



Mutah University

المواصفات الفنية
وحدات القياس الطورية

Technical Specification
For
Phasor Measurement Units (PMUs)

العطاء رقم / / ٢٠١٨

Tender No. (/2018)

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1 Acronyms & Abbreviations

Abbreviation	Description
IEC	International Electro technical Commission
IEEE	Institute of Electrical and Electronics Engineers
GPS	Global Positioning System
CT	Current Transformer
VT	Voltage Transformer
PMU	Phasor Measurement Unit
PDC	Phasor Data Concentrator
WAMS	Wide area monitoring system
ROCOF	Rate of Change of Frequency
UTC	Coordinated Universal Time
Employer	Mutah university Or his representative
Bidder	Organization making formal offer
IRIG-B	Inter-range instrumentation group time codes group B
iSCSI	Small Computer System Interface protocol over TCP/IP
SFP	Small Form-factor Pluggable
IGMP	Internet Group Message Protocol
GVRP	Generic VLAN Registration Protocol
RAID	Redundant Array of Independent Disk
HQ	Head Quarter
ACL	Access Control List
NCC	National Control Centre (at Amman South)
NEPCO	National Electric Power Company

NTP	Network Time Protocol
NTU	Network Termination Unit
SNMP	Simple Network Management Protocol
SSH	Secure Shell
SAN	Storage Area Network
VLAN	Virtual Local Area Network
PDF	Portable document Format
XLS	Microsoft Excel spreadsheet file
CSV	Comma Separated Value
XML	Extensible Markup Language
SAS	Serial Attached SCSI
DDR4	Double Data Rate Fourth-Generation
LACP	Link Aggregation Control Protocol

2 Background

The main idea of the proposed research pilot project, lead by Mutah university, is to introduce and implement Phasor measurement units (PMUs) in Jordanian National Grid and establish a seed for wide area system monitoring. The project will focus on application of PMUs at the southern section of National grid at **TWO substations** at National Electric Power Company (NEPCO) system. The WAMS to be installed inside the NEPCO Headquarter (HQ) data center (or at Mutah University) shall be capable for the planned future expansion of the system.

NEPCO owns and operates the high voltage electricity transmission system throughout the Hashemite Kingdom of Jordan. In its role as administrator of the financial settlement process for bulk energy transfers throughout the country, NEPCO has about 70 Substations around Jordan and some of them are connected to renewable energy generation.

The obtained real time data from PMUs will be used for several power system studies and investigations such as; phase angle displacement, stability investigations and system oscillations, Investigation the impact of renewable energy resources on system dynamics and oscillations.

Based on the results from this initial project, the research team at Mutah University will start working in the second stage, as future plan of the project, of application of PMUs to cover the entire Jordanian National Grid, substations, and its international connections.

3 General

- The Bidders are encouraged to offer their standard products that meet or exceed the specification requirements. Although the bidder is encouraged to use as much standard hardware and software as possible, the proposal will be judged by its conformance to the Specification. The proposal shall clearly identify all deviations from the Specification to help EMPLOYER evaluate the degree of conformance of the Bidder's offering.
- The substations normally are provided with CTs on each bay of the switchyard and CVTs in each transmission line bay. Generally CTs have one metering core and four protection cores. The CVTs are provided with two cores, one for measuring and the other core for protection. The PMUs to be supplied shall be connected to these CT and CVT cores.
- The specification identifies some minimum requirements for each of the major component which are essentially required for measurement of complex quantities and transmitting the same to the PDC (Phasor Data Concentrator) Locally at each Substation Then these PDC's shall be connected to Wide Area Monitoring System (WAMS) Located at the NEPCO HQ using NEPCO owned communication system. The delivered system is expected to provide meaningful measurement of the acquired data so that it is useful to

the operators in assessing the current state of grid. The system shall have the capability to integrate with SCADA system to allow the operator using the data for carrying out the post- fact analysis. The offered PMU, PDC and WAMS must be in operation at least for one year as on date of bid opening.

