M65x

Measurement Centre and Transducer

User Manual

M65x

Measurement Centre and Transducer

Publication Reference: M65x/EN/M/B

GRID

ALSTOM

CONTENTS

CERTIFICATION

Alstom Grid certifies that the calibration of our products is based on measurements using equipment whose calibration is traceable to the United States National Institute of Standards Technology (NIST).

INSTALLATION AND MAINTENANCE

Alstom Grid products are designed for ease of installation and maintenance. As with any product of this nature, installation and maintenance can present electrical hazards and should be performed only by properly trained and qualified personnel. If the equipment is used in a manner not specified by Alstom Grid, the protection provided by the equipment may be impaired.

In order to maintain UL recognition, the following Conditions of Acceptability shall apply:

a) After installation, all hazardous live parts shall be protected from contact by personnel or enclosed in a suitable enclosure.

ASSISTANCE

For assistance, contact Alstom Grid Worldwide Contact Centre:

http://www.alstom.com/grid/contactcentre/

Tel: +44 (0) 1785 250 070

M65x Manual Set

M65x	User Manual
M65x	Modbus Protocol Manual
M65x	DNP3 Protocol Manual

COPYRIGHT NOTICE

TRADEMARKS

SAFETY SECTION

This Safety Section should be read before commencing any work on the equipment.

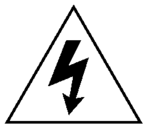
Health and safety

The information in the Safety Section of the product documentation is intended to ensure that products are properly installed and handled in order to maintain them in a safe condition. It is assumed that everyone who will be associated with the equipment will be familiar with the contents of the Safety Section.

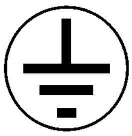
Explanation of symbols and labels

The meaning of symbols and labels that may be used on the equipment or in the product documentation is given below.

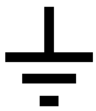
Caution: refer to product documentation



Caution: risk of electric shock



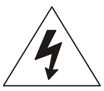
Protective Conductor Terminal (Safety Ground/Earth)



Functional Ground/Earth Terminal

Installing, Commissioning and Servicing

Equipment connections



Personnel undertaking installation, commissioning or servicing work on this equipment should be aware of the correct working procedures to ensure safety. The product documentation should be consulted before installing, commissioning or servicing the equipment.

Terminals exposed during installation, commissioning and maintenance may present a hazardous voltage unless the equipment is electrically isolated.

If there is unlocked access to the equipment, care should be taken by all personnel to avoid electric shock or energy hazards.

Voltage and current connections should be made using insulated crimp terminations to ensure that terminal block insulation requirements are maintained for safety. To ensure that wires are correctly terminated, the correct crimp terminal and tool for the wire size should be used.

Before energizing the equipment, it must be grounded (earthed) using the protective ground (earth) terminal, or the appropriate termination of the supply plug in the case of plug connected equipment. Omitting or disconnecting the equipment ground (earth) may cause a safety hazard.

The recommended minimum ground (earth) wire size is 2.5 mm^2 (#12 AWG), unless otherwise stated in the technical data section of the product documentation.

Before energizing the equipment, the following should be checked:

Voltage rating and polarity

CT circuit rating and integrity of connections

Protective fuse rating

Integrity of ground (earth) connection (*where applicable*)

Equipment operating conditions

The equipment should be operated within the specified electrical and environmental limits.

Current transformer circuits

Do not open the secondary circuit of a live CT since the high voltage produced may be lethal to personnel and could damage insulation.

Insulation and dielectric strength testing

Insulation testing may leave capacitors charged up to a hazardous voltage. At the end of each part of the test, the voltage should be gradually reduced to zero, to discharge capacitors, before the test leads are disconnected.

Do not attempt to perform installation, maintenance, service or removal of this device without taking the necessary safety precautions to avoid shock hazards. De-energize all live circuit connections before work begins.

Fibre optic communication

Where fibre optic communication devices are fitted, these should not be viewed directly. Optical power meters should be used to determine the operation or signal level of the device.

WARNING: EMISSIONS – CLASS A DEVICE (EN55011)

This is a Class A industrial device. Operation of this device in a residential area may cause harmful interference, which may require the user to take adequate measures.

Decommissioning and Disposal

1. Decommissioning

The auxiliary supply circuit in the equipment may include capacitors across the supply or to ground (earth). To avoid electric shock or energy hazards, after completely isolating the supplies to the meter (both poles of any dc supply), the capacitors should be safely discharged via the external terminals before decommissioning.

2. Disposal

It is recommended that incineration and disposal to watercourses is avoided. The product should be disposed of in a safe manner. Any products containing batteries should have them removed before disposal, taking precautions to avoid short circuits. Particular regulations within the country of operation may apply to the disposal of lithium batteries.

1.0 DESCRIPTION & SPECIFICATIONS

1.1 Introduction

The M65x family of multifunction, Measurement centres and transducers provides a range of measurement and communications capabilities for 3-phase metering. They offer an outstanding display, superior communications flexibility and easy setup.

The M65x family consists of the following, which are covered by this manual

M650	Measurement Centre
M651	Multifunction Transducer
M653	Measurement Centre with 3 simultaneous displays

Any mention of Displays and Keypad buttons in this manual does not apply to the M651 Transducer.

1.2 Features

1. Full basic measurement set with optional demand and harmonic values
2. 0.2% revenue accuracy
3. Updates every 100ms
4. DNP3 or Modbus protocol available via configurable RS-232/RS-485 serial port
5. Available Ethernet protocol support for DNP3 TCP/UDP or Modbus TCP
6. Web Based configuration via Ethernet service port
7. Wide-range universal power supply
8. Rugged aluminium case
9. One model covers all wiring options
10. Standard 4” round meter or transducer, M653 can be mounted in a 19” 3U panel
11. 3-line at once, easy-to-read, long-life LED displays (not M651)
12. Ultimate precision with five digits per line (not M651)
13. Instant recognition of the displayed function from the alphanumeric display in engineering units (not M651)
14. Easy setup and scrolling from front display with “Touch-Sense” buttons (not M651)
15. Optional Split Core CT inputs, whilst maintaining instrument accuracy

1.3 Specifications

Power Supply Input (Auxiliary) Voltage – terminals L1(+) and L2(-)

Installation Category (Auxiliary Power Supply) – CAT II

Nominal:	48-250V dc, 69-240V ac (50/60Hz)
Operating Range:	36-300V dc, 55-275V ac (45-65Hz)
Burden:	8W max, 24VA max
Display:	Three separate displays, each with 3 lines of 5 digits, red LED, 15mm (0.56”) high, and 1 line of 8 characters alphanumeric, red LED, 5mm (0.20”) high. (x3 on M653)
Display Interface:	4 buttons on centre display plus right and left buttons on M653

	Input Signals – Measurement Inputs		
CT Current Inputs	Configuration	All Input Options	3 Inputs. 3 Phase Currents (IA, IB, IC).
	Nominal	Input Option 1	1A ac
		Input Option 5	5A ac
		Input Option C	5A ac with split-core CTs
	Range	Input Option 1	0 to 2A rms continuous at all rated temperatures
		Input Option 5	0 to 10A rms continuous at all rated temperatures
		Input Option C	0 to 10A rms continuous at all rated temperatures
	Overload	Input Option 1	Withstands 30A ac continuous, 400Aac for 2 seconds
		Input Option 5	Withstands 30A ac continuous, 400Aac for 2 seconds
		Input Option C	Not applicable
	Isolation	Input Option 1	2500V ac, minimum.
		Input Option 5	2500V ac, minimum.
		Input Option C	2500V ac, minimum, with external split core transducers
	Burden	Input Option 1	0.016VA @ 1A rms, 60Hz (0.0016ohms @ 60Hz)
		Input Option 5	0.04VA @ 5A rms, 60Hz (0.0016ohms @ 60Hz)
		Input Option C	Not applicable
	Frequency	All Input Options	45-65 Hz
VT (PT) Voltage Inputs	Configuration		4 Inputs, Measures 1 Bus, 3 or 4 Wire. 3 Phase Voltages (VA, VB, VC, VN). See Appendix A1 Connection Diagrams.
	Nominal		120Vac
	Range		0 to 150V rms
	System Voltage		Intended for use on nominal system voltages up to 208 V rms, phase-to-phase (120V rms, phase-to-neutral).
	Common Mode Input Voltage		Reads to 400V peak, any input-to-case (ground)

	Input Signals – Measurement Inputs		
	Impedance		>12M ohms, input-to-case (ground)
	Voltage Withstand		2.5kV rms 1min, input-to-case (ground) 2kV rms 1min, input-to-input
	Frequency		45-65 Hz

Sampling System		
Sample Rate	64 samples per cycle	
Data Update Rate	Amps, Volts	Available every 100 ms
	Watts, VAs, VARs, PF	Available every 100 ms
Number of Bits	16	

Communication Ports	
Serial (option*)	RS-232, RS-485, Software configurable ports
	Baud rate: 9600 bps to 115.2 kbps
Ethernet	Single port; copper 10/100 Base-TX (standard)
	Single port; LC fibre 100 Base-FX (option)
Analogue Transducer Outputs (option*)	Refer to section 7.0 for specifications

*Either the serial port or analogue output may be ordered as an option, but not both

Accuracy Accuracies are specified at nominal Frequency and 25C, (unless otherwise noted). Unless noted, all values are true RMS and include Harmonics to the 31st (minimum).		
Voltage		AC: Better than 0.1% of reading (20 to 150 V rms, input-to-case). (+/- 25ppm/DegC)
Voltage Aux	Only included with meters manufactured with the monitoring option	AC/DC: Better than 1.0% of reading
Current	Input option 1 (Internal Isolation - 1A ac)	Better than 0.1% of reading +/- 20uA (>0.1A to 2.0A, -20C to 70C)
		Better than 0.1% of reading +/- 50uA (0.01A to 0.1A, -20C to 70C)
		Minimum reading 1mA
	Input option 5 (Internal Isolation - 5A ac)	Better than 0.1% of reading +/- 100uA (>0.5A to 10.0A, -20C to 70C)
		Better than 0.1% of reading +/- 250uA (0.05A to 0.5A, -20C to 70C)
		Minimum reading 5mA
	Input option C (External Split-Core CTs)	Better than 0.1% of reading +/- 100uA (>0.5A to 10.0A, -20C to 70C)
		Better than 0.1% of reading +/- 250uA (0.05A to 0.5A, -20C to 70C)
		Minimum reading 5mA
Frequency	+/- 0.001 Hertz	+/- 0.001 Hertz
Power	Meets or exceeds IEC 60687 0.2S	Meets or exceeds IEC 60687 0.2S

Environmental	
Operating Temperature	-40°C to +70°C
Relative Humidity	0-95% non-condensing
Measurement Inputs (VTs, CTs) Installation/Measurement Category	CAT III (Distribution Level): Refer to definitions below.
Pollution Degree	Pollution Degree 2: Refer to definitions below.
Enclosure Protection (to IEC60529: 2001)	Front Panel: IP 20, Rear: IP 20 When equipment is mounted in an appropriately rated protective enclosure to NEMA or IP protection classifications, as required for the installation. Ratings are applicable for enclosure category 2 (see definitions)
Altitude	Up to and including 2000m above sea level
Intended Use	Indoor use; Indoor/Outdoor use when mounted in an appropriately rated protective enclosure to NEMA or IP protection classifications, as required for the installation. Class 1 equipment to IEC61140: 2001

Physical		
Connections	Protective Conductor Terminal	10-32 Studs for connection with protective earth ground. Recommended Torque: 1.36 N-m (12 in-lbs). Cable temperature rating: 85C minimum
	Current (CT)	Internal Isolation - Current Input Option 1 or 5. 10-32 Studs for current inputs. Recommended Torque: 1.36 N-m (12 in-lbs). Cable temperature rating: 85C minimum
		External Split-Core CTs – Current Input Option C: Terminal Block accepts #22-12 AWG (0.35 to 3.3mm^2) wire, or terminal lugs up to 0.325" (8.26mm) wide. Recommended Torque: 1.02 N-m (9 in-lbs). Cable temperature rating: 85C minimum
	Voltage (VT) & (AUX PWR)	Terminal Block accepts #22-10 AWG (0.35 to 5mm^2) wire, or terminal lugs up to 9.53mm (0.375") wide. Precautions must be taken to prevent shorting of lugs at the terminal block. A minimum distance of 3mm (1/8") is recommended between uninsulated lugs to maintain insulation requirements. Recommended Torque: 1.02 N-m (9 in-lbs) Cable temperature rating: 85C minimum
	Serial Port	6 position removable terminal block, accepts 26-14AWG solid or 26-12 AWG stranded wire. Recommended Torque 0.79 N-m (7 in-lbs). Cable temperature rating: 85C minimum
	Ethernet (optional)	LC connector fibre port
	Ethernet	RJ45, 8 position modular jack, Category 5 for copper connection; 100m (328 ft.) UTP (unshielded twisted pair) cable.
Weight (typical)	0.82Kg (1.8 lbs) or 1.5 Kg (3.4 lbs).	
Size	Industry standard 4" round case, 178mm (7.0 in) long	

Definitions:

Enclosure Category 2: Enclosures where no pressure difference relative to the surrounding air is present.

Installation Category II (Overvoltage Category II) or CAT II: Equipment is intended for connection to the fixed installation of a building. The power supply to the electronic equipment is separated from other circuits, usually by a dedicated transformer for the mains power supply.

Measurement/Installation Category III (Overvoltage Category III) or CAT III: Distribution Level, fixed installation, with smaller transient overvoltages than those at the primary supply level, overhead lines, cable systems, etc.

Pollution: Any degree of foreign matter, solid, liquid, or gaseous that can result in a reduction of electric strength or surface resistivity of the insulation.

Pollution Degree 2: Only non-conductive pollution occurs except that occasionally a temporary conductivity caused by condensation is to be expected.

1.4 Standards and Certifications

1.4.1 Revenue

The M65x family of meters exceeds the accuracy requirements of ANSI C12.20 and IEC 60687 (or IEC62053-22).

Type	Nominal Current	Certification
M3	1A, 5A	ANSI C12.20, 0.2CA IEC 60687 (or 62053-22), 0,2S

The M65x meters were tested for compliance with the accuracy portions of the standards only. The form factor of the M65x meters differs from the physical construction of revenue meters specified by the ANSI/IEC standards and no attempt has been made to comply with the standards in whole.

1.5 Environment

UL/CSA Recognized, File Number E164178
UL61010-1, Edition 3, Issue Date 2012/05/11
Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use – Part 1: General Requirements
UL61010-2-30, Edition 1 – Issue Date 2012/05/11
Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use – Part 2: Particular Requirements for Testing and Measuring Circuits

CSA C22.2 No. 61010-1-12-CAN/CSA, Edition 3, Issue Date 2012/05/01
CAN/CSA Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use – Part 1: General Requirements
CSA C22.2 No. 61010-2-30-12-CAN/CSA, Edition 1 – Issue Date 2012/05/01
Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use – Part 2-030: Particular Requirements for Testing and Measuring Circuits

If applicable, the CE mark must be prominently marked on the case label.

European Community Directive on EMC 2004/108/EC and Directive 91/263/EC [TTE/SES].
European Community Directive on Low Voltage 2006/95/EC)

Product and Generic Standards
The following product and generic standards were used to establish conformity:

Low Voltage (Product Safety)
IEC 61010-1, Edition 3, Issue Date 2013/02/01
Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use – Part 1: General Requirements
IEC 61010-2-30, Edition 1 – Issue Date 2010/06/02
Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use – Part 2-030: Particular Requirements for Testing and Measuring Circuits

EMC: EN 61326-1: 2013 (Supersedes EN61326-1: 2006), EN 61000-6-2: 2005, EN 61000-6-4: 2007/ A1:2011 (IEC date 2010)

Radiated Emissions Electric Field Strength
EN 55011: 2009/ A1: 2010
EN 61000-6-4: 2007/ A1:2011 (IEC date 2010)
Group 1, Class A
Frequency: 30 - 1000 MHz

AC Powerline Conducted Emissions
EN 55011: 2009/ A1: 2010
EN 61000-6-4: 2007/ A1:2011 (IEC date 2010)
Group 1, Class A
Frequency: 150 kHz – 30 MHz

Electrostatic Discharge (ESD)
EN61000-4-2: 2009
Discharge voltage: ± 8 KV Air; ± 4 KV Contact & Additionally meets ± 6 KV Contact

Immunity to Radiated Electromagnetic Energy (Radio Frequency)
EN 61000-4-3: 2006/ A1: 2008/ A2:2010, Class III
Frequency: 80 – 1000 MHz, Modulation: 80% AM @ 1 kHz
Frequency: 1400 – 2000 MHz, Amplitude: 3.0 V/m, Modulation: 80% AM @ 1 kHz
Frequency: 2000 – 2700 MHz Amplitude: 1.0 V/m Modulation: 80% AM @ 1 kHz
Digital Radio Telephones:
Frequency: 900 MHz & 1890 MHz, Amplitude: 10.0 V/m, 3.0 V/m, Modulation: 80% AM @1kHz

Electrical Fast Transient / Burst Immunity
EN 61000-4-4: 2012 (supersedes EN 61000-4-4: 2004/ A1:2010)
Burst Frequency: 5 kHz
Amplitude, AC Power Port: ± 4 KV (Severity Level 4), exceeds ± 2 KV requirement
Amplitude, Signal Port: ± 1 KV, Additionally meets ± 2 KV (Severity Level 3)
Amplitude, Telecom ports (Ethernet): ± 1 KV

Current/Voltage Surge Immunity
EN 61000-4-5: 2007 (supersedes EN 61000-4-5: 2006)
Open Circuit Voltage: 1.2 / 50 µs
Short Circuit Current: 8 / 20 µs
Amplitude, AC Power Port: 2 KV common mode, 1 KV differential mode

Immunity to Conducted Disturbances Induced by Radio Frequency Fields
EN 61000-4-6: 2009
Level: 3
Frequency: 150 kHz – 80 MHz
Amplitude: 10 V rms
Modulation: 80% AM @ 1 kHz

Power Frequency Magnetic Fields
EN 61000-4-8: 2010
Amplitude: 30A/m
Frequency: 50 and 60 Hz

AC Supply Voltage Dips and Short Interruptions
EN 61000-4-11: 2004

Surge Withstand Capability Test For Protective Relays and Relay Systems
ANSI/IEEE C37.90.1: 2002 (2.5 kV oscillatory wave and 4 kV EFT)

2.0 PHYSICAL CONSTRUCTION & MOUNTING

M650
The M650 meters are packaged in rugged aluminium case specifically designed to meet the harsh conditions found in utility and industrial applications.

The Front panel view is shown in Figure 1a. The mechanical dimensions are shown in Figure 2a.

Figure 1a – M650 Front View

M651
The M651 digital transducers are packaged in rugged aluminium case specifically designed to meet the harsh conditions found in utility and industrial applications.

The mounting plate panel view is shown in Figure 1b. The mechanical dimensions are shown in Figure 2b.

Figure 1b – M651 Mounting Plate View

M653
The M653 meters are packaged in a rugged aluminium case mounted on an aluminium 19” 3U panel or as a 14" panel mount version and are specifically designed to meet the harsh conditions found in utility and industrial applications.

The Front panel view is shown in Figure 1c. The mechanical dimensions are shown in Figure 2c.

