of the installed system and specific instructions for operating the installed system. Upon completion of this course, each student shall be able to start the system, operate the system, recover the system after a failure, and describe the specific hardware architecture and operation of the system. This course shall include:

- a. System architecture.
- b. Functional operation of the system.
- c. User commands.
- d. Display generation.
- e. Database entry.
- f. Reports generation.
- g. Diagnostics.
- h. LAN operation, if required.

#### 3.3.3 Operator's Training II

The second course shall be taught at the project site for a period of one training day approximately one month after completion of the PVT. The Government will determine the specific date of the training session. A maximum of [6] [\_\_\_\_\_] personnel shall attend the course. The course shall be structured to address specific topics that the students need to discuss and to answer questions concerning the operation of the system. Upon completion of the course, the students should have no unanswered questions regarding operation of the installed system.

#### 3.3.4 Maintenance Training

The maintenance course shall be taught at the project site within thirty days after completion of the PVT for a period of two training days. A maximum of [6] [\_\_\_\_\_] personnel will attend the course. The training shall include:

- a. Physical layout of each piece of hardware.
- b. Troubleshooting and diagnostics procedures.
- c. Repair instructions.
- d. Preventive maintenance procedures and schedules.
- e. Calibration procedures.

-- End of Section --