- Mutah University has the right of excluding items, exchange items and changing the quantities when awarding this tender, in order not to exceed the available budget without effecting the technical requirements and actual need.
- The bidder shall make presentations to the client representatives (if requested) at the conclusion during the stage evaluation, using power point software or similar electronic format.
- The bidder can offer more than one option/suggestion.
- Mutah University has the right to select the best solution design, construction and Operation that satisfy its requirements, needs and interests.

4 Scope of Work

The scope of work shall include supply of materials and provide support on the integration of the offered system components, including the following:

- a) Integration of supplied PMUs to PDC conforming to IEEE C37.118 .1 IEEE C37.118.2 and IEEE C37.244 -2013 standards.
- b) Maintenance of the supplied equipment (software and hardware) for one year.
- c) Installing the Equipment and connection with the CTs and VTs will be NEPCO Scope.
- d) All cabling, wiring, terminations and interconnections to the equipment including necessary trench/surface conditioning to interconnect the PMUs, PDCs and WAMS to be installed by (Mutah university and its representatives), integration with network and communication equipment also will be done by NEPCO.
- e) The bidder scope is to configure the supplied PMU's, PDC and WAMS by the provided software's and related system(s) components.
- f) The bidder is required to provide on-site technical support regarding any raised issue to enable (Mutah university and its representatives) staff to connect and integrate the system.

5 Technical Specifications

5.1 PMU Requirements

The offered PMUs shall be complete in all respect to meet the last standards so that they can be installed at the substation and communicate to the Phasor Data Concentrator (PDC) which installed in the substation. The necessary cable and connector and installation hardware shall also be supplied by the bidder. The PMUs shall normally be installed near to the control & relay panels and CT/CVT connections to the PMU shall be extended from the control & relay panels. The PMUs shall conform to IEEE C37.118.1 and C37.118.2 standards and shall be designed to meet the following requirements:

1. The PMUs shall be designed to measure the electrical parameters in the power system frequency band of 45-55 Hz.
2. The supplied PMU will be standalone/separate module in the substation control rooms /relay panel room.
3. The power supply of the PMUs will be provided from the station DC which is used for control and protection of substation devices. Accordingly the PMUs shall be suitable to operate on 110V ($\pm 10\%$) DC power supply.
4. The minimum offered configuration of PMUs shall have at least 8 analog input channel (One set of 3-phase voltages, One set of 3-phase current added to Neutral for both) and 4 digital inputs.

The required PMUs are to covers TWO substations, each one shall be suitable to measure 6 circuits.

Therefore, the offered PMU(s) shall be sufficient to measure all the connected circuits (i.e., the PMU(s) in each Location shall has/have 48 analogue inputs and 24 digital inputs at least).

The PMUs shall be used to measure the following at least:

- 3 phase positive sequence voltages magnitude and angle (polar form) quantities.
- 3 phase positive sequence currents magnitude and angle (polar form) quantities.
- Local frequency.
- Local rate of change of frequency (ROCOF).
- Circuit breaker and switch status.
- **Measuring power system oscillations of: voltage, angle difference, frequency, active and reactive power transfer.**

5. All the measurements shall be tagged with UTC (Coordinated Universal Time). The time tagging accuracy shall be at least one micro-second.
6. The PMU output shall be in IEEE C37.118.1 2014 format and shall communicate with the PDC using the C37.118.2 2014 standards level . The accuracy of the measurements shall be as per IEEE standard.
7. The PMUs shall be suitable for configuring the data sampling rate of 10, 25, 50 samples per second, sampling rate of 100 sample per second is optional and preferable. The actual rate shall be user selectable.
8. The PMUs shall have continuous self-monitoring, diagnostic feature and capable to identify communication problems and shall generate alarm in case of any abnormality which shall be displayed locally as well as shall be transferred to the PDC.
9. The PMU design shall ensure that the impact of frequency fluctuation (45-55 Hz) on accuracy is within permissible limit as per prevailing standards.
10. Testing & configuration accessories such as cables, connectors ,software etc which are not in-built to the PMUs but are required for testing and configuration changes, at least one set of such testing & configuration accessories shall be supplied complete with necessary hardware.
11. **(Optional)** Provision for Display/HMI (Human Machine Interface) in PMU to perform setting changes. In addition HMI should display the measured quantities for ease during testing. The Operation indications and time tagged events shall be available by the Local HMI. Alternatively Portable configuration device for PMUs at end can be provided for configuring the PMUs.
12. In case that the PMUs shall communicate with the PDC, at least One communication port of 10/100/1000 Base Tx for TCP/IP for streaming data in IEEE C 37.118.1 2014 format shall be provided in the PMU.
13. Remote configuration facility shall be provided in PMU and the supplier shall supply the software required for remote configuration of PMU.
14. Remote firmware upgrade feature shall be made available in case if it is required.
15. PMU shall be capable of sending data in Unicast and multicast both.