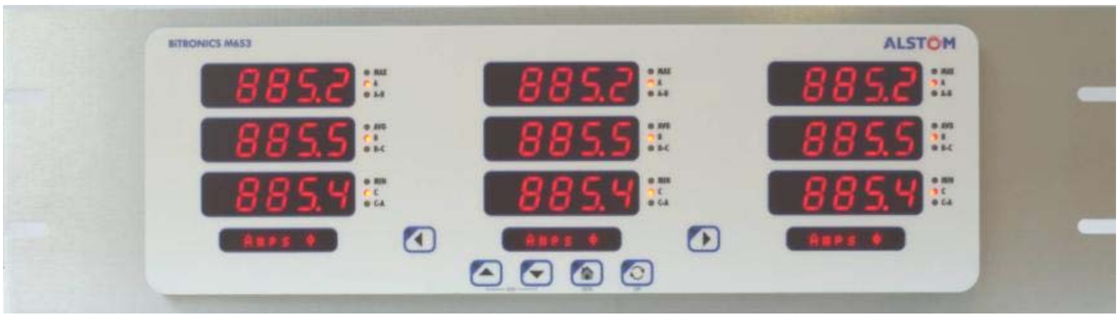


Figure 1c – M653 Rack mount version Front View

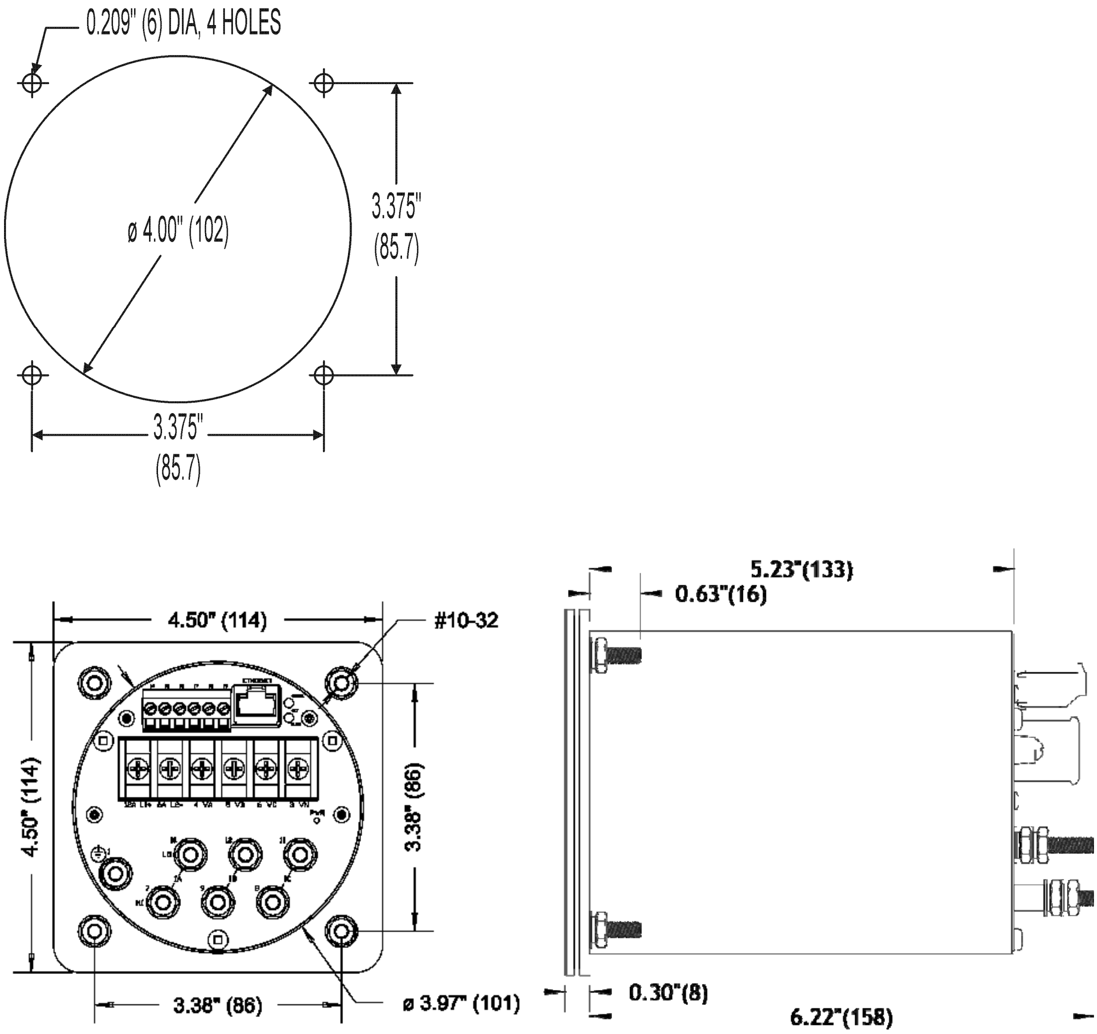


Figure 2a - Mounting and Overall Dimensions M650

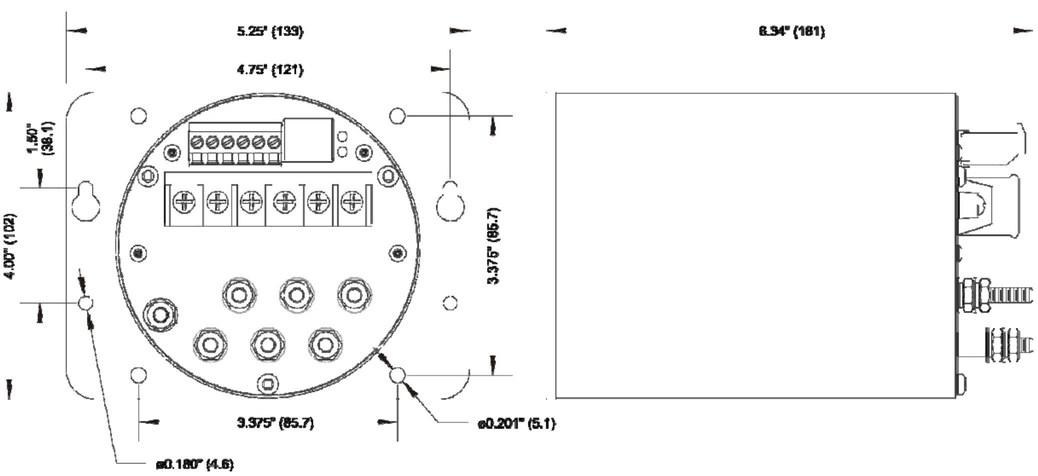


Figure 2b - Mounting and Overall Dimensions M651

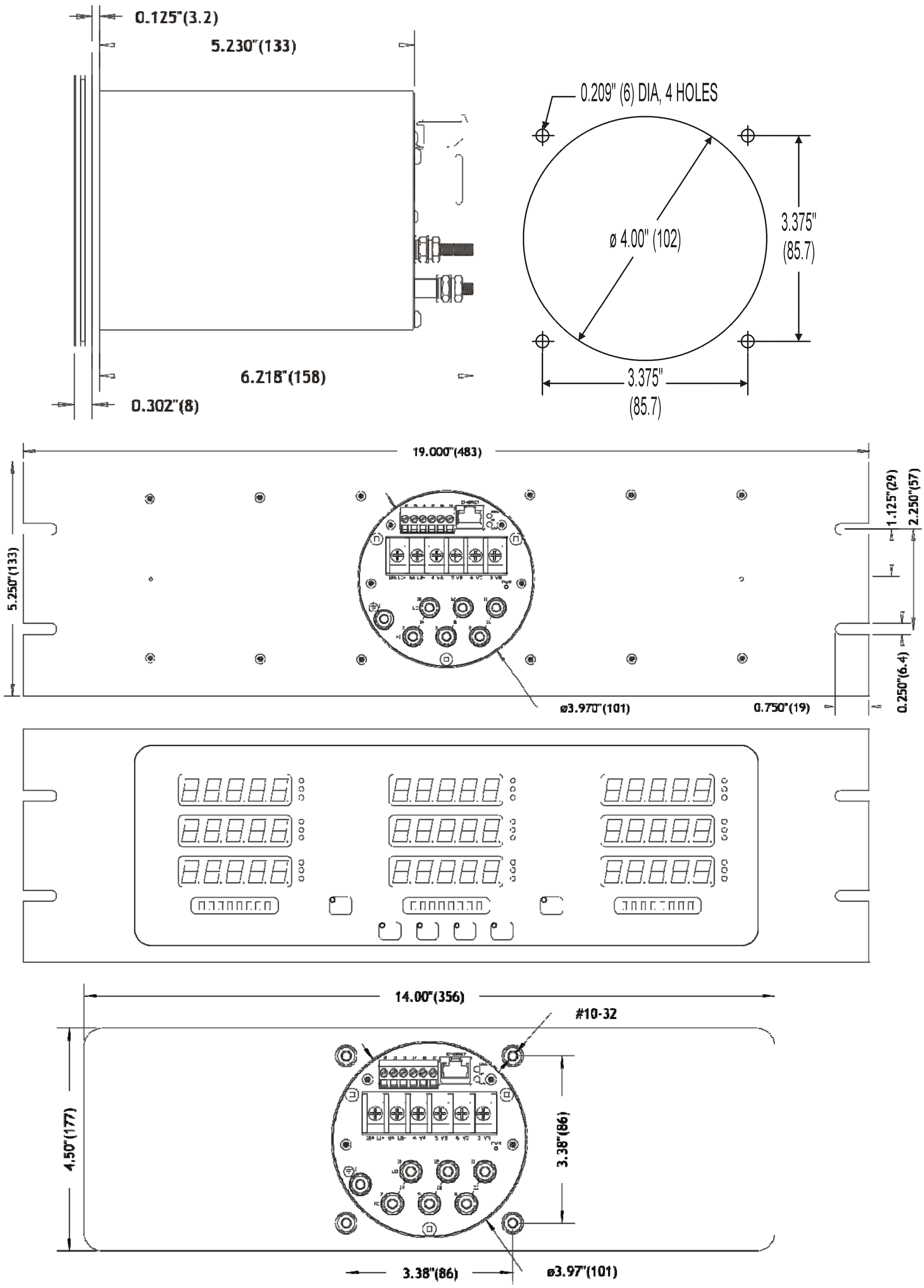


Figure 2c - Mounting and Overall Dimensions M653

(rack mount above, panel mount below; back panel may vary due to options ordered)

2.1 Installation

WARNING - INSTALLATION AND MAINTENANCE SHOULD ONLY BE PERFORMED BY PROPERLY TRAINED OR QUALIFIED PERSONNEL.

2.2 Initial Inspection

Alstom Grid instruments are carefully checked and "burned in" at the factory before shipment. Damage can occur however, so please check the instrument for shipping damage as it is unpacked. Notify Alstom Grid immediately if any damage has occurred, and save any damaged shipping containers.

2.3 Protective Ground/Earth Connections

The device must be connected to Protected Earth Ground. The minimum Protective Ground wire size is 2.5 mm^2 (#12 AWG). Alstom Grid recommends that all grounding be performed in accordance with ANSI/IEEE C57.13.3-1983.

2.4 Overcurrent Protection

To maintain the safety features of this product, a 3 Ampere time delay (T) fuse must be connected in series with the ungrounded/non-earthed (hot) side of the supply input prior to installation. The fuse must carry a voltage rating appropriate for the power system on which it is to be used. A 3 Ampere slow blow UL Listed fuse in an appropriate fuse holder should be used in order to maintain any UL product approval.

2.5 Supply/Mains Disconnect

Equipment shall be provided with a Supply/Mains Disconnect that can be actuated by the operator and simultaneously open both sides of the mains input line. The Disconnect should be UL Recognized in order to maintain any UL product approval. **The Disconnect should be acceptable for the application and adequately rated for the equipment.**

2.6 Instrument Mounting

M650

The M650 may be mounted into a standard 4” round panel opening as shown in Figure 2a. The unit will mount through the 4-inch round panel opening from the front. Align the four #10-32 studs attached to the flange with their appropriate mounting holes, as shown by the panel hole pattern. Use four #10-32 nuts with lock washers applied onto the studs from the back side of the panel. **Make sure that any paint or other coatings on the panel do not prevent electrical contact.**

WARNING – DO NOT over tighten the nuts on the mounting studs, **HAND** tighten with a standard nut driver, 1.35 N-m (12 in-lbs) is recommended, **MAXIMUM** torque is 1.7 N-m (15 in-lbs).

Several instruments may be mounted on a 19" Rack panel if desired. Three units will fit side by side on a standard (3U) 133mm (5.25") high panel. Figure 2a indicates the dimensions of the panel hole cut-out. Leave adequate space surrounding the instrument when determining mounting arrangements.

M651

The M651 transducer may be surface mounted as shown in Figure 2b. The instrument may be mounted on a standard transducer mounting hole pattern. The unit should be mounted with four #8-32 screws. The transducer is intended to be connected to earth ground at the mounting plate. **Make sure that any paint or other coatings on the panel do not prevent electrical contact.**

Several instruments may be mounted on a 19" Rack panel if desired. Three units will fit side by side on a standard 133mm (5.25") high panel. Leave adequate space surrounding the instrument when determining mounting arrangements

M653

The rack mount version may be mounted into a standard 19”, 3U high rack opening. The panel mount version may be mounted into a standard 4” round panel opening as shown in Figure 2c. The unit will mount through the 4-inch round panel opening from the front. Align the four #10-32 studs attached to the flange with their appropriate mounting holes, as shown by the panel hole pattern. Use four #10-32 nuts with lock washers applied onto the studs from the back side of the panel. **Make sure that any paint or other coatings on the panel do not prevent electrical contact.**

WARNING – If the meter is removed from the panel at any time upon reinstalling, **DO NOT** over tighten the nuts on the mounting studs, **HAND** tighten with a standard nut driver, 1.36 N-m (12 in-lbs) is recommended, **MAXIMUM** torque is 1.69 N-m (15 in-lbs).

Split Core CT

For details of mounting the optional split-core CTs - – Refer to section 8

2.7 Cleaning

Cleaning the exterior of the instrument shall be limited to the wiping of the instrument using a soft damp cloth applicator with cleaning agents that are not alcohol based, and are non-flammable and non-explosive.

3.0 REAR PANEL & WIRING

The rear views of the M65x are shown in figures 3a and 3b with the option port shown (removable terminal block at the top), which may be selected at order time, as either, the serial communication option, the 0-1mA analogue output option, or the 4-20mA analogue output option. However, it is also possible to have a meter without this option port.

See Appendix A1 for detailed wiring diagrams covering the CT/VT measurement inputs. Refer to the appropriate section in this user manual when wiring either the serial communication option, or either analogue output option, whichever applies to the option port for your meter.

Figure 3a – Rear View M65x (shown with Current (CT) Inputs with internal isolation (#10-32 stud terminals) – Current Input Option 1 or 5)

Figure 3b –Rear View M65x (shown with 6 position terminal block for External Split-Core CTs – Current Input Option C)

3.1 Auxiliary Power

The M65x meters are powered by connections to L1(+) and L2(-). A Blue LED Power (PWR) indicator is provided on the rear panel to indicate that the unit is powered ON. It is located on the right of the rear panel.

There is an option that allows the voltage across the Auxiliary Power input voltage across terminals L1(+) and L2(-) to be monitored. This monitoring option is only found in M65x that have been manufactured with this monitoring option. Refer to the order guide to verify whether the meter is made with this monitoring option. 'V Aux' will appear on the display as a measurement on meters equipped with this monitoring option and the measured values can be obtained via the communications.

3.1.1 Specifications (per section 1.3)

Power Supply Input (Auxiliary) Voltage – terminals L1(+) and L2(-)

Nominal: 48-250V dc, 69-240V ac (50/60Hz)

Operating Range: 36-300V dc, 55-275V ac (45-65Hz)

3.2 VT Inputs – VA, VB, VC, VN (See Appendix A1 and Section 1.3)

The M65x voltage (VT) signal inputs are connected to terminals 3-6 (see Appendix A1 for specific wiring configurations). Voltage signals are measured using a 12M ohm resistor divider with a continuous voltage rating of 7kV. This ideal impedance provides a low burden load for the VT circuits supplying the signals. Grounding of VT & CT signals per ANSI/IEEE C57.13.3-1983 is recommended. The polarity of the applied signals is important to the function of the instrument.

3.3 CT Inputs - IA, IB, IC (See Appendix A1 and section 1.3)

The M65x can be connected directly to a current transformer (CT). The Current (CT) signal inputs are connected to terminals 7-12.

Several hardware options are offered for the M65x current inputs. Distinctions are based on the current option ordered and the physical constructions.

The 1 Amp and 5 Amp current inputs, current input options 1 and 5 respectively, feature 10-32 terminals to assure reliable connections. This results in a robust current input (CT) connection with negligible burden to ensure that the user's external CT circuit can't ever open-circuit, even under extreme fault conditions. Grounding of CT signals per ANSI/IEEE C57.13.3-1983 is required.

Current inputs, option 1: 1 Amp input with internal current isolation transformer, constructed with 10-32 studs as the current terminals. (**See Figure 3a for the physical construction shown for the current terminals**). It is intended that this meter connects to the output from the secondary of permanently installed Current Transformers (CTs).

WARNING: DO NOT loosen existing 10-32 hardware that secures the current input studs to the back panel. When making connections to the current input studs, use #10 ring lugs. Fasten ring lugs with the 10-32 bagged hardware (flat washer, lock washer, and nut) provided. DO NOT OVERTORQUE. HAND Tighten with a standard nut driver. 1.36 N-m (12 in-lbs) is recommended, MAXIMUM torque is 1.69 N-m (15 in-lbs).

Current inputs, option 5: 5 Amp input with internal current isolation transformer, constructed with 10-32 studs as the current terminals. (**See Figure 3a for the physical construction shown for the current terminals**). It is intended that this meter connects to the output from the secondary of permanently installed Current Transformers (CTs).

WARNING: DO NOT loosen existing 10-32 hardware that secures the current input studs to the back panel. When making connections to the current input studs, use #10 ring lugs. Fasten ring lugs with the 10-32 bagged hardware (flat washer, lock washer, and nut) provided. DO NOT OVERTORQUE. HAND Tighten with a standard nut driver. 1.36 N-m (12 in-lbs) is recommended, MAXIMUM torque is 1.69 N-m (15 in-lbs).

Current inputs option C: This option is used with external Split core CTs. External split core CT secondary wires connect to the current terminal block **(see figure 3b)**. The Current inputs for this model are touch safe. No internal current isolation is provided within the meter. DO NOT CONNECT Hazardous Live voltages to the current input terminal block. Only connect the external Split Core CT secondary current outputs to the meter's current input terminal block. Isolation is provided from the external Split Core CTs. Recommended torque is 1.02 N-m (9 in-lbs).

For additional details of the optional split-core CTs refer to section 8.

3.4 Serial Port (See section 4.2)

The M65x meters are equipped with an optional serial port. The port is software (user) configurable for RS-232 or RS-485. The RS-232 drivers support full and half duplex modes. See Figures 7-8 for signal assignments.

3.5 Ethernet

The M65x Ethernet port meets or exceeds all requirements of ANSI/IEEE Std 802.3 (IEC 8802-3:2000) and additionally meets the requirements of part 8-1 TCP/IP T-profile for physical layer 1 (Ethernet copper interface).