5.2 GPS based Time Facility

GPS based time facility to synchronize PMU clock with UTC source, shall be provided for each PMU. The time receiver shall include propagation delay compensation and shall also include an offset to permit correction to local time to achieve time accuracy of at least 1 microsecond. The time receiver shall detect the loss of signal from the UTC source and a loss-of-signal event shall be sent to the PMU which will be transferred to PDC and shall result in an alarm at PDC. Upon loss of signal, the PMU time facility shall revert to an internal time base. The internal time base shall have minimum stability of 1pps. Within five minutes of reacquisition of signal, the time shall return to within 1.5 micro-second of UTC. Proper correction of leap second shall be provided. The supplied GPS receiver shall contains sufficient outputs (either IRIGB/ NTP) to synchronize all the connected PMU's locally inside each substation (i.e., 2 GPS clocks are required).

The Antenna and the cable required to be connected with the GPS receiver shall be supplied, the supplied GPS receiver shall operate on 110V ($\pm 10\%$) DC power supply.

5.3 Phasor Data Concentrator (PDC) Requirements

The PMU to be supplied shall communicate with the PDC. The required PDC is in the scope of the present specifications. However, the PDC which PMUs to be integrated shall meet at least the following features:

1. The offered PDC shall support standard IEEE C37.244 -2013.
2. Shall be capable of receiving data in Unicast and Multicast.
3. PDC shall be able to receive the loss of signal event of the time receiver from PMU and shall result in an alarm at PDC.
4. PDC shall support Remote configuration of the PMU.
5. The PDC shall communicate with any PMU supports the protocols IEEE C37.118.1 and IEEE C37.118.2 protocols irrespective of the manufacture or the brand name of the PMU.
6. Hardware based PDC
7. Ability to Log results of unusual activity.
8. Retrieval of archives based on time and date, manually or automatically.
9. Management of user accounts and firmware versions.
10. Basic firewall feature **is preferred**
11. Automatic collection and storage of phasor archive data on local drives.
12. Internal storage of the PDC should be sized to aggregate and archive phasor data for the connected PMU's analog inputs and events for up to 30-days at maximum sample rate.
13. 2x 10/100/1000 base TX Ethernet ports each should be configured with different IP address ,one for receiving data from PMUs and management access and the other for sending data to upstream server.
14. Configurable input and output message rates and content for outputs.
15. Web OR client based management software.
16. Support minimum of 84 phasor input streams.

5.4 Wide Area Monitoring System (WAMS) requirements

Visualization, archiving and analysis software should satisfy the following minimum specifications:

1. Ability to monitor phase angle difference of voltage and current, perform calculations and deliver comprehensive and real-time human representation of these calculations across transmission lines.
2. Concentrate and archive Phasor Data in order to view trended charts and phasor diagrams in real time or offline (historian data) from all inputs.
3. Historian (offline) data retention should be derived from configurable policy to reserve storage resources. This could be achieved by either down sampling data older than x days/weeks/months/years or by overwrite it.
4. Quickly Find and Analyze System Event and determine the order of operations of system events with instant access to real-time and historical data by searching the archive database.
5. Automatic oscillation and disturbance Detection with the ability for immediate Email notifications.
6. Provide the ability to determine the disturbance location by referring to the source PMU.
7. Provide hints regarding disturbance or oscillation causes or types either by frequency or other comprehensive means.
8. Provide the ability for sharing events and views by means of snapshots across company or between different parties.
9. Reporting tool to allow the user to create customized reports.
10. Easily export synchro phasor data for further analysis with other applications, such as (PDF, XLS, CSV, XML).
11. Automatically detect transients induced by generation.
12. Provide convenient access with a web browser from any computer on the network.
13. Provide the ability to configure custom alarms.
14. Provide geographic map with the ability to import custom shape files for power lines and substations.
15. Allow individual authentication and secure access for all users.
16. 5 concurrent user accesses.
17. Multiple user roles ranging from system administrator to viewer.
18. Archiving database should be **perpetually licensed if required.**
19. Visualization and Archiving software should be **perpetually licensed for 5 concurrent users.**
20. The system shall allow the user to change DST (Day Light Saving Time) depending on settings for both date and time, these setting shall be user configuration.

5.5 Environmental Requirements

The PMU and PDC will be installed inside buildings without temperature or humidity control. The PMU and PDC shall be capable of operating in ambient temperatures from -10 deg C to +55 deg C and relative humidity up to 10-90% non-condensing.

6 Maintenance and support

Contractor shall be responsible for providing "Maintenance on call" of the system under warranty (WAMS and hardware components) including the ability to supply spares for ensuring the successful and continuous operation of the system. The maintenance and support period for the WAMS system components shall be for one year.

7 Documentation

7.1 PMU Documentation

Complete documentation is required to support PMU setup, operation and maintenance. The documentation shall include following:

1. Procedures for PMU setup and use with regards to all features.
2. Documentation of procedures regarding routine maintenance including use of system diagnostics.
3. Detailed connection diagrams showing how the PMUs are installed at site.
4. A complete copy of PMUs functional design.
5. Details of PMU database.
6. Details of hardware/software and as built system.

All documentation shall be delivered in both electronic format (e.g. PDF, MS WORD, Hypertext, etc.) on CDs/DVDs/USB drive, and in hardcopy format. Sufficient on-line, documentation, such as help screens, user guidance messages, context-sensitive help information links, etc., shall be included with the system to minimize the need for users to consult the hardcopy documentation.

7.2 PDC and wide area monitoring system Documentation

PDC and wide area monitoring system full documentation is required including the following:

1. Step by step guide for installation and configuration.
2. User guide include but not limited to the following:
 - Adding new PMU to the system.
 - View in details the functionalities of the system.
 - build and extract new reports from the system.
 - Troubleshooting manual including fault scenarios and fixing procedures.

8 Testing of PMUs

The offered PMUs, PDCs, and GPS clock sources shall conform to the type tests as per applicable standard and the bidder shall supply type tested for all offered equipment. The bidder shall submit the type test reports along with the bid for the offered make and model. The type test report shall include at least these tests indicated as follows:

1. Level-1 accuracy test as per IEEE C37.118.1 standard.
2. Electromagnetic compatibility (EMC), Immunity conforming to the requirements of IEC-60255/IEC 61000.
3. Emission test conforming to the requirements of EN 55011
4. Insulation Test per IEC 60255-5
5. Environmental Test as per IEC 60068-2-2

In case the type tests are conducted after placement of order, the Bidder shall get the type test procedure approved by the Employer/Owner and then these tests shall be conducted at bidder's own cost in presence of owner representative (if requested). The Bidder shall supply the Factory Test Reports for the above mentioned equipment or any other required equipment to the system and not mentioned here. (i.e., Factory Test Reports for active components shall be provided).

9 Wide area Monitoring system IT Infrastructure

9.1 Server

- **Quantity = 1**
 - **This server will be used to host WAMS visualization software and it is sized to accommodate future expansion. The minimum specifications as follows:**
1. Original Rack Mounted, with rack Kit, Sliding Rails, Cable Management Arm & all Accessories.
 2. Processor: 8 cores, 2.x GHz, 64-bit architecture with hyper threading and virtualization technology.
 3. 32GB DDR4 Memory ,ECC registered.
 4. Minimum 4X 10/100/1000 BASE-TX Network Interface Cards ,should support Link Aggregation standard LACP & VLAN Tagging 802.1Q .
 5. 16 TB raw local storage , using a combination of 12Gbps SAS,10K RPM hard drives with hardware RAID controller that support multiple raid levels (RAID 0,1,5) as minimum.
 6. 2x redundant power supplies 220V AC
 7. DVD+/-RW, SATA, Internal optical drive.
 8. Minimum 2x USB port ,1 management port,1 VGA port.
 9. Operating system support : Microsoft Windows Server 2012 & 2016 ,VMware 5.x,6.x.
 10. Minimum 2x USB port ,1 management port,1 VGA port.
 11. Management License: standard management license.