M65x meters are offered with a standard Ethernet 10/100 Megabit (Mb) RJ45 (copper) interface (10BASE-T and 100BASE-TX) which automatically selects the most appropriate operating conditions via auto-negotiation. This interface is capable of operating either as half-duplex (compatible with all Ethernet infrastructures) or full-duplex interfaces (which allow a potential doubling of network traffic). Note that the meters come with the port setup as a service port, with Modbus TCP/IP or DNP3 TCP/IP or UDP software offered as an option. An option to replace the standard RJ45 port with a LC 100BASE-FX fibre port also exists, operating at 1300 nm (far infra-red), full-duplex.

3.5.1 Network settings

The M65x meters come preconfigured for interconnection to an HTML web server with default settings for IP address, SUBNET mask, and ROUTER (GATEWAY) address.

Network Default (Preconfigured) Settings		
IP Address	Subnet mask	Router (Gateway) Address
192.168.0.171	255.255.255.0	192.168.0.1

It is very important that the network have no duplicate IP addresses, so that an IP address conflict is NOT created for your network. It is recommended to perform your initial setup for network addresses using the front buttons on the meter, unless it is known that the default (preconfigured) IP address is not already an assigned address on your network. Changing the stored Configuration of these network addresses may be accomplished by using one of the following methods

Enter Network addresses using the meter's front buttons (not M651):

Refer to the section in this manual on "Navigating the M65x's setup menu from the Front panel" for further instruction regarding the button sequence you will use to scroll through the menu structure. This will provide a handy menu tree.

Activate the setup mode using the front buttons on the meter by pressing the Up + Toggle (Exit) buttons simultaneously. Scroll to menu selection "1.3", "Network", in order to change the Network settings. Enter an IP address that you know is an unassigned address for your network. You can ping the IP address to make sure it is not already in use on your network. You may also want to check with your network administrator to make sure the IP address you plan on using is available to use on your network. After entering the Network addresses exit out of the menu, and when prompted to save the new configuration settings, press the button directly under the SAVE prompt identified as "Y" (Yes). Reboot the meter for the configuration changes to take effect.

Enter the IP Address for the meter through a standard web browser:

Before entering an IP address with this method make sure the current IP address and the new IP address to be assigned to the meter will not cause IP address conflicts on your local network.

To connect to the web server enter the meter's current IP Address in your web browser's address bar. When the web server screen appears click on the "Settings" tab. Type the new Network settings (IP address, Subnet mask, Gateway) in the appropriate fields and click the "**Apply**" button to send the new network settings to the meter. Reboot the meter for the configuration change to take effect.

The M65x uses the following port numbers for each type of protocol:

Protocol	Port Number
DNP3	20000 (TCP, UDP)
HTML	80 (TCP)
Modbus	502 (TCP)

Determining the IP Address if unknown:

Although the IP address can be obtained via the display, for the M651 which does not have a display, a utility program has been created to request the IP address for a specific MAC address on an Ethernet network. This program can be used with the M650 and M653 as well. The program is available on website (http://www.novatechweb.com/downloads/inarp/).). The program uses the Inverse Address Recognition Protocol to perform the lookup and thus is called inarp. The InARP protocol definition can be found at www.apps.ietf.org/rfc/**rfc2390**.html. The inarp utility can also scan an Ethernet network for a range of MAC addresses, printing the IP address for any devices which respond.

Currently, the only Alstom Grid devices which respond to inarp are M65x products with a release code >= 2.00.0.

The general form of inarp is defined below, followed by some usage examples.

inarp usage:

```
 inarp [-i <if_ipaddr>] [-n <cnt>] [-p <ms>] [-v] <mac-spec>

   where
     <if_ipaddr> := interface ip address (default is 1st Ethernet interface)
           <cnt> := count of addresses to poll (default 1)
            <ms> := period between polls (100ms)
      <mac-spec> := <6ByteMac> | <[3-5]ByteMac> | <macRangeName>
      <6ByteMac> := xx:xx:xx:xx:xx:xx - <cnt> can specify a range to scan
      <5ByteMac> := xx:xx:xx:xx:xx - default <cnt> is 256
        ...
      <3ByteMac> := xx:xx:xx - default <cnt> is 16,777,216
   <macRangeName> := "50series"
               50Series MAC base (00:d0:4F:03), default <cnt> is 65,536
           -v := request verbose information

   CTRL-C stops a scan.
```

The inarp utility requires the WinPcap and Packet libraries which are bundled in the WinPcap "Installer for Windows." This can be downloaded from www.winpcap.org.

Installation requires Administrator privileges.

To use the inarp utility, open a 'cmd' window and change the directory to the location where inarp.exe is stored. Then type the commands as defined below

Examples:

to poll the 1st IPv4 interface,
inarp -v 50series
CTRL-C stops the scan

This scan takes some minutes to poll the full range of MAC addresses.

to poll the IPv4 interface associated with 192.168.1.1, use
inarp -v -i 192.168.1.1 50series

or to poll a specific MAC, use
inarp -v -i 192.168.1.1 00:D0:4F:03:00:15

3.5.2 Indicators – Ethernet (ACT) & Serial LEDs

There are 2 LEDs on the rear panel to indicate activity is occurring on the communication ports. These LEDs are useful in determining that there is activity occurring on the ports. The "ACT" LED will flash to indicate there is activity on the Ethernet port. It will also indicate that a link has been established. The Serial LED flashes to indicate there is activity occurring for the serial port.

A troubleshooting guide is found in Appendix A2, which may be useful in establishing Ethernet connections.

3.5.3 Firmware upgrades – Ethernet service port

New versions of firmware may be released by Alstom Grid from time to time, either to add new functionality or to correct errors in code that may have escaped detection prior to commercial release. Consult the factory for detailed information pertaining to the availability of firmware upgrades. In cases such as this, it is desirable to support a mechanism for new firmware to be installed remotely. The ability to upgrade the Firmware is done over the Ethernet port. The M65x family utilizes a page in the Web Server interface to upload and install new firmware. A password protected hyperlink is provided from the Configuration Settings Page that navigates to the Firmware Upload page.
First obtain a copy of the firmware image. The firmware image is a binary file, less than 1 MB in length, that can be attached to email, distributed on a CD, or downloaded from an FTP site as circumstances dictate. Place a copy of the firmware image on your computer then access the upload page from the Firmware Update link on the Configuration Settings page.
This will take you to the firmware upload page, which looks like the screen capture in Figure 4.

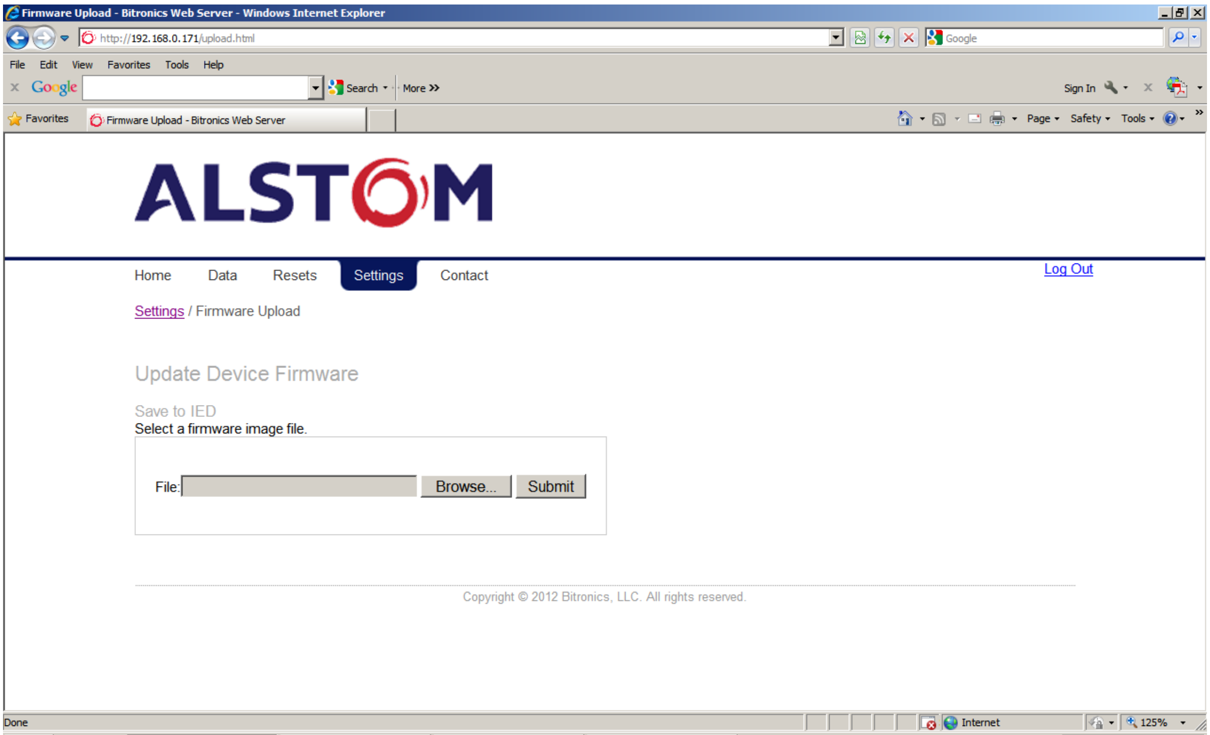
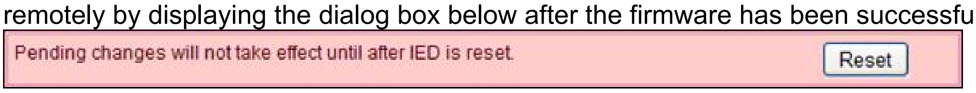


Figure 4 –M65x Firmware Upload Page

Once the Firmware Upload page is visible, use the Browse button to locate the firmware image on your computer. Next use the Submit button to initiate the file transfer and installation process. The instrument must be rebooted to make the new firmware active. At the completion of the file transfer and installation process, the instrument will prompt you to reset the instrument remotely by displaying the dialog box below after the firmware has been successfully installed.



It is strongly recommended that you clear your web browser's cache (delete the temporary internet files) after updating the firmware so that the new content will be loaded into your browser. Please refer to your browser's help file on how to clear the cache. A useful keyboard shortcut common to Internet Explorer, Firefox and Chrome is CONTROL + SHIFT + DELETE, which will take you directly to the relevant panel. Carefully select the items to be cleared. Be sure to check the boxes that clear "temporary internet files", "cache" or "website data" and uncheck any boxes that preserve data.

4.0 OPERATION

4.1 Display (not applicable to M651)

The M650 can display several per-phase and total quantities for the circuit being monitored. In order to make all quantities available, the display scrolls from quantity to quantity approximately every 5 seconds. The quantities are refreshed once a second. The Alphanumeric display at the bottom of the instrument indicates to the user what quantity is being displayed. The Alphanumeric display also provides the user with primary engineering units (Watts, kWatts, MWatts, etc.).

The Middle Display of the M653 retains all the functionality of the M650 Display including Scrolling, Home Screen designation, Custom screens, Setup mode, etc. The M653 adds a Left Display, a Right Display, a Left Button and a Right Button to the front panel. All three displays can display several per-phase and total quantities for the circuit being monitored.

Any pre-defined or custom screen that is displayed on the Middle Display of the M653 can be copied to the Left or Right Display by pressing the corresponding Left or Right button on the front panel. The last selection made is retained through power down events. In addition to the front panel buttons, the screen selection for the Left and Right Display may be made on the Settings/Screen Enable webpage. The screens that appear on the left and right displays do not need to be enabled on the middle display.

Listed on the following pages are standard screens available in the M65x. Configurable screen enable settings allow the user to enable or disable each of the display screens, in order to view only a selected subset of all the measurements the meter is capable of displaying. Refer to the section in this manual on Setup Mode for instructions on programming Screen Enable Settings (Setup menu - $^{1.6}$ Scrn Ena).

The following screens are enabled by default:

Amps A,B,C
Volts AN,BN,CN
Volts AB,BC,CA
Total Watts / Total Vars
VAs Total / Power Factor
Frequency
Demand Amps A,B,C

The Default HOME screen is:

Amps A,B,C.

INSTANTANEOUS DISPLAY SCREENS

	Format	Quantity
1.	00000	Phase A Amperes
	00000	Phase B Amperes
	00000	Phase C Amperes
	AmpsΦ	
2.	00000	Residual Amperes [1]
	□□□□□	Unused
	□□□□□	Unused
	AmpsR	
3.	00000	Phase A Volts [1]
	00000	Phase B Volts
	00000	Phase C Volts
	xVolts	
4	00000	Phase A-B Volts
	00000	Phase B-C Volts
	00000	Phase C-A Volts
	xVolts	
5.	00000	Phase A Watts [1]
	00000	Phase B Watts
	00000	Phase C Watts
	xWatts Φ	
6.	00000	Phase A VARs [1]
	00000	Phase B VARs
	00000	Phase C VARs
	xVAR Φ	
7.	00000	Total Watts
	00000	Total VARs
	□□□□□	Unused
	xW·xVAR	
8.	00000	Phase A VAs [1]
	00000	Phase B VAs
	00000	Phase C VAs
	xVA Φ	
9.	00000	Phase A PF [1]
	00000	Phase B PF
	00000	Phase C PF
	PF Φ	

10.	00000	Total VAs
	00000	3Φ PF
	□□□□□	Unused
	xVAs·PF	
11.	00.000	Frequency
	□□□□□	Unused
	□□□□□	Unused
	Hz	
12.	12345	Positive
	6789A.	kWh
	□□□□□	Unused
	+kWh	
13.	12345	Negative
	6789A.	kWh
	□□□□□	Unused
	-kWh	
14.	12345	Positive
	6789A.	kVARh
	□□□□□	Unused
	+kVARh	
15.	12345	Negative
	6789A.	kVARh
	□□□□□	Unused
	-kVARh	
16.	000.00	VA hours (Most significant half)
	000.00	VA hours (Least significant half)
	□□□□□	Unused
	kVAh	
17.	00000	Watt hours Net (Most significant half)
	00000	Watt hours Net (Least significant half)
	□□□□□	Unused
	kWh NET	
18.	00000	Total Watts
	00000	3Φ PF
	0000	Frequency
	xW·PF·Hz	

[1] - Screen available on WYE meters only
x - indicates blank, (k)ilo, (M)ega, or (G)iga

DEMAND DISPLAY SCREENS

	Format	Quantity
19.	000.00	Phase A Amps Demand
	000.00	Phase B Amps Demand
	000.00	Phase C Amps Demand
	Amps Dmd	
20.	00000	Phase A Maximum Amperes Demand
	00000	Phase B Maximum Amperes Demand
	00000	Phase C Maximum Amperes Demand
	Amps MAX	
21.	000.00	Residual Amps Demand Maximum
	000.00	Residual Amps Demand
	□□□□□	Unused
	AmpsDmdR	
22.	000.00	Phase A Average Voltage
	000.00	Phase B Average Voltage
	000.00	Phase C Average Voltage
	xV Avg	
23.	00000	Phase A Maximum Volts Demand [1]
	00000	Phase B Maximum Volts Demand
	00000	Phase C Maximum Volts Demand
	xV MAX	
24.	00000	Phase A Minimum Volts Demand [1]
	00000	Phase B Minimum Volts Demand
	00000	Phase C Minimum Volts Demand
	xV MIN	
25.	000.00	Phase A-B Average Voltage
	000.00	Phase B-C Average Voltage
	000.00	Phase C-A Average Voltage
	xV Avg	
26.	00000	Phase A-B Maximum Volts Demand
	00000	Phase B-C Maximum Volts Demand
	00000	Phase C-A Maximum Volts Demand
	xV MAX	
27.	00000	Phase A-B Minimum Volts Demand
	00000	Phase B-C Minimum Volts Demand
	00000	Phase C-A Minimum Volts Demand
	xV MIN	
28.	00000	Total Maximum Watt Demand
	00000	Total Watts (Also on Screen 7)
	00000	Total Minimum Watt Demand
	xW · ↑ · ↓	

	Format	Quantity
29.	00000	Total Maximum VAR Demand
	00000	Total VARs (Also on Screen 7)
	00000	Total Minimum VAR Demand
	xVAR · ↑ · ↓	
30.	00000	Total Maximum VAs
	00000	Total VAs (Also on Screen 10)
	00000	Total Minimum VAs
	xVA · ↑ · ↓	

[1] - Screen available on WYE meters only
x - indicates blank, (k)ilo, (M)ega, or (G)iga

HARMONIC SUMMARY DISPLAY SCREENS

	Format	Quantity
31.	00000	Phase A Fundamental Amperes
	00000	Phase B Fundamental Amperes
	00000	Phase C Fundamental Amperes
	Fnd Amps	
32.	00000	Fundamental Residual Amperes [1]
	□□□□□	Unused
	□□□□□	Unused
	FndN · Amps	
33.	00000	Phase A Fundamental Volts
	00000	Phase B Fundamental Volts
	00000	Phase C Fundamental Volts
	Fnd xV	
34.	000.00	Phase A-B Fundamental Voltage
	000.00	Phase B-C Fundamental Voltage
	000.0	Phase C-A Fundamental Voltage
	Fnd xV	
35.	000.00	Phase A Current %Total Demand Distortion (%TDD)
	000.00	Phase B Current %Total Demand Distortion (%TDD)
	000.00	Phase C Current %Total Demand Distortion (%TDD)
	%TDD I	
36.	000.00	Phase A Voltage %Total Harmonic Distortion (%THD)[1]
	000.00	Phase B Voltage %Total Harmonic Distortion (%THD)
	000.00	Phase C Voltage %Total Harmonic Distortion (%THD)
	%THD V	
37.	000.00	Phase A-B Voltage %Total Harmonic Distortion (%THD)
	000.00	Phase B-C Voltage %Total Harmonic Distortion (%THD)
	000.00	Phase C-A Voltage %Total Harmonic Distortion (%THD)
	%THD V	
38.	00.000	K-Factor Phase A (Current)
	00.000	K-Factor Phase B (Current)
	00.000	K-Factor Phase C (Current)
	K-Factor	

39.	0.0000	Phase A Displacement PF [1]
	0.0000	Phase B Displacement PF
	0.0000	Phase C Displacement PF
	DispPF Φ	
40.	00000	3Φ Displacement PF
	□□□□□	Unused
	□□□□□	Unused
	DispPF T	
41.	000.00	Phase A Fundamental Demand Amps
	000.00	Phase B Fundamental Demand Amps
	000.00	Phase C Fundamental Demand Amps
	FndDmdIΦ	
42.	000.00	Phase A Maximum Fundamental Demand Amps
	000.00	Phase B Maximum Fundamental Demand Amps
	000.00	Phase C Maximum Fundamental Demand Amps
	FndDmdIΦ	
43.	000.00	Maximum Fundamental Demand Amps Residual
	000.00	Fundamental Demand Amps Residual
	□□□□□	Unused
	FundDmdIR	
44.	000.00	Phase A Average Watts
	000.00	Phase B Average Watts
	000.00	Phase C Average Watts
	xW Avg	
45.	000.00	Phase A Maximum Average Watts
	000.00	Phase B Maximum Average Watts
	000.00	Phase C Maximum Average Watts
	xW Max	
46.	000.00	Phase A Minimum Average Watts
	000.00	Phase B Minimum Average Watts
	000.00	Phase C Minimum Average Watts
	xW Min	
47.	000.00	Phase A Average VARs
	000.00	Phase B Average VARs
	000.00	Phase C Average VARs
	xVAR Avg	