9.2 NAS (Network Attached Storage)

- **Quantity = 1**
 - **This NAS will be used for regular system backups and Phasor data backup. The minimum Specifications as follows:**
1. CPU: Dual Core 1.x GHz
 2. Memory: 1GB
 3. Storage: **30TB** raw capacity implemented by any number of hot swappable drives of any type.
 4. External Ports:2x1GB RJ45 LAN Ports & 1 USB 3.0.
 5. Networking Protocols: CIFS, NFS, iSCSI,SNMP
 6. Utilities: Web Based management Interface.
 7. Supported Language: English.
 8. Supported RAID Type: RAID 0,1,5
 9. AC Input Power Voltage: 50/60Hz 220V AC.

9.3 Substations Data Network Equipment:

Figure 1 below shows the general architecture of the suggested Wide Area Monitoring System.

- For each substation, phasor measurement units (PMUs) will be connected by their Ethernet connections to L3 switches using screened unshielded twisted pairs (S/UTP) cables (or equivalent) in addition to Phasor data concentrators using one of its Ethernet ports in order to receive sampled phasor data from PMUs. PMUs default gateway will be configured as L3 switch PMUs VLAN IP address.
- For each substation, phasor data concentrators (PDCs) shall be also connected to the L3 switch mentioned above by other dedicated Ethernet connection where the IP default gateway is also configured to point to the L3 switch, this interface will be also used as remote management interface for the PDC itself.
- L3 switch will be connected by an uplink to the substation communication cabinet where concentrated PDC data is transmitted up to NEPCO datacenter over NEPCO metro network. The transmitted data to be displayed and archived accordingly by the WAMS system.
- Basic security will be implemented as stateful ACL (Access Control List) both at substation L3 switch and at NEPCO datacenter sense no security gateway at this stage is implemented at any side of data end points. Basic firewall functionality of the PDCs itself (if supported) will be also helpful.

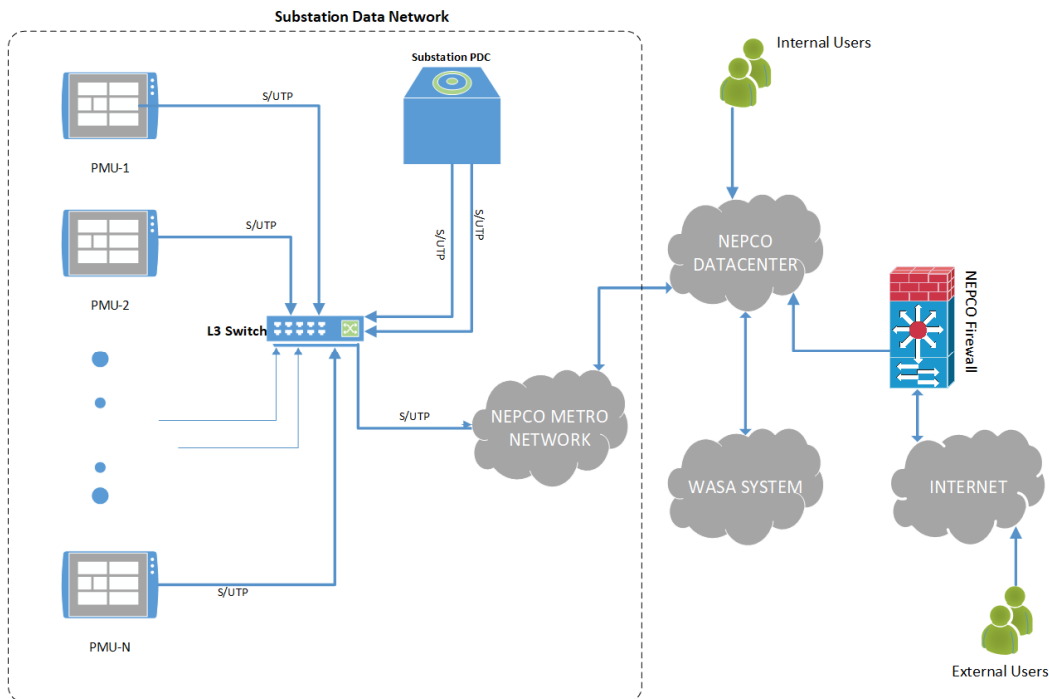


Figure 1 Suggested Wide Area Monitoring System architecture.

9.3.1 L3 Switch (If required)

- **Quantity = Two (one for each substation)**
- **The minimum specifications as follows:**
 1. 24 x RJ45 autosensing 10/100/1000 ports, Auto MDIX, Auto negotiation.
 2. 1 x 1000BASE-LX optical uplink ports.
 3. 1 x 1000BASE-LX sfp transceiver.
 4. Standard 19" rack-mountable with all required equipment.
 5. Wire speed non-blocking forwarding.
 6. Throughput: 38 Mpps.
 7. Routing/Switching capacity: 50 Gbps.
 8. Supports IEEE 802.1Q with 4,094 simultaneous VLAN IDs.
 9. Layer 3 routing: dual stack, inter-vlan routing, Static IP routing, Routing Information Protocol (RIP).
 10. Routing table size 512 entries (IPv4), 256 entries (IPv6).
 11. Power supply 110V (±10%) DC **(Power supply must operate by DC power at substations sites as NEPCO policy).**
 12. Management and monitoring: Console, Telnet, SSHv1/2, HTTP/HTTPs, Syslog, NTP, SNMP v2c, SNMPv3, FTP, TFTP, SCP, NetFlow/sFlow, LLDP, GVRP
 13. Support IEEE802.1Q tagging for all ports
 14. Spanning Tree Protocols: STP, RSTP, MST
 15. IPv4/IPv6 Multicast: IGMPv1/2/3, IGMP snooping, IGMP filtering, multicast routes and groups
 16. LACP different load sharing Algorithms: Source/Destination - MAC/IP/TCP/UDP
 17. Security:
 - MAC filtering/restriction
 - Dynamic ARP inspection (DAI)
 - DHCP snooping
 - IP source guard
 - BPDU and root STP filtering/protection
 - Port based unicast/multicast/broadcast storm control
 - Control plane security/protection
 - provides IP Layer 2 to Layer 4 traffic filtering; supports global ACL, VLAN ACL, port ACL, and IPv6 ACL
 18. Temperature sensor & Fan monitoring.**(fanless models will be rejected)**
 19. Quality of Service:
 - Broadcast control, classification based on Layer 2, 3, and 4 information
 - QoS policies (priority level and rate limit to selected traffic) a port, VLAN, or whole switch.
 - Congestion actions: strict priority (SP) queuing, weighted round robin (WRR), and SP+WRR.
 - Traffic policing: supports Committed Access Rate (CAR) and line rate.

9.4 Microsoft and other licenses

1. Microsoft Server 2012/2016 standard license should be provided and should cover the licensing requirement for the number of cores of each processor mentioned above for each option.
2. All required license to provide all functionalities mentioned in the specifications of the Servers, Switches should be provided.

10 Bill OF Quantities

<u>Item No.</u>	<u>Item</u>	<u>Required PMU Unit(s) for Two substation (Bidder to specify)</u>	<u>Unit cost</u>	<u>Total cost</u>
1.	Phasor Measurement unit			

<u>Item No.</u>	<u>Item</u>	<u>Quantity</u>	<u>Unit cost</u>	<u>Total cost</u>
2.	Phasor Data Concentrator (PDC)	2		
3.	Wide Area Monitoring System Software (5 concurrent users)	1		
4.	GPS Clock Source associated with Antenna cables and connectors	2		
5.	Server	1		
6.	NAS	1		
7.	Microsoft Server 2012/2016 standard license	1		
8.	Layer 3 Switch with DC power supply (if requires)	2		
9.	1000BASE-LX sfp transceiver	2		
10.	[Miscellaneous - Bidder to specify]			
	Total			