48. 000.00 Phase A Maximum Average VARs
000.00 Phase B Maximum Average VARs
000.00 Phase C Maximum Average VARs
xVAr Max

49. 000.00 Phase A Minimum Average VARs
000.00 Phase B Minimum Average VARs
000.00 Phase C Minimum Average VARs
xVAR Min

50. 000.00 Phase A Average VAs
000.00 Phase B Average VAs
000.00 Phase C Average VAs
xVA Avg

51. 000.00 Phase A Maximum Average VAs
000.00 Phase B Maximum Average VAs
000.00 Phase C Maximum Average VAs
xVA Max

52. 000.00 Phase A Minimum Average VAs
000.00 Phase B Minimum Average VAs
000.00 Phase C Minimum Average VAs
xVA Min

53. 00000 Phase A Secondary Volts[1]
00000 Phase B Secondary Volts
00000 Phase C Secondary Volts
SecVolts

54. 00000 Phase A-B Secondary Volts
00000 Phase B-C Secondary Volts
00000 Phase C-A Secondary Volts
SecVolts

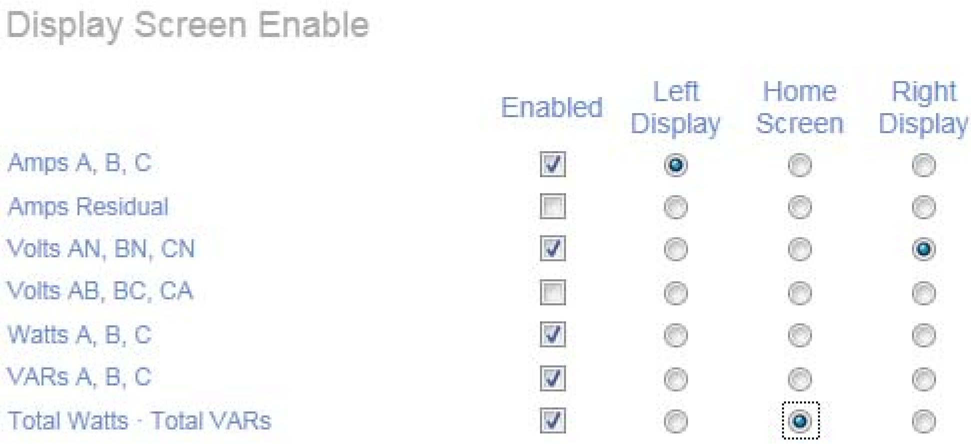
55. 000.00 Auxiliary Voltage
□□□□□ Unused
□□□□□ Unused
V aux

[1] - Screen available on WYE meters only
x - indicates blank, (k)ilo, (M)ega, or (G)iga

The screens that are displayed in the scrolling mode can be programmed (ENABLED/DISABLED) by the user. This programming can be done by using the front panel buttons of the device or through the web server.

Enable/Disable Display Mode Screens via the front buttons on Display:
The Screens can be enabled or disabled (refer to Section 5.5) via the front display buttons by entering the setup mode section and going to the Screen Enable menu ([1.6], Scrn Ena).

Enable/Disable Display Mode Screens via the Web Server:
The screens can be enabled or disabled via the web server. (Refer to section 5.6) From the web page, select the Settings tab then click on Screen Enable in the menu list. One screen each can be selected for the left and right displays on the M653 and for the home screen. Other screens enabled will be available on the display of the M650 and on the centre display of the M653.



For all the Watt, VAR and/or PF displays the "SIGN" of the quantity is indicated by the centre segment of the left most digit, which will be illuminated to produce a "-" for negative quantities. Positive quantities will have no polarity indication. This restricts the display to 4 digits in the Watt and/or VAR display, however this is a restriction for the display only, internally the instrument still carries full precision.

4.1.1 Overview – Buttons Functions

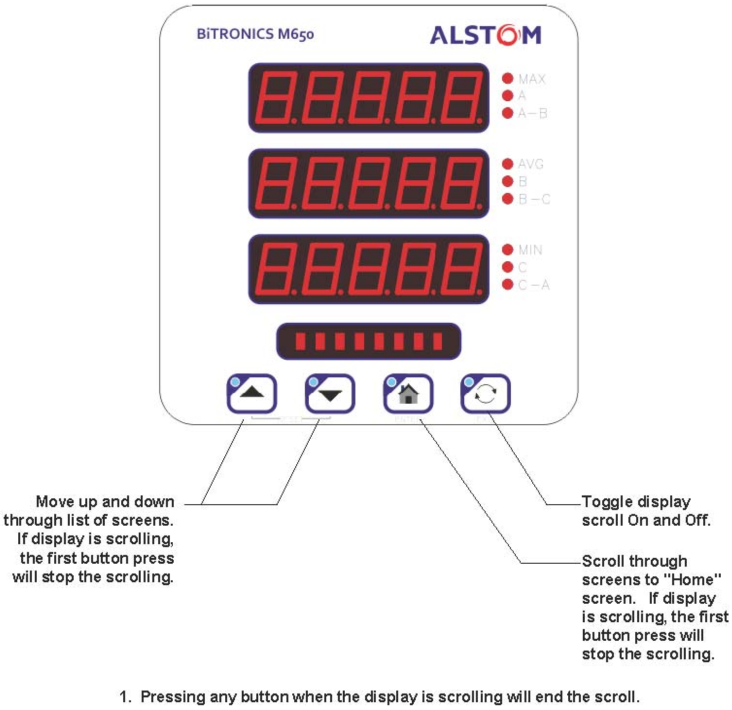


Figure 5 – Button functions for Display Mode

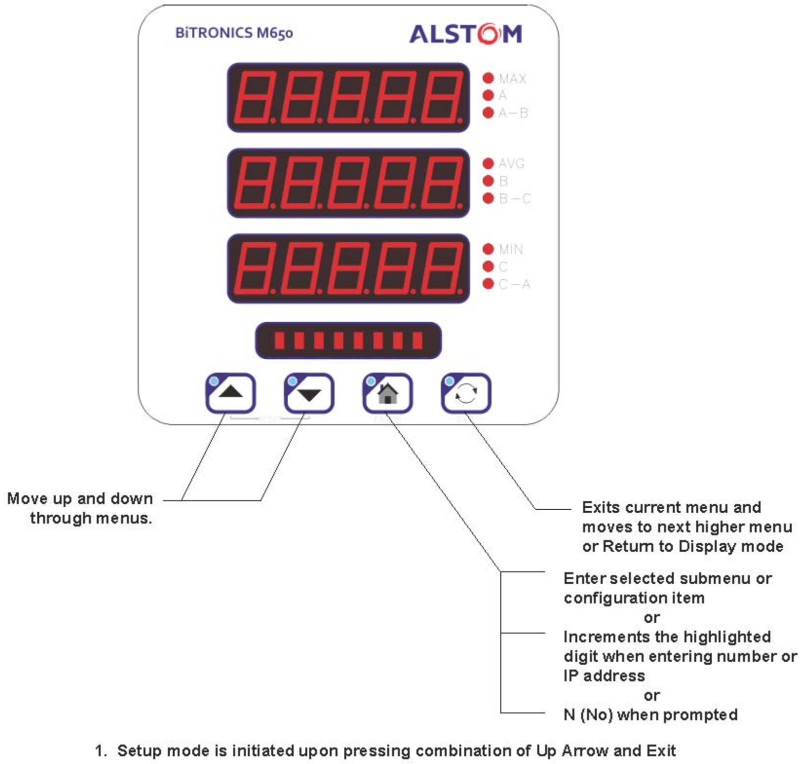


Figure 6 – Button functions in Set-up Mode

4.1.2 Keypad Functions for Display Mode

Measurements screens may be stepped through manually by pushing the up and down arrow keys. Pushing the Toggle (Exit) key turns the scroll function off and on. When the scroll function is activated, the measurement screens will automatically step through the user-defined screens. Auto scroll state (ON/OFF) is stored in non-volatile memory. Pressing the Home (Enter) key will bring up the home screen. The factory default home screen will be Amps A, B, C. If a user enables or disables screens via the front display buttons from Setup Mode ($^{1.6}$ Scrn Ena), then the home screen will automatically become the 1st enabled screen. The home screen can be setup as any one of the enabled screens by simultaneously pressing the Home (Enter) and Toggle (Exit) buttons when on the desired screen and can also be done through the web server Settings tab.

Table 1 –Button Functions

Button	Display Mode Function	Setup Mode Function
Up Arrow	Next measurement/value	Next menu item
Down Arrow	Previous measurement/value	Previous menu item or Y (Yes) when prompted
Home (Enter)	Scroll to designated home screen	Enter selected submenu (or configuration item), or Increments the highlighted digit when entering number, or IP address, or N (No) when prompted
Toggle (Exit) EXI	Toggle Auto Scroll On/Off	Exits current menu selection and moves up to next higher menu level. Returns to display mode on exit from main setup menu
Combination Up and Exit keys	Enter Setup Mode (Resets and configuration setting are done in the setup menu)	
Combination Up and Down Keys	Resets Demand Values	
Combination Home (Enter) and Toggle (Exit) keys	Designate the displayed screen as “Home Screen”	
Left Arrow	Copies screen from middle display to left display (M653 only)	
Right Arrow	Copies screen from middle display to right display (M653 only)	

Resets are found in the setup menu

4.1.3 Display Error Messages

Error messages from self test are shown on the display. The table below summarizes the errors and the messages displayed:

SELF TEST RESULT SUMMARY FOR M65x DEVICES

Fault	Fault Indication	Effects of Fault	Corrective Action
Display Overflow	Display flashes 9999	Measured quantity is too large to be displayed. Communication option output may still be accurate, if overload does not exceed meter input ratings	Correct fault external to instrument.
Input gain calibration checksum error	G CAL	Calibration constants for the input gain are in error. The display and the communication option output are reduced in accuracy to approximately +/-3%.	Return to factory for repair
Input phase calibration checksum error	P CAL	Calibration constants for the phase are in error. The display and the communication option output are reduced in accuracy to approximately +/-3%.	Return to factory for repair
Analog outputs calibration checksum error	A CAL	Calibration constants for the analogue outputs are in error. The analogue output option is reduced in accuracy to approximately +/-3%.	Return to factory for repair
Input Over-Range	CLIP	Peak input quantity exceeds the range of the instrument. Both display and communication option output accuracy reduced by an amount depending upon the degree of over-range.	Verify input signals are within range. If within range, return to factory for repair.
Protocol Configuration Error	P CFG	Instrument protocol configuration may be corrupted and inaccurate. This may cause communication errors.	Reset configuration.
Firmware Download in Progress	FLASH	Will be displayed during download and will disappear shortly after user reboots meter	Reboot meter when prompted.

4.2 Serial Port

This port when ordered can be set to RS-232 or RS-485, and support baud rates up to 115200. Set-up of the Serial Port can be accomplished by using a web browser connected to the Ethernet port, or via the front display buttons (Setup menu - 1.4 Serial). The default configuration for the serial ports is:

Serial Port Default Setting					
Port	Protocol	Parity	Baud	IED Address	Physical Media
Serial	DNP 3	None	9600	1	RS-232

Serial cable requirements for RS485 connection:
Tie RS-485 cable shields (pin 15) to earth ground at one point in system.

The recommended torque ratings for the terminal block wire fasteners are listed in the Physical Specifications table (section 1.3).

Transient Voltage Suppressor (TVS) clamp devices are used on the serial port as the method of protection. The serial port is clamped to a voltage of 16.7-18.5V nominal, 24.46V max. The clamps are rated for a peak pulse current of 24.6 max.

4.2.1 RS485 Connections

Note that various protocols and services have different port connection requirements. When making connections to serial ports for Modbus or DNP3 over RS485, 2-wire half duplex is required. This is because it is imperative to maintain a minimum time period (3 1/3 characters) from the time the transmitter shuts off to the next message on the bus in order to guarantee reliable communications. See figure 7 below for RS485 cable wiring diagrams.

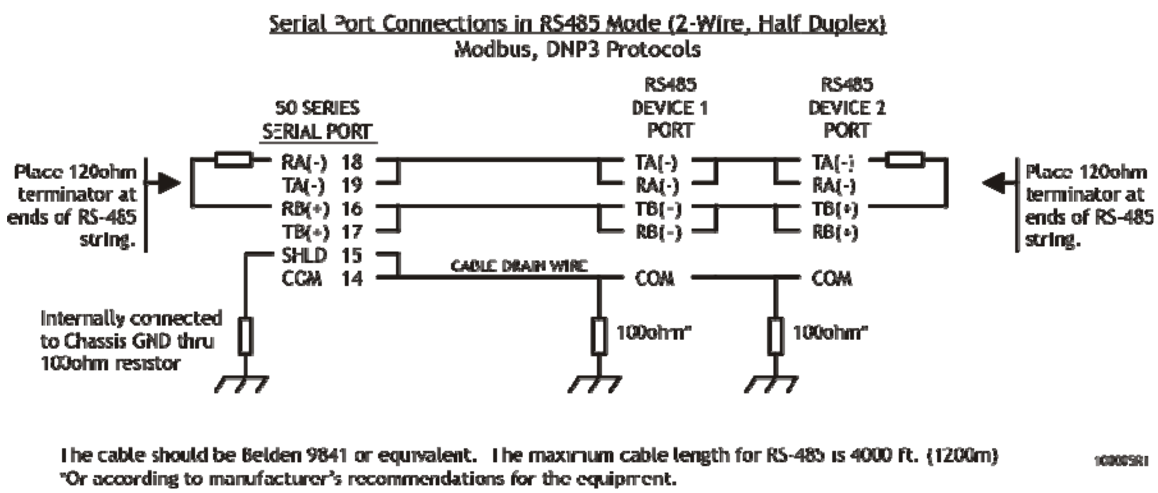


Figure 7 - Typical RS-485 Cable Wiring

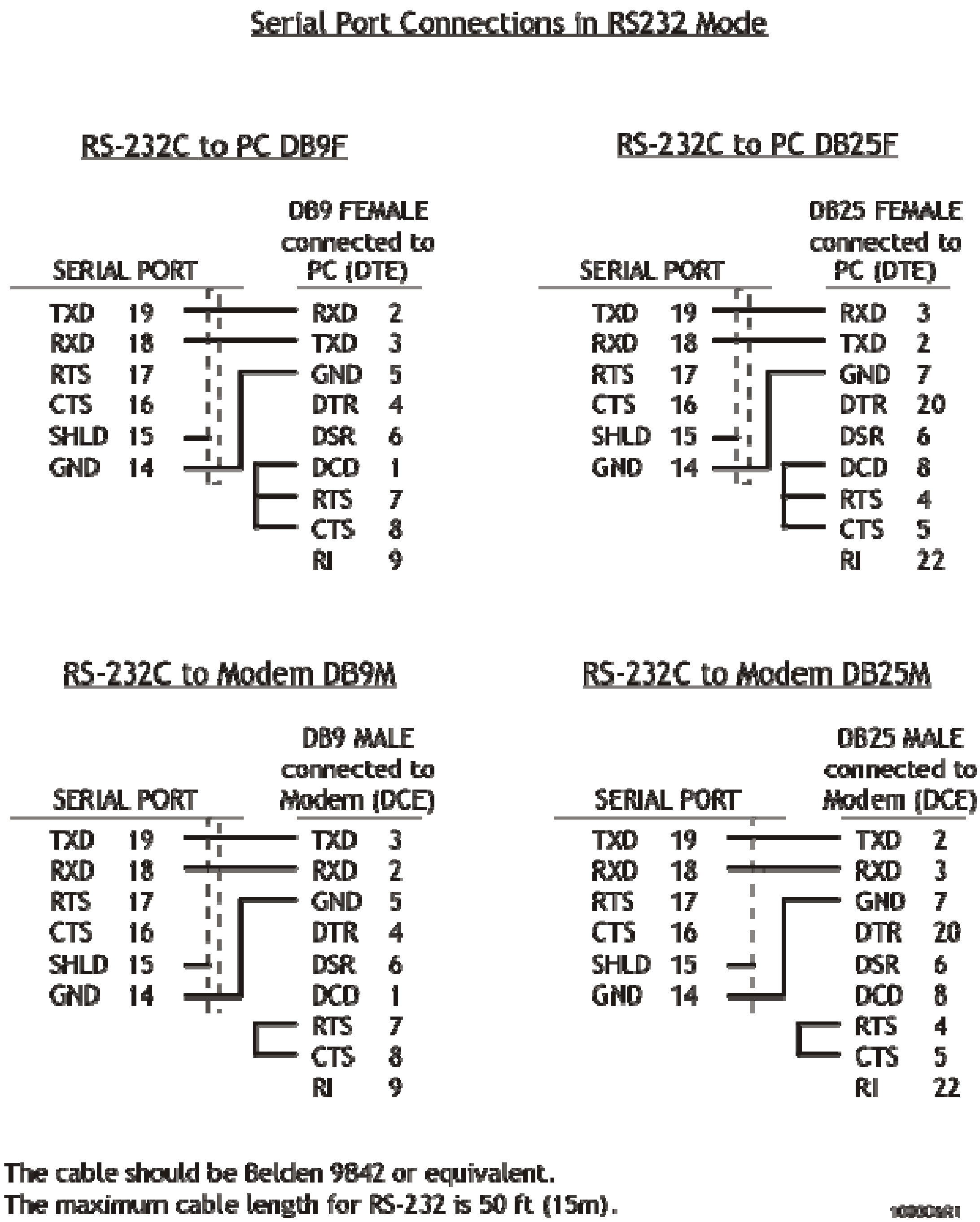


Figure 8 – RS-232 Cable Wiring Diagram

5.0 FUNCTIONAL DESCRIPTION

5.1 Configuration

Setup of the M65x meters is most easily performed using the web interface via the Ethernet service port. Basic configuration can also be done from the front display of the M650 and M653 by entering the setup mode.

5.2 HTML Web Server

The M65x incorporates an internet compatible HTML web page.

5.3 Passwords

Passwords can be setup through the web interface in the M65x for use in controlling access to configuration and other functions available through the Ethernet port or the front panel display. Passwords may be comprised of the 95 printable ASCII characters as defined by http://en.wikipedia.org/wiki/ASCII#ASCII_printable_characters which includes 0-9, a-z, A-Z, and special characters. Passwords may have maximum length of 20 characters and a minimum of 1 character. Passwords prompts are disabled by leaving the new password field blank and clicking the 'Change Password' button. The default password from the factory is to have no password set.

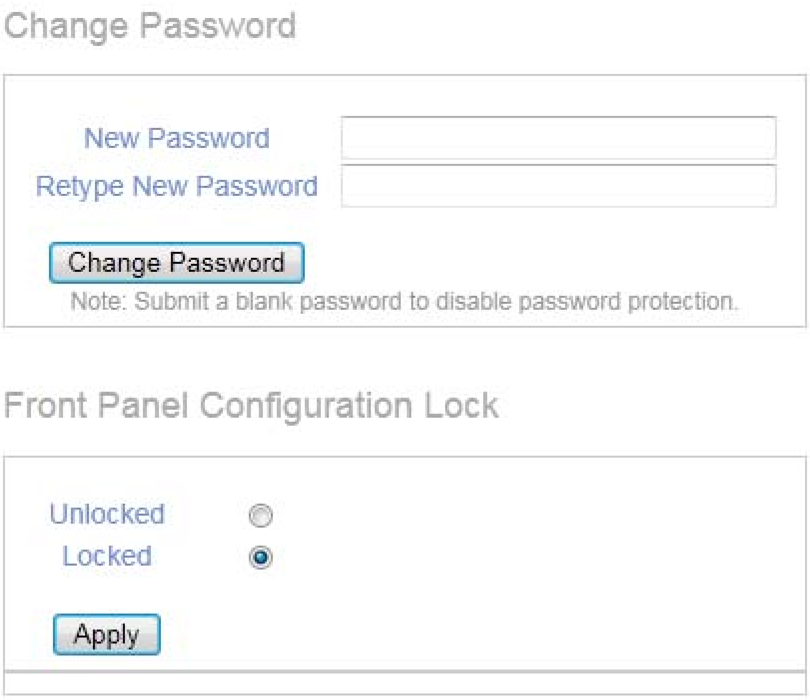
The password is used to authenticate a session when prompted. The session authentication will last until the user clicks the 'Log Out' link on the upper right corner of the Web Interface or after five minutes elapses. Authentication will be required when attempting the following actions:

Resetting demand and energy values on the Web Interface Resets page
Applying changes to any settings on the Web Interface Settings tab
Uploading new firmware on the Firmware Upload page
Changing the password on the Password Security page
Rebooting the IED

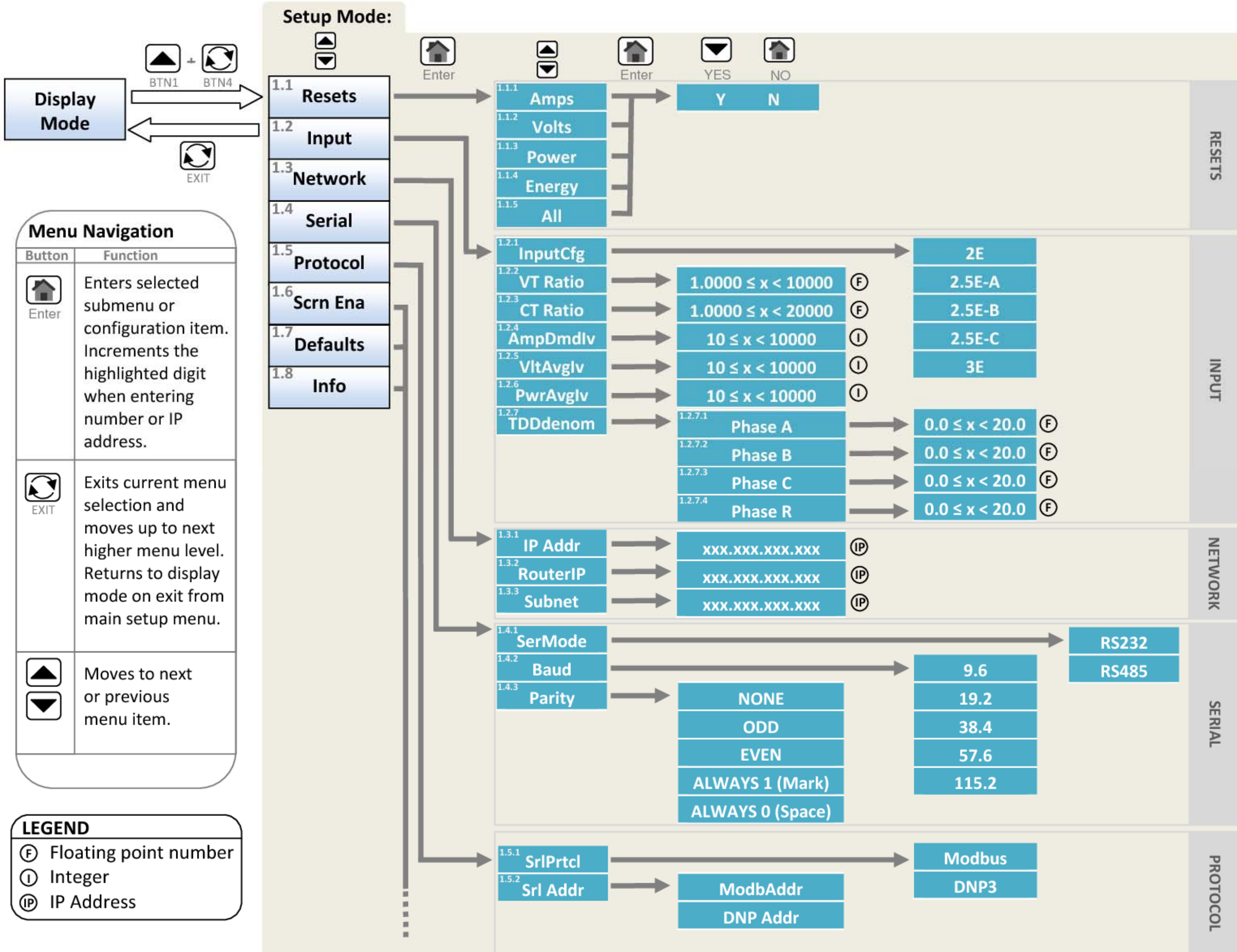
The Password Security page includes the Front Panel Configuration Lock, which may be used to prevent access to the following actions (not M651):

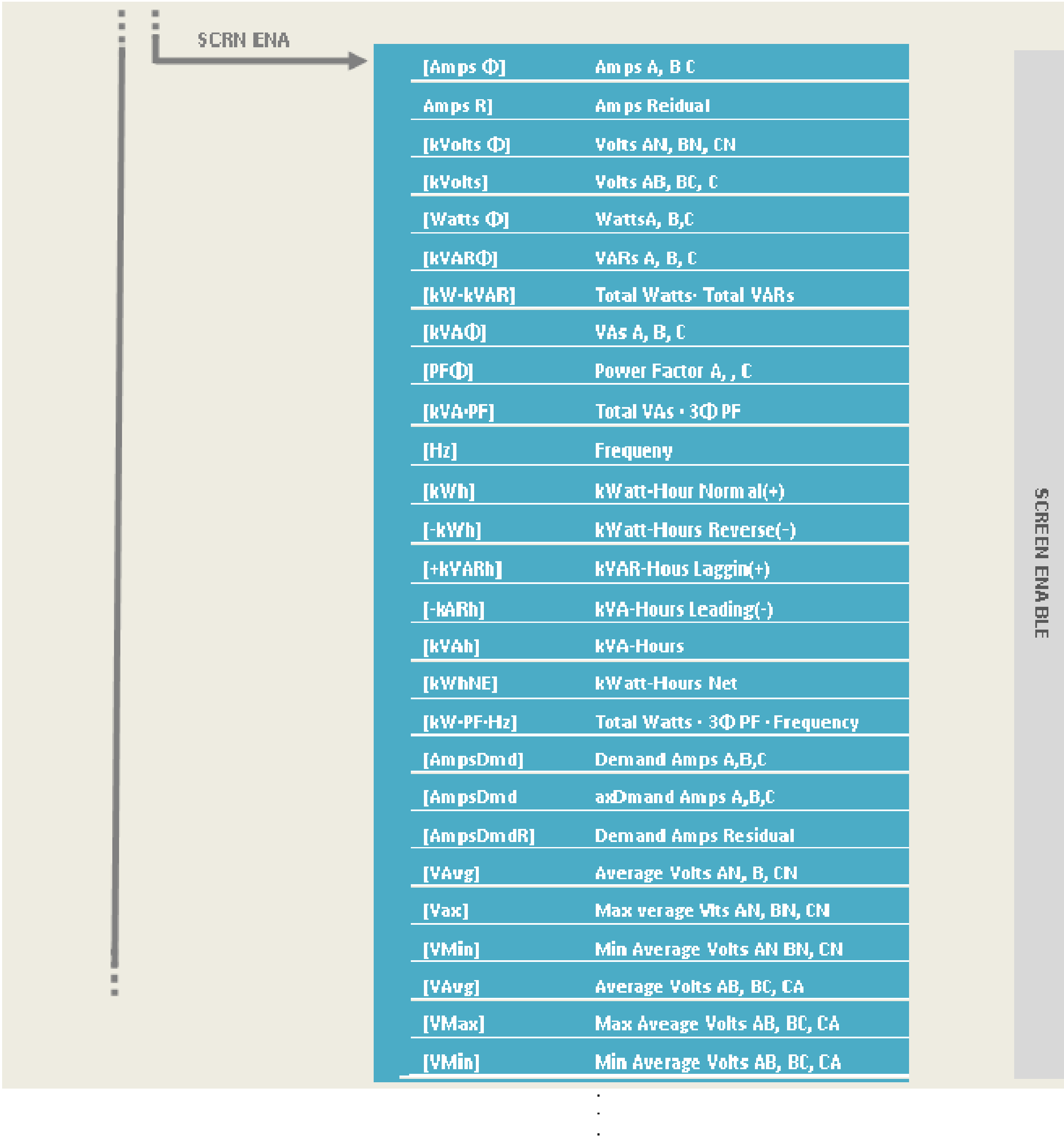
Setup Mode on the Front Panel (see section 5.5)
Demand Resets from the Front Panel (section 6.9.4).
Home Screen selection from the Front Panel (section 4.1.2)

If these options are attempted while the lock is enabled, the message 'Locked' will be briefly displayed on the front panel alphanumeric display for M65x.



5.4 Navigating the M65x's setup menu from the front panel

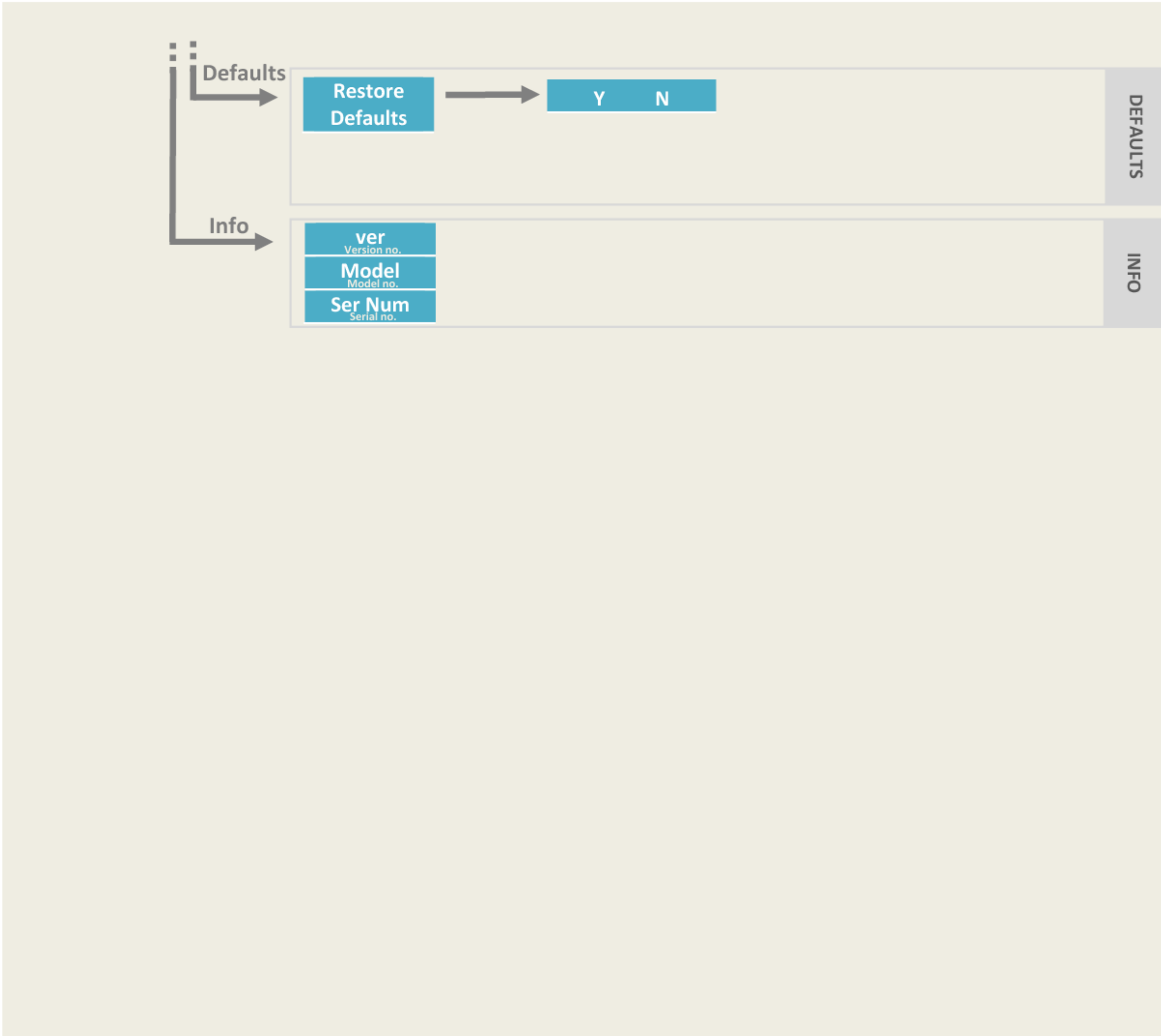

Setup Mode:
Display Mode
BTN1
BTN4
EXIT
Enter
YES
NO
1.1 Resets
1.2 Input
1.3 Network
1.4 Serial
1.5 Protocol
1.6 Scrn Ena
1.7 Defaults
1.8 Info
1.1.1 Amps
1.1.2 Volts
1.1.3 Power
1.1.4 Energy
1.1.5 All
Y N
1.2.1 InputCfg
1.2.2 VT Ratio
1.2.3 CT Ratio
1.2.4 AmpDmdlv
1.2.5 VltAvglv
1.2.6 PwrAvglv
1.2.7 TDDenom
1.0000 ≤ x < 10000
1.0000 ≤ x < 20000
10 ≤ x < 10000
10 ≤ x < 10000
10 ≤ x < 10000
1.2.7.1 Phase A
1.2.7.2 Phase B
1.2.7.3 Phase C
1.2.7.4 Phase R
2E
2.5E-A
2.5E-B
2.5E-C
3E
0.0 ≤ x < 20.0
0.0 ≤ x < 20.0
0.0 ≤ x < 20.0
0.0 ≤ x < 20.0
1.3.1 IP Addr
1.3.2 RouterIP
1.3.3 Subnet
xxx.xxx.xxx.xxx
xxx.xxx.xxx.xxx
xxx.xxx.xxx.xxx
1.4.1 SerMode
1.4.2 Baud
1.4.3 Parity
NONE
ODD
EVEN
ALWAYS 1 (Mark)
ALWAYS 0 (Space)
9.6
19.2
38.4
57.6
115.2
RS232
RS485
1.5.1 SrlPrtcl
1.5.2 Srl Addr
ModbAddr
DNP Addr
Modbus
DNP3
RESETS
INPUT
NETWORK
SERIAL
PROTOCOL
Menu Navigation
Button Function
Enter Enters selected submenu or configuration item. Increments the highlighted digit when entering number or IP address.
EXIT Exits current menu selection and moves up to next higher menu level. Returns to display mode on exit from main setup menu.
Moves to next or previous menu item.
LEGEND
F Floating point number
I Integer
IP IP Address


SCRN ENA
[Amps Φ] Amps A, B C
Amps R] Amps Reidual
[kVolts Φ] Volts AN, BN, CN
[kVolts] Volts AB, BC, C
[Watts Φ] WattsA, B,C
[kVARΦ] VARs A, B, C
[kW-kVAR] Total Watts· Total VARs
[kVAΦ] VAs A, B, C
[PFΦ] Power Factor A, , C
[kVA·PF] Total VAs · 3Φ PF
[Hz] Frequeny
[kWh] kWatt-Hour Normal(+)
[-kWh] kWatt-Hours Reverse(-)
[+kVARh] kVAR-Hous Laggin(+)
[-kARh] kVA-Hours Leading(-)
[kVAh] kVA-Hours
[kWhNE] kWatt-Hours Net
[kW-PF-Hz] Total Watts · 3Φ PF · Frequency
[AmpsDmd] Demand Amps A,B,C
[AmpsDmd axDmand Amps A,B,C
[AmpsDmdR] Demand Amps Residual
[VAvg] Average Volts AN, B, CN
[Vax] Max verage Vlts AN, BN, CN
[VMin] Min Average Volts AN BN, CN
[VAvg] Average Volts AB, BC, CA
[VMax] Max Aveage Volts AB, BC, CA
[VMin] Min Average Volts AB, BC, CA
SCREEN ENABLE

...contd.

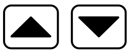
[kWTot]	Average Watts Max · Total · Min
[kVARTot]	Average VARs Max · Total · Min
[kVATot]	Average VAs Max · Total · Min
[FndAmps]	Fund Amps A, B, C
[FndAmpsR]	Fund Amps Residual
[FndV]	Fund Volts AN, BN, CN
[FndV]	Fund Volts AB, BC, CA
[%TDDI]	TDD Amps A,B,C
[%THDV]	THD Volts AN, BN, CN
[%THDV]	THD Volts AB, BC, CA
[K-Factor]	K-Factor Amps A,B,C
[DispPFΦ]	Displacement Power Factor A,B,C
[DispPFT]	Displacement Power Factor Total
[FndDmdIΦ]	Fund Demand Amps A,B,C
[FndDmdIR]	Max Fund Demand Amps Residual
[FndDmdIΦ]	Max Fund Demand Amps A,B,C
[kWAvg]	Average Watts A, B, C
[kWMax]	Max Average Watts A, B, C
[kWMin]	Min Average Watts A, B, C
[kVARAvg]	Average VARs A. B, C
[kVARMax]	Max Average VARs A. B, C
[kVARMin]	Min Average VARs A. B, C
[kVAAvg]	Average VAs A, B, C
[kVAMax]	Max Average VAs A, B, C
[kVAMin]	Min Average VAs A, B, C
[VAux]	Volts Aux
[SecVolts]	Secondary Volts AN, BN, CN
[SecVolts]	Secondary Volts AB, BC, CA
[All]	All on/off

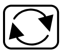
SCREEN ENABLE


Defaults
Restore Defaults
Y N
DEFAULTS
Info
ver
Version no.
Model
Model no.
Ser Num
Serial no.
INFO

How to Enter an Integer:

 Increment highlighted digit by 1.

 Highlight Previous/Next digit.

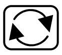
 Exit to menu

How to Enter a Floating Point Number:

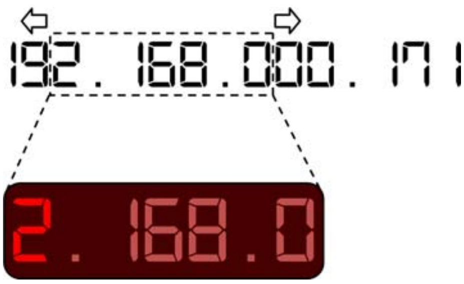
 Increment highlighted digit by 1.

 Shifts decimal point one place to right. Decimal moves to left-most digit when right-most digit is passed.

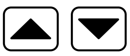
 Highlight Next digit. Highlights left-most digit when right-most digit is passed.

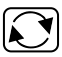
 Exit to menu

How to Enter an IP address:



 Increment highlighted digit by 1.

 Highlight Previous/Next digit. Numbers scroll left and right to follow highlighted digit.

 Exit to Network menu

5.5 Performing set-up through the web page interface

This section will assume you are able to use the factory default IP address of 192.168.0.171 to connect to the web page using an HTML web server. If this is not the case you may need to refer to section 3.5.1 (Network settings) and the previous section (Navigating the M65x's setup menu from the Front panel) to change your network configuration settings.

Enter the M65x's IP address into your internet browser to connect with the M65x web page interface. Internet browsers supported are Firefox, Internet Explorer, Safari and Google Chrome. The Home page screen should appear as shown below.

Home page:

From the home screen you can select from the following tabs:
Data – This page displays current data measurements
Resets – This page allows certain quantities to be reset
Settings – This page allows the user to change the configuration settings. Making M65x configuration changes require the unit to be rebooted. Configuration settings for the M65x are stored in flash memory.
Contact – This page indicates how to contact Alstom Grid

NOTE: Some screen shots shown below may not exactly match the appearance of those from your actual meter.

Data page: Two views – Instantaneous and Demands

Live Data View

Instantaneous | Demands

	Amps	Volts		Volts
Phase A	0.000	123.29	A-B	0.08
Phase B	0.000	123.29	B-C	0.11
Phase C	0.000	123.33	C-A	0.09
Residual	0.000			

	Watts	VARs	VAs	PF
Phase A	0.0	0.0	0.0	0.000
Phase B	0.0	0.0	0.0	0.000
Phase C	0.0	0.0	0.0	0.000
Total	0.	0.	0.	0.000

Energy Used (+kWh)	101
Energy Produced (-kWh)	121
Energy Lag (+kVARh)	154
Energy Lead (-kVARh)	76

VT Scaling	1.0000 : 1.
CT Scaling	5.0000 : 5.

Frequency	60.013	Health	0000 0000
Time Between Polls	1.004 sec	Heartbeat	12

Live Data View

Instantaneous | **Demands**

Amps

	Maximum	Present Demand	
Phase A	0.000	0.000	Amps
Phase B	0.000	0.000	Amps
Phase C	0.000	0.000	Amps

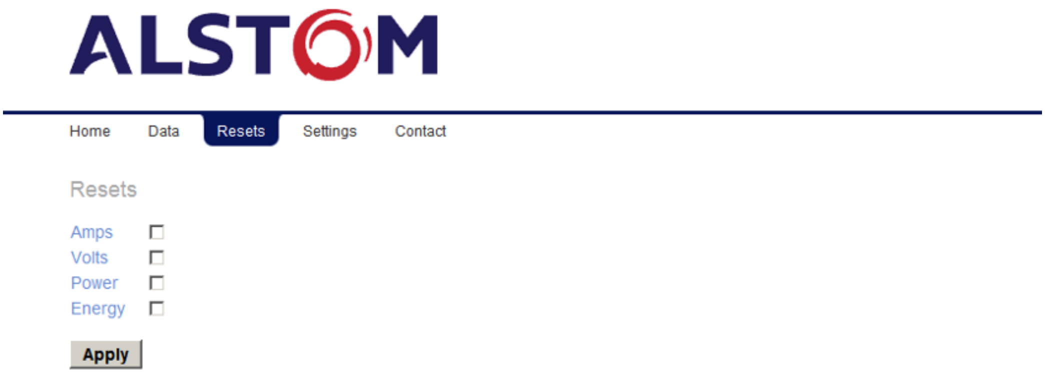
Volts

	Maximum	Present Demand	Minimum	
Phase A	123.70	123.57	0.00	Volts
Phase B	123.71	123.57	0.00	Volts
Phase C	123.74	123.61	0.00	Volts

Total Power

	Maximum	Present Demand	Minimum	
Watts	0.	0.	0.	Watts
VARs	0.	0.	0.	VARs
VAs	0.	0.	0.	VAs

Resets page: From this page select the quantity to be reset and click apply



Settings page: Click on one of the settings categories (Identity, Input, Network, Serial Port, Protocol, Screen Enable, Custom Screens, Load/Store Settings, Password Security, or Firmware Upload) to be taken to the next page.

Contact Page:

Settings Page Selections:
From the Settings page screen you can select one of the following selections:

Identity– This page allows the user to enter information that is necessary to identify the meter. It gives an identity to a particular M65x. Each M65x should have different information entered for its identity.

Input – This page allows for the selection of wiring configuration, setup of CT and PT ratios, demand intervals, and TDD denominator.

Network – This page allows the user to change the network configuration settings for IP address, gateway and router address.

Serial Port – This page allows user configuration for the serial port settings. Note that if no serial port is ordered this setting won't appear and if the transducer output option is selected then that setting will replace serial.

Protocol – This page allows user configuration of the protocols – DNP or Modbus

Screen Enable - Allows the screens shown on the M65x display (front panel) to be enabled or disabled by the user. (Not applicable for M651)

Custom Screens – Allows the user to set up custom display screens if the standard screens don't meet their needs. (Not applicable for M651)

Load/Store Settings – This page allows you to save and retrieve settings for the M65x meter

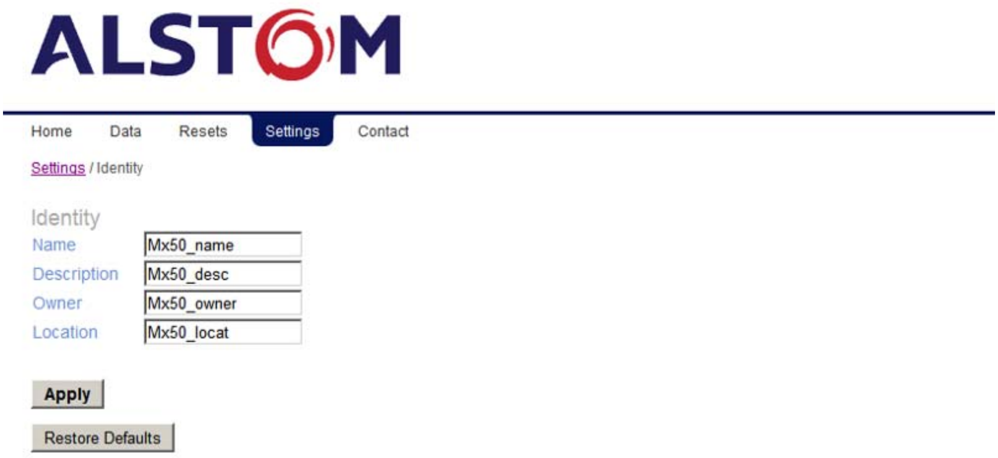
Password Security – This page allows the user to set a password and to enable or disable access to front display configuration.

Firmware Upload – This page allows the user an interface to browse for or type in the location on their PC of new firmware for purposes of uploading to the unit.

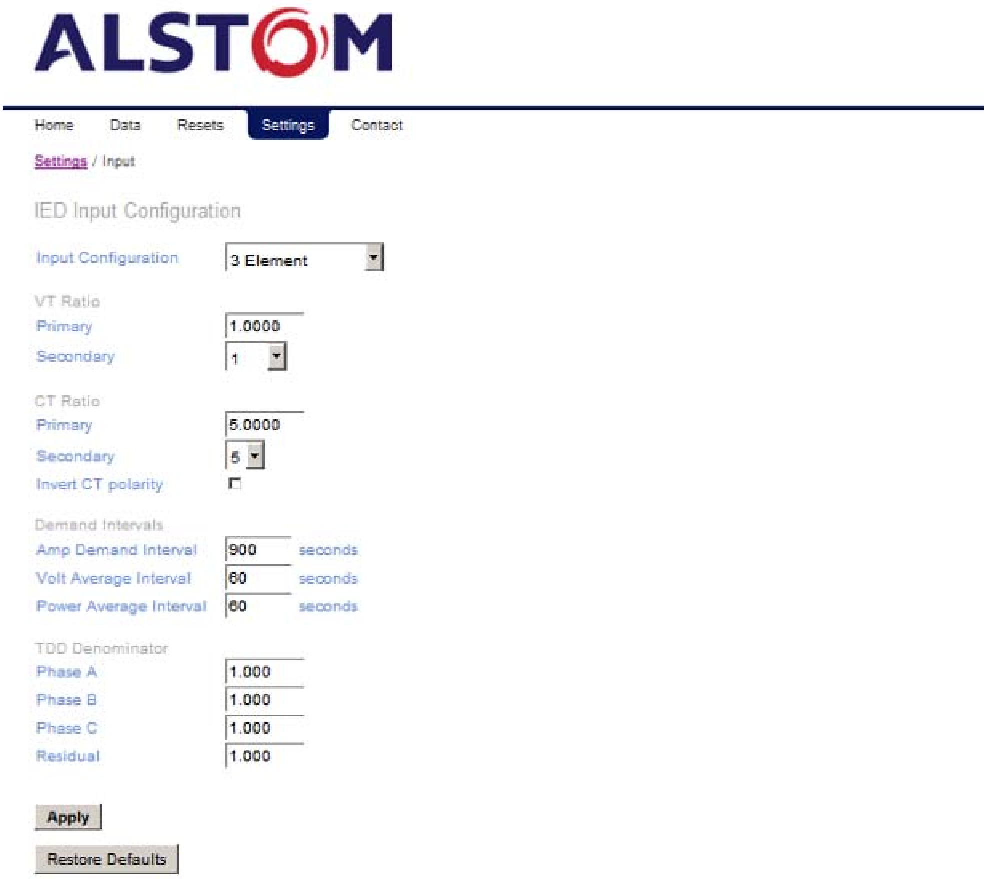
Screen shots showing the selections to be made for each of the above selections follow on the next few pages. Default values are shown where applicable.

M65x configuration changes require the unit to be rebooted. Configuration settings for the M65x are stored in flash memory.

Identity:

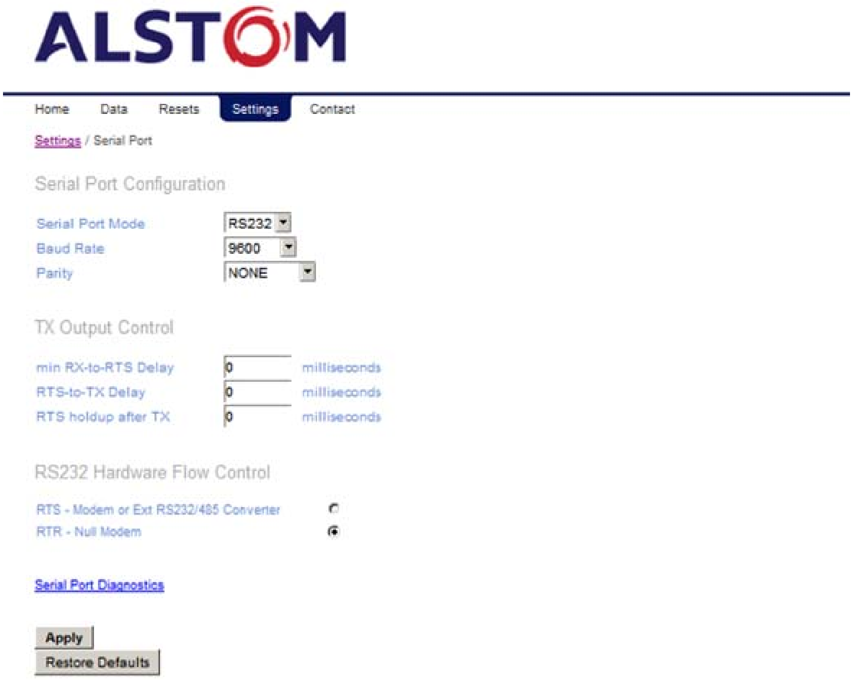


Input:

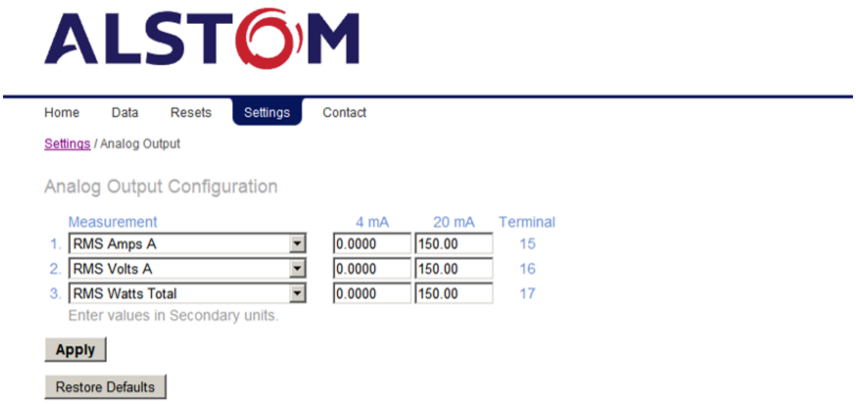


Network:

Serial Port (if option ordered):



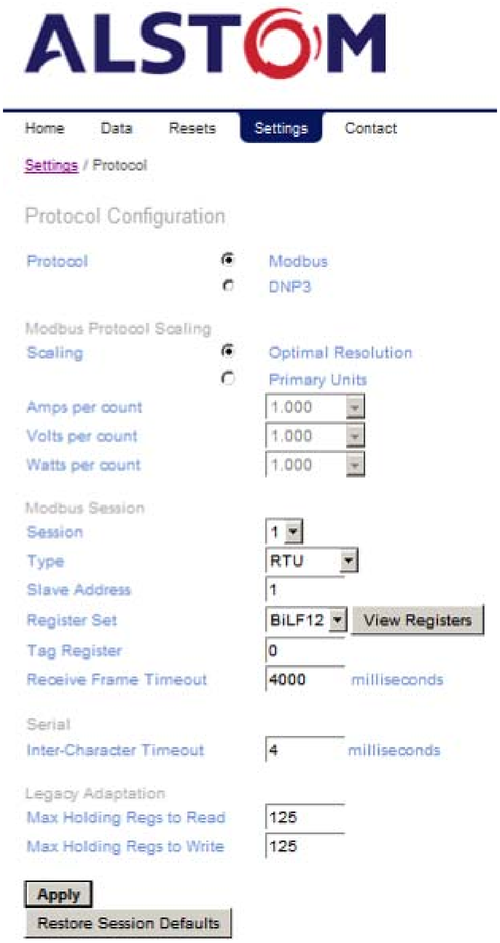
Analogue Output (if option ordered):

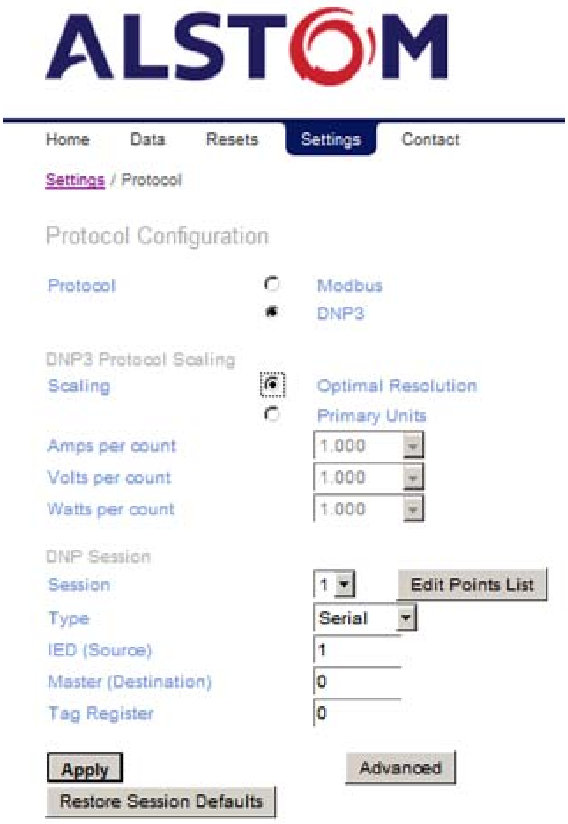


Protocol Selection (if Option ordered):

First select between Modbus or DNP3. You will then select Optimal Resolution (default) or Primary Units. Next you will choose a session. Under Type, there will be 4 different selections for Modbus and 3 for DNP3. Under Modbus the options are Disabled, TCP, ASCII, or RTU. For DNP3 the selections are Disabled, Serial, or TCP. Under DNP3, clicking on the Advanced button reveals more advanced functions that may or may not need to be changed. Clicking on the Basic button hides the advanced functions. A detailed description of the setup parameters for Modbus and DNP3 can be found in the Appendix of the respective protocol manuals.

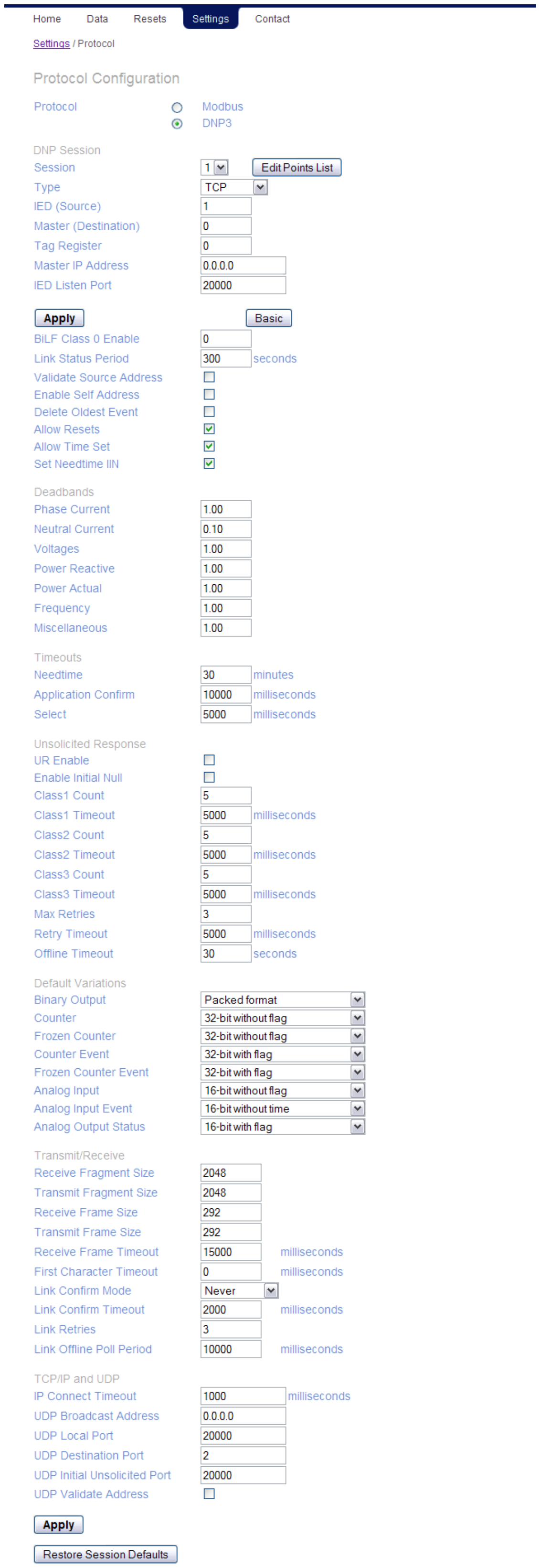
There are both fixed and configurable register/point lists. Please refer to the appropriate protocol manual for more information regarding how to view or edit the register/point list.



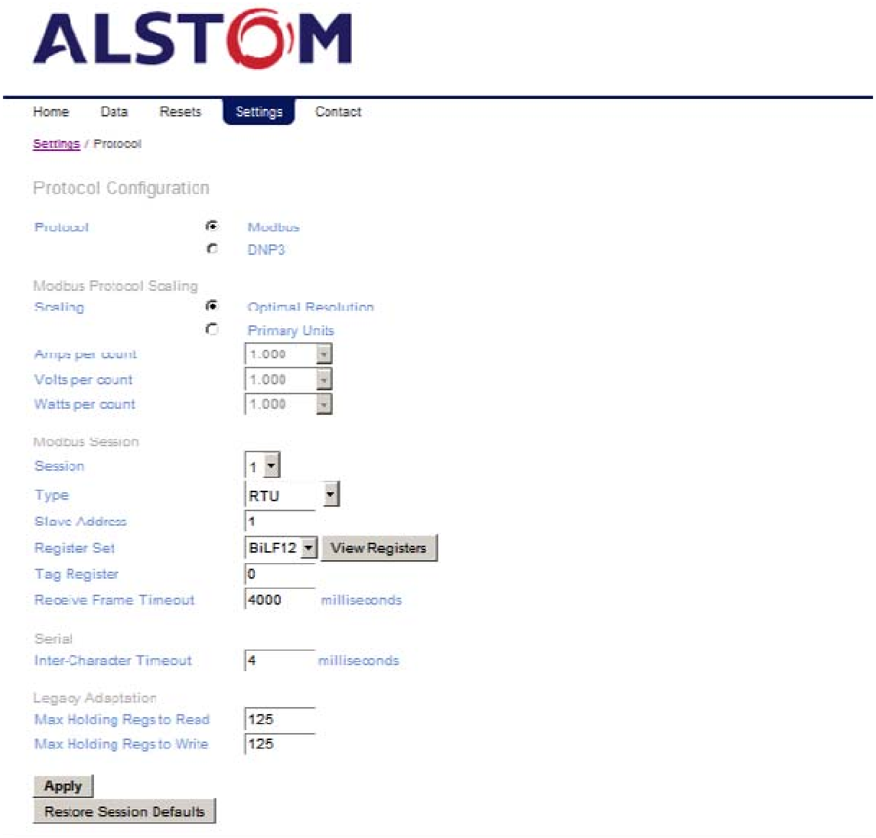


Modbus **DNP3**

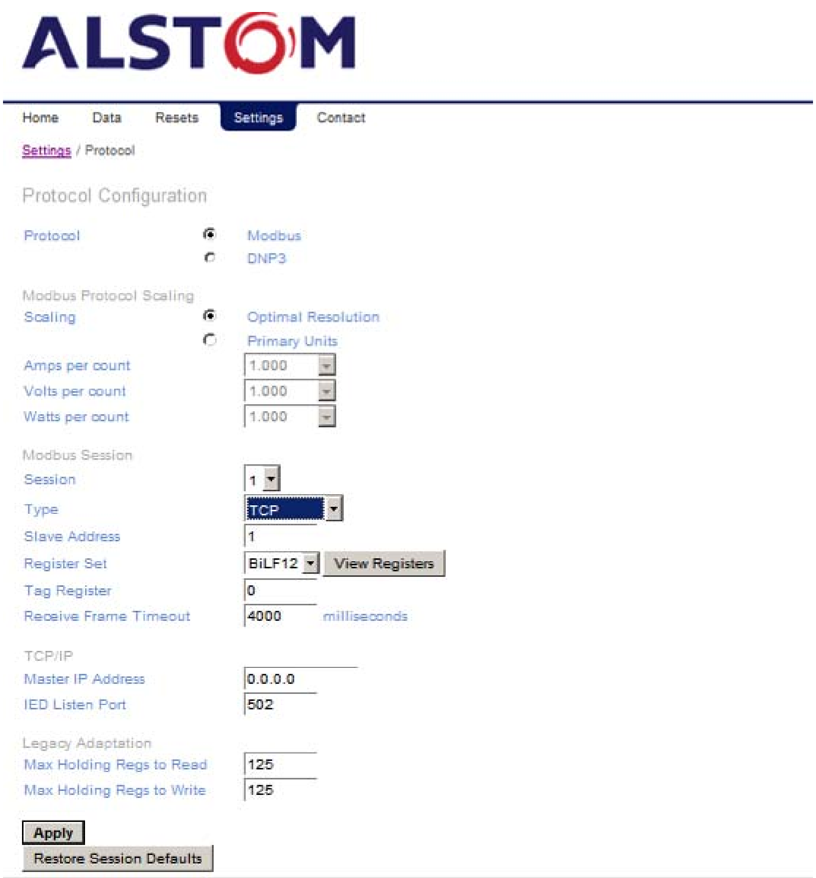
DNP Serial



DNP TCP

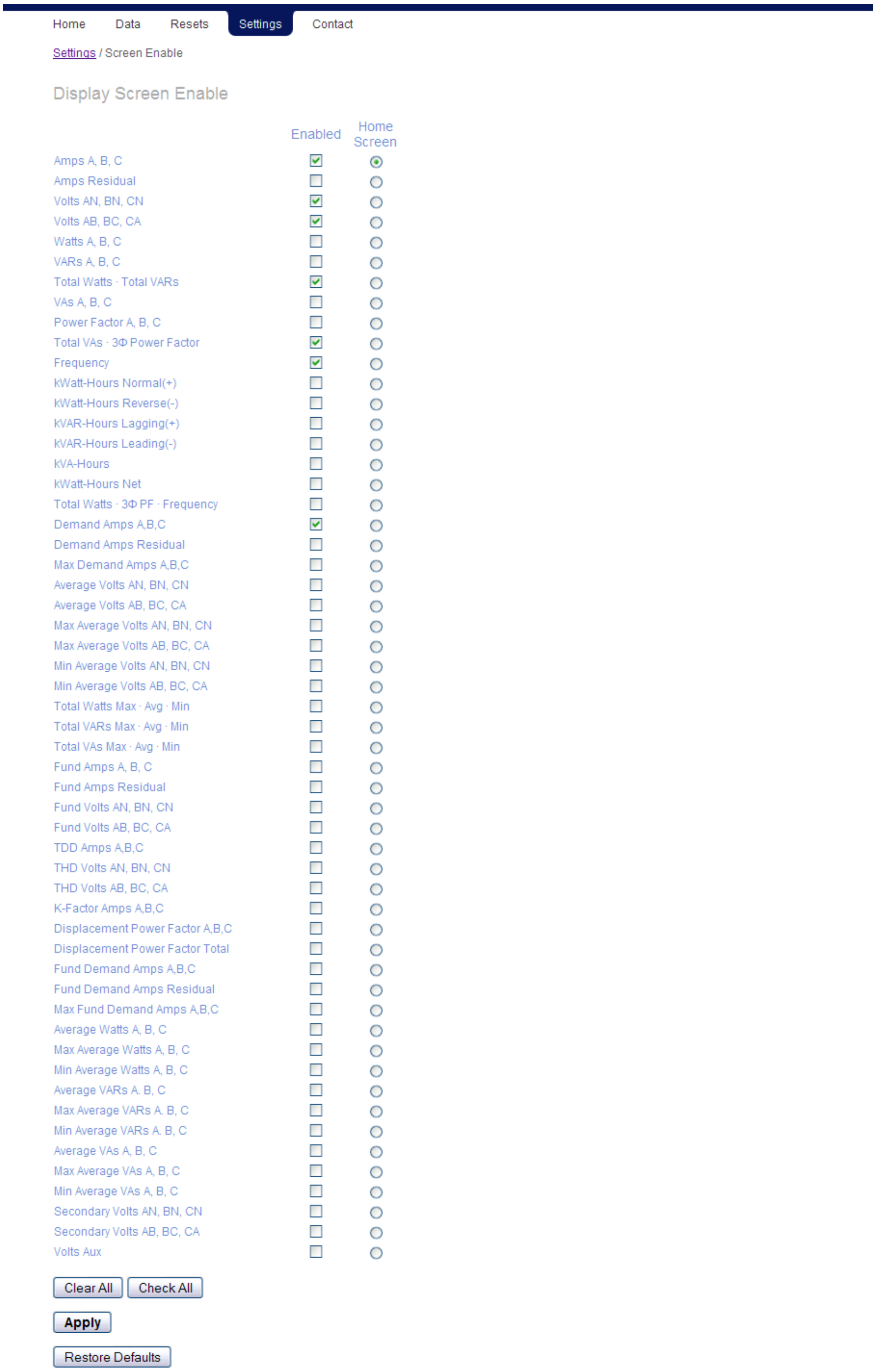


Modbus RTU



Modbus TCP

Screen Enable: (not M651)



Custom Display Screen Settings: Two Sections – Build/Edit and Summary

The Custom Display Screen Configuration page contains two sections: the Build/Edit panel and the Summary panel. One custom display screen is built at a time in the Build/Edit panel and is then added to the Summary panel, which presents a list of all the custom screens that have been built. The Build/Edit panel is presented if there are no custom screens stored on the IED when the page is loaded; otherwise, the Summary panel is presented. Only one panel is visible at a time.

Build/Edit panel
Select a measurement to be displayed on each display line from the dropdown lists and enter an alphanumeric label that describes the display screen.

Special character buttons insert the characters shown on the buttons into the "Label" field. The "k/M/G" (kilo/Mega/Giga) button inserts an underscore character into the "Label" field, which is automatically replaced with the appropriate unit prefix when displayed on the IED's front panel. The dot character is used to separate parts of a single label into multiple labels that apply to the different display lines. It is necessary to place dots between underscore that apply to different display lines.

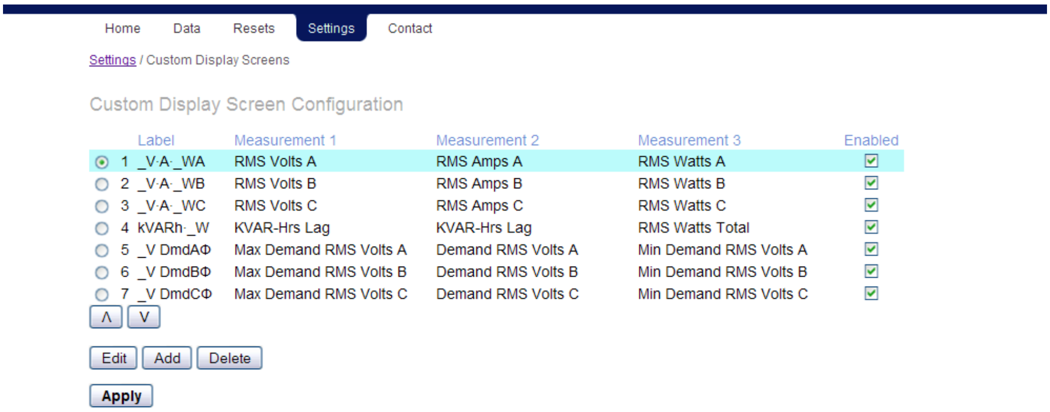
The MIN, MAX, AVG, line and phase LEDs are automatically lit by the IED, based on the selected measurements.

Click the "Next >" button to view the summary panel.

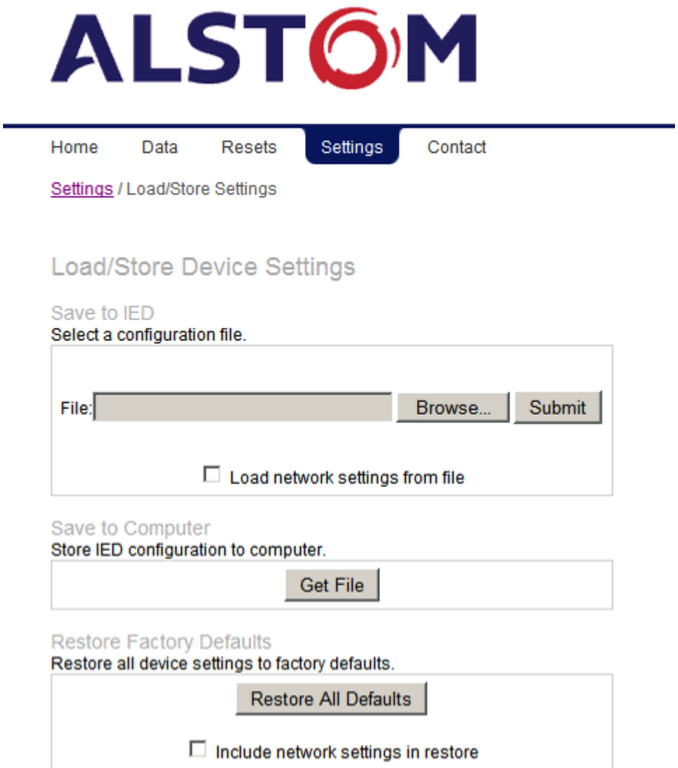
Summary panel:

Screens are saved to IED once the “Apply” button has been clicked. A row (screen) from the summary table can be selected for viewing, editing or deleting by clicking its radio button.

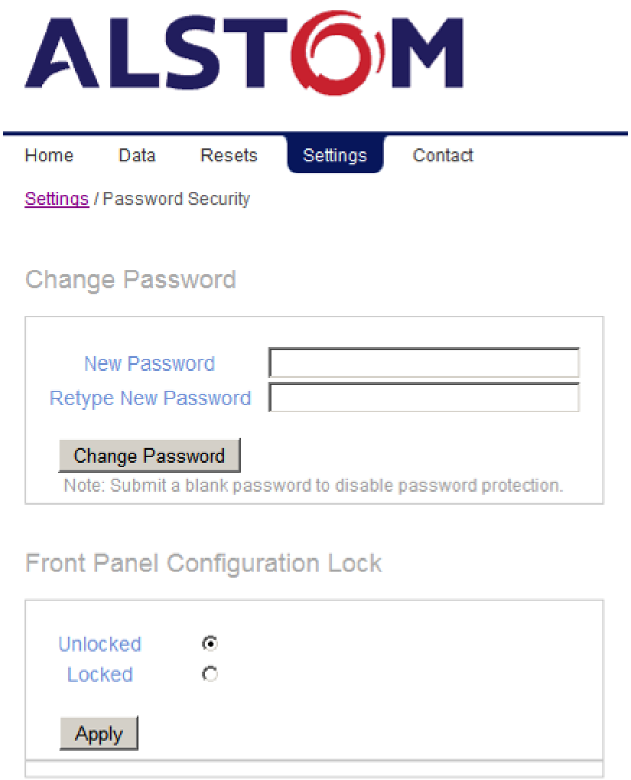
The order of the screens can be changed by selecting a screen from the list and clicking on the up or down arrows.



Load/Store Device Settings:



Password Security Settings:



Firmware Upload:

6.0 MEASUREMENTS

Basic measurement quantities are calculated and updated every 100ms. These quantities include RMS Amperes and RMS Volts, Watts, VARs, VAs, Power Factor, all harmonic-based measurements (such as fundamental-only quantities), Energy, and Frequency, and Phase Angle.

Note: For all of the following measurements, it is important to keep in mind that the specific protocol used to access the data may affect the data that is available, or the format of that data. No attempt is made here to describe the method of accessing measurements - always check the appropriate protocol manual for details.

6.1 Changing Transformer Ratios

The M65x has the capability to store values for Current Transformer (CT) and Potential Transformer (VT) turns ratios. The VT and CT values are factory set to 1:1 CT and 1:1 VT. These values can be entered into the M65x over the network or via front display buttons or web page, and will be stored in internal non-volatile memory. All measurements are presented in primary units, based on these ratios. Please note that the value entered via the front display should be the result of the division of the primary value by 5. For example for a ratio of 6000:5, you would enter a value of 1200 through the front display. The web interface allows you to choose either 1A or 5A for the denominator, and the primary value is entered directly. The PT ratio is to 1 when entering through the front display. The web allows other denominators (110, 115, or 120) to be used. Refer to the appropriate protocol manual for more information on changing transformer ratios.

6.2 Current

The M65x has three current inputs, with an internal CT on each channel except in the case where external split-core CTs are used. These inputs can read to 2x nominal ($2A_{RMS}$ for 1A input, $10A_{RMS}$ for 5A input (symmetrical)) under all temperature and input frequency conditions. No range switching is used, allowing a high dynamic range.

The current signals are transformer coupled, providing a true differential current signal. Additionally, a continuous DC removal is performed on all current inputs. Instrument Transformer Ratios can be entered for each current input, as described above.

6.2.1 Residual Current

The M65x calculates the vector sum of the three phase currents, which is known as the Residual Current. The Residual Current is equivalent to routing the common current return wire through the neutral current input on systems without separate current returns for each phase.

6.3 Voltage Channels

All voltage inputs are measured relative to a common reference level (essentially panel ground). See Appendix 1 for input connection information. Common mode signals can be removed by signal processing algorithms, instead of the more traditional difference amplifier approach. This greatly simplifies the external analogue circuitry, increases the accuracy, and allows measurement of the Neutral-to-Ground voltage at the panel. The 7kV input divider resistors are accurate to within +/- 25ppm/°C, and have a range of $400V_{PEAK}$, from any input to panel ground. Each sample is corrected for gain using factory calibration values stored in non-volatile memory on the board. Additionally, a continuous DC removal is performed on all inputs.

The advantages of this method of voltage measurement are apparent when the M65x is used on the common 2, 2½, and 3 element systems (refer to Section 6.6). The M65x is always calculating Line-to-Neutral, and Line-to-Line voltages with equal accuracy. On 2 element connections, any phase can serve as the reference phase.

On 2½ element systems, one of the phase-to-neutral voltages is missing, and the M65x must create it from the vector sum of the other two phase-to-neutral voltages. In order to configure the M65x for 2½ element mode and which phase voltage is missing, select one of the following: 2.5 element - A, 2.5 element - B, or 2.5 element – C.

6.4 Voltage Aux

The M65x provides a measurement for the voltage connected to the power supply terminals. This is a differential voltage. The value can be AC or DC depending upon the power supply voltage source.

6.5 Power Factor

The per-phase Power Factor measurement is calculated using the "Power Triangle", or the per-phase WATTS divided by the per-phase VAs. The Total PF is similar, but uses the Total WATTS and Total VAs instead. The sign convention for Power Factor is shown in Figure 9.

6.6 Watts / Volt-Amperes (VAs) / VARs

On any power connection type (2, 2½, and 3 element), the M65x calculates per-element Watts by multiplying the voltage and current samples of that element together. This represents the dot product of the voltage and current vectors, or the true Watts. The per-element VAs are calculated from the product of the per-element Volts and Amps. The per-element VARs are calculated from fundamental VARs.

In any connection type, the Total Watts and Total VARs is the arithmetic sum of the per-element Watts and VARs. The sign conventions are shown in Figure 9.

When used on 2-element systems, the reference phase voltage (typically phase B) input, is connected to the Neutral voltage input, and effectively causes one of the elements to be zero. ***It is not required to use any particular voltage phase as the reference on 2-element systems. When used on 2-element systems the per-element Watts, VARs, and VAs have no direct physical meaning***, as they would on 2½ and 3 element systems where they represent the per-phase Watts, VARs, and VAs.

When used on 2½ element systems, one of the phase-to-neutral voltages is fabricated, as described in Section 6.3. In all other respects, the 2½ element connection is identical to the 3 element connection.

6.6.1 Geometric VA Calculations

$$GEOMETRIC\ VA_{TOTAL} = \sqrt{Watts_{TOTAL}^{\ 2} + VARs_{TOTAL}^{\ 2}}$$

This is the traditional definition of Total VAs for WYE or DELTA systems, and is the default method for Total VAs calculation. The value of Total VAs calculated using this method does not change on systems with amplitude imbalance, relative to a balanced system.

There is also a relationship to the Total Power Factor, which is described in Section 6.5. Total Power Factor calculations using the Geometric VA method will still indicate a "1" on a system with phase amplitude imbalance, or cancelling leading and lagging loads.

For example, on a system with a lagging load on one phase and an equal leading load on another phase, the Geometric VA result will be reduced relative to a balanced system but the Total Power Factor will still be "1".

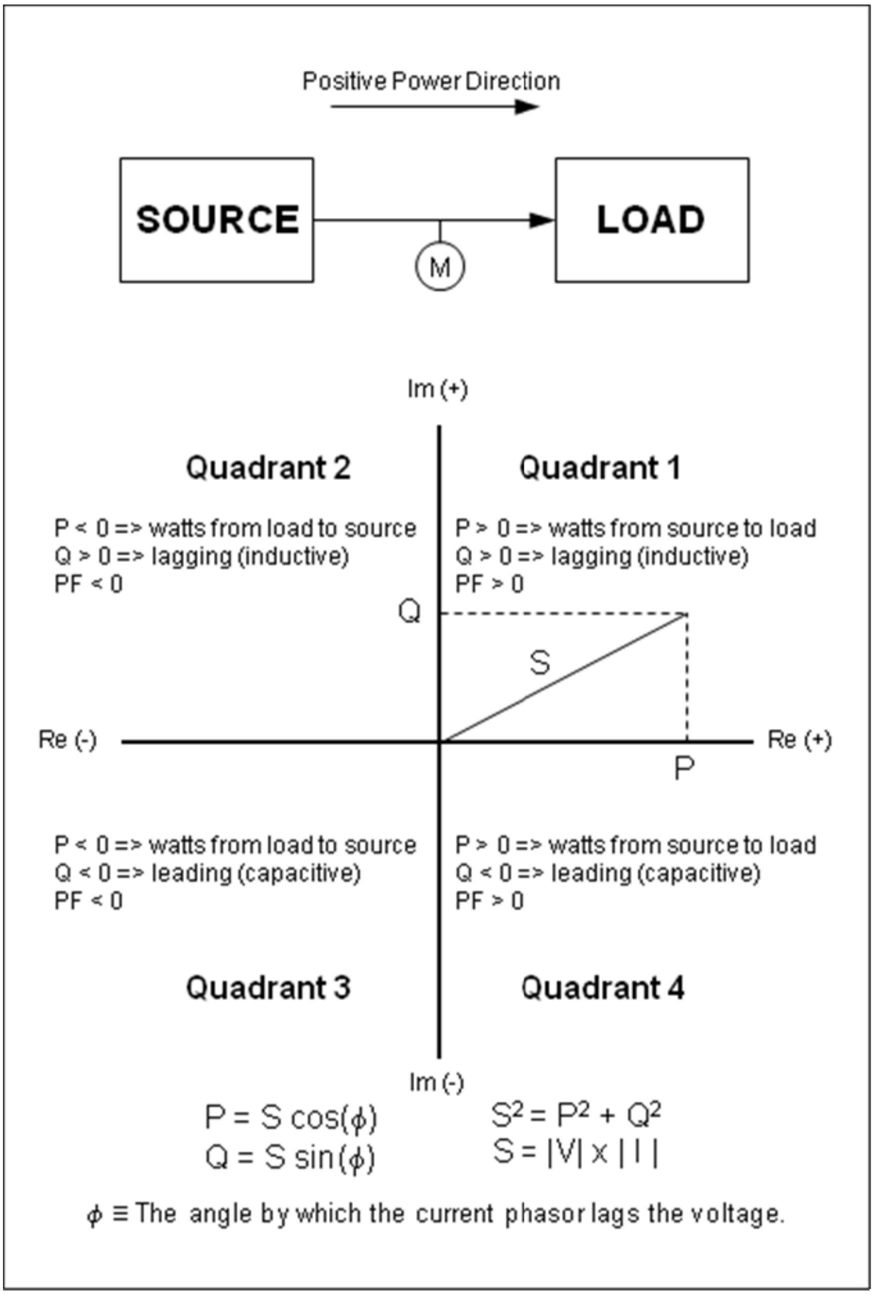


Figure 9 - Sign Conventions for Power Measurements

(P is Power, Q is VARS and S is VA)

6.7 Compensated Watts and VARs (Line and Transformer Loss Compensation)

The total Watt and Var losses can be calculated using five user entered parameters and measured current and voltage values. These losses are added or subtracted to/from the measured Total Watts and Total Vars when accumulating Energy.

Loss compensation on the M65x takes the following general form:

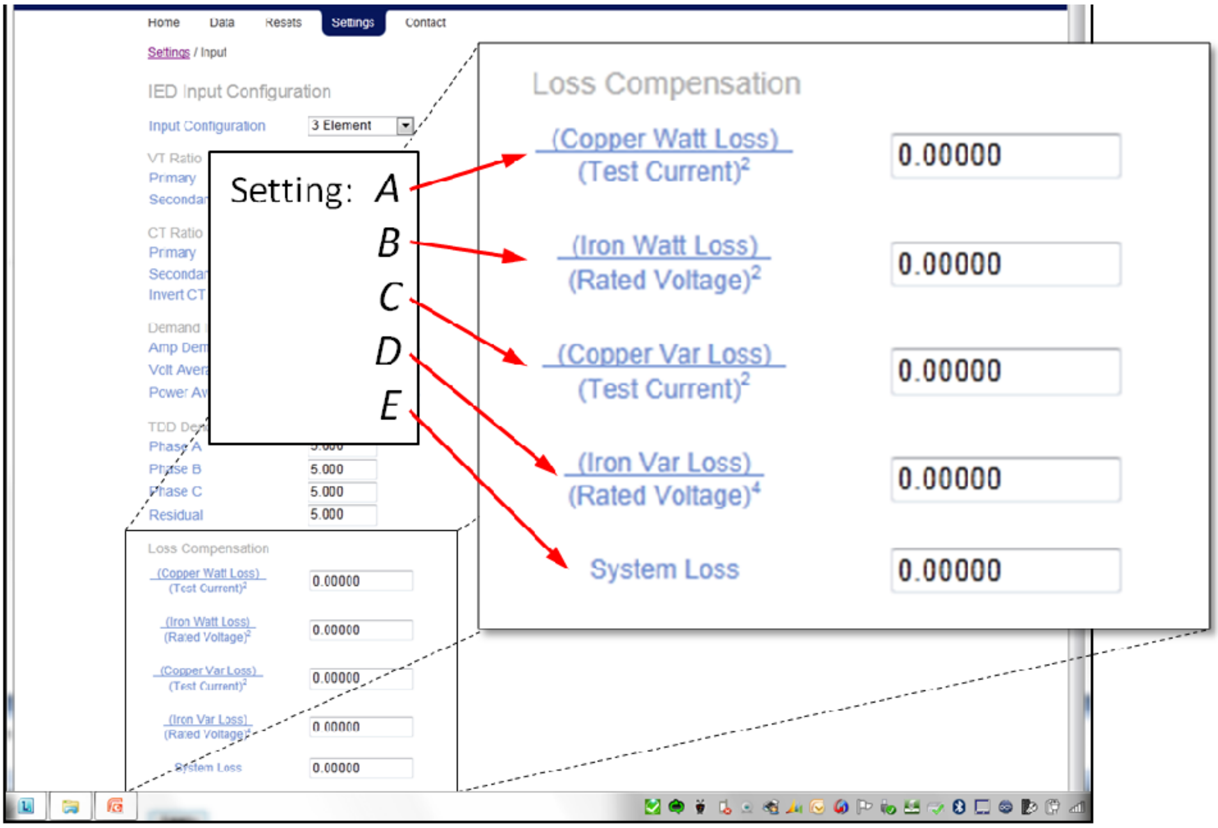
$$P_{COM} = P_{UNC} + A \cdot I^2 + B \cdot V^2 + E \cdot P_{UNC}$$

$$Q_{COM} = Q_{UNC} + C \cdot I^2 + D \cdot V^4 + E \cdot Q_{UNC}$$

Where:

- P_{COM} Compensated three-phase total watts. Note the accumulators for +kWh and –kWh in the M65x are calculated by integrating the P_{COM} measurement over time.
- P_{UNC} Uncompensated three-phase total watts measured at the point where the meter is connected.
- Q_{COM} Compensated three-phase total VARs. Note the accumulators for +kVARh and –kVARh in the M65x are calculated by integrating the Q_{COM} measurement over time.
- Q_{UNC} Uncompensated three-phase total VARs measured at the point where the meter is connected.
- I RMS line current measured at the point where the meter is connected.
- V RMS *line-line* voltage measured at the point where the meter is connected.
- *A* **Meter setting** that accounts for the sum of the full-load-watt-losses from all sources.
- *B* **Meter setting** that accounts for the transformer's no-load-watt-losses.
- *C* **Meter setting** that accounts for the sum of the full-load-VAR-losses from all sources.
- *D* **Meter setting** that accounts for the transformer's no-load-VAR-losses.
- *E* **Meter setting** that accounts for any "system" losses, proportional to the uncompensated power.

Configuring the meter to perform loss compensation simply requires the user to calculate the coefficients *A, B, C, D,* and *E* defined above, and enter them in the appropriate fields in the M65x's webserver interface on the Settings/Input page as shown in the screen shot below
The *sign* of the settings *A*, *B*, C, *D*, and *E* determines whether losses will be added to or subtracted from the uncompensated measurements in order to determine the compensated power and energy. To add losses, be sure the settings are all positive. To subtract losses, be sure the settings are all negative. Settings should always have the same sign.
Making all of the settings equal to zero *turns off* loss compensation.
System losses (*E*) are a fixed percentage, mutually agreed upon between two electric utilities, about an interchange point that lies on a branched line. As such, *E* is not a physical property of any particular line, transformer or the meter, so no further guidance on how best to calculate the coefficient *E* can be provided here. All instructions following will be concerned only with the calculation of the coefficients *A, B, C,* and *D*. Users who do not intend to use system losses should simply set *E* equal to zero.



6.8 Energy

Separate values are maintained for both positive and negative Watt-hours, positive and negative VAR-hours, and VA-hours, for each feeder. These energy quantities are calculated every cycle from the Total Watts, Total VARs, and Total VAs, and the values are stored into non-volatile memory every 15 seconds. Energy values may be reset. All values are reset simultaneously. Refer to the appropriate protocol manual for details.

6.9 Frequency

The M65x monitors the change in Phase Angle per unit time using the Phase Angle measurement for the fundamental generated by the FFT. The System Frequency is the frequency of the input used for synchronizing the sampling rate.

6.10 Demand Measurements

The traditional thermal demand meter displays a value that represents the logarithmic response of a heating element in the instrument driven by the applied signal. The most positive value since the last instrument reset is known as the maximum demand (or peak demand) and the lowest value since the last instrument reset is known as the minimum demand. Since thermal demand is a heating and cooling phenomenon, the demand value has a response time T, defined as the time for the demand function to change 90% of the difference between the applied signal and the initial demand value. For utility applications, the traditional value of T is 15 minutes, although the M65x can accommodate other demand intervals (Section 6.9.5).

The M65x generates a demand value using modern microprocessor technology in place of heating and cooling circuits, it is therefore much more accurate and repeatable over a wide range of input values. In operation, the M65x continuously samples the basic measured quantities, and digitally integrates the samples with a time constant T to obtain the demand value. The calculated demand value is continuously checked against the previous maximum and minimum demand values. This process continues indefinitely, until the demand is reset or until the meter is reset (or power removed and reapplied). The demand reset and power up algorithms are different for each measurement. These routines are further described in following paragraphs. The maximum and minimum demand values are stored in non-volatile memory on the Host Processor module.

NOTE: Changing VT or CT ratios does NOT reset demand measurements to zero.

Demand Quantity	Phase Reference	Function
Amperes	Phase, Residual	Present, Max
Fundamental Amperes	Phase, Residual	Present, Max
Volts	Phase - Neutral, Phase - Phase	Present, Max, Min
Total Watts (A, B, C, Total)	Phase, Total	Present, Max, Min
Total VARs (A, B, C, Total)	Phase, Total	Present, Max, Min
Total VAs (A, B, C, Total)	Phase, Total	Present, Max, Min

6.10.1 Ampere and Fundamental Ampere Demand

Present Ampere Demands are calculated via the instantaneous measurement data used to calculate the per-phase Amperes.

Upon power up, all Present Ampere Demands are reset to zero. Maximum Ampere Demands are initialized to the maximum values recalled from non-volatile memory. Upon Ampere Demand Reset, all per-phase Present and Maximum Ampere Demands are set to zero. When Ampere Demands are reset, Fundamental Current Demands are also reset.

6.10.2 Volt Demand

Present Volt Demands are calculated via the instantaneous measurement data used to calculate the per-phase Volts. Upon power-up all Present Volt Demands are reset to zero. The Maximum Volt Demands and Minimum Volt Demands are initialized to the minimum and maximum values recalled from non-volatile memory. In order to prevent the recording of false minimums a new Minimum Volt Demand will not be stored unless two criteria are met. First, the instantaneous voltage for that particular phase must be greater than $20V_{rms}$ (secondary). Second, the Present Demand for that particular phase must have dipped (Present Demand value must be less than previous Present Demand value). Upon Voltage Demand Reset, all per-phase Maximum Voltage Demands are set to zero. Minimum Voltage Demands are set to full-scale.

6.10.3 Power Demands (Total Watts, VARs, and VAs)

Present Total Watt, VAR, and VA Demands are calculated via the instantaneous measurement data. The Total VA Demand calculation type is based on the instantaneous Total VA calculation type (Section 6.6)

Upon power-up, all Present Total Watt, VAR, and VA Demands are reset to the average of the stored Maximum and Minimum values. The Maximum and Minimum Demands are initialized to the minimum and maximum values recalled from non-volatile memory. Upon a demand reset, the Maximum and Minimum Demands are set equal to the Present Total Watt, VAR, and VA Demand values. A demand reset does not change the value of the Present Total Watt, VAR, and VA Demands.

6.10.4 Demand Resets

The demand values are reset in 3 groups: current, voltage, and power. This can be accomplished via the front display or from a web browser.

6.10.5 Demand Interval

The M65x uses 900 seconds (15 minutes) as the default demand interval for current. The default for average volts and average power measurements is 60 seconds. Three separate, independent demand intervals may be set for current, voltage, and power. The range of demand intervals is 10 to 9999 seconds. These settings can be accomplished by using the front display or web server setup.

6.11 Harmonic Measurements

All harmonic and harmonic related measurements are calculated every 100 ms. In the following sections, Harmonic 0 indicates DC, Harmonic 1 indicates the fundamental, and Harmonic N is the nth multiple of the fundamental.

6.11.1 Voltage Distortion (THD)

Voltage Harmonic Distortion is measured by phase in several different ways. The equation for Total Harmonic Distortion (THD) is given in Equation 1. Note the denominator is the fundamental magnitude.

$$\%THD = \frac{\sqrt{\sum_{h=2}^{63} V_h^2}}{V_1} \times 100\%$$

Equation 1 – Voltage THD

6.11.2 Current Distortion (THD and TDD)

Current Harmonic Distortion is measured by phase in several different ways. The first method is Total Harmonic Distortion (THD). The equation for THD is given in Equation
2. Note the denominator is the fundamental magnitude.

$$\%THD = \frac{\sqrt{\sum_{h=2}^{63} I_h^2}}{I_1} \times 100\%$$

Equation 2 – Current THD

Alternatively, Current Harmonic Distortion can be measured as Demand Distortion, as defined by IEEE-519/519A. Demand Distortion differs from traditional Harmonic Distortion in that the denominator of the distortion equation is a fixed value. This fixed denominator value is defined as the average monthly peak demand. By creating a measurement that is based on a fixed value, TDD is a "better" measure of distortion problems. Traditional THD is determined on the ratio of harmonics to the fundamental. While this is acceptable for voltage measurements, where the fundamental only varies slightly, it is ineffective for current measurements since the fundamental varies over a wide range. Using traditional THD, 30% THD may mean a 1 Amp load with 30% Distortion, or a 100 Amp load with 30% Distortion. By using TDD, these same two loads would exhibit 0.3% TDD for the 1 Amp load and 30% TDD for the 100 Amp load (if the Denominator was set at 100 Amps). In the M65x, Current Demand Distortion is implemented using Equation 3. The TDD equation is similar to Harmonic Distortion (Equation 2), except that the denominator in the equation is a user-defined number. This number, I_L, is meant to represent the average load on the system. The denominator I_L is different for each phase and neutral, and is set by changing the denominator values within the M65x.

$$\%TDD = \frac{\sqrt{\sum_{h=2}^{63} I_h^2}}{I_L} \times 100\%$$

Equation 3 – Current TDD

Note that in Equation 3, if I_L equals the fundamental, this Equation becomes Equation 2 - Harmonic Distortion. In the instrument this can be achieved by setting the denominator to zero amps, in which case the instrument will substitute the fundamental, and calculate Current THD.

Note that there is a separate, writeable denominator for each current input channel. The TDD Denominator Registers are set by the factory to 5 Amps (secondary), which is the nominal full load of the CT input with a 1:1 CT. These writeable denominators can be used in conjunction with the distortion measurements to obtain the magnitudes of harmonics, in other words, convert from percent to amps. This is simply done by multiplying the percent TDD by the TDD Denominator for that phase, and the result will be the actual RMS magnitude of the selected harmonic(s). This technique can also be used if the THD mode (denominator set to zero) is used, by multiplying the percent THD by the Fundamental Amps for that phase.

6.11.3 Fundamental Current

Fundamental Amps are the nominal component (50/60 Hz) of the waveform. The M65x measures the magnitude of the fundamental amps for each phase. These measurements can be used in conjunction with the distortion measurements to obtain the magnitudes of harmonics, in other words, convert from percent to amps. As was mentioned previously, this is simply done by multiplying the percent THD by the Fundamental Amps for that phase (which is the denominator), and the result will be the actual RMS magnitude of the selected harmonic.

6.11.4 Fundamental Voltage

Fundamental Volts are the nominal component (50/60Hz) of the waveform. The M65x measures the magnitude of the fundamental phase-to-neutral and phase-to-phase volts. These measurements can be used in conjunction with the distortion measurements to obtain the magnitudes of harmonics, in other words, convert from percent to volts. This is simply done by multiplying the percent THD by the Fundamental Volts for that phase (which is the denominator), and the result will be the actual RMS magnitude of the selected harmonic.

Fundamental Volts and Amps can be used in conjunction to obtain Fundamental VAs, and when used with Displacement Power Factor can yield Fundamental Watts and Fundamental VARs.

6.11.5 K-Factor

K-Factor is a measure of the heating effects on transformers, and it is defined in ANSI/IEEE C57.110-1986. Equation 4 is used by the M65x to determine K-Factor, where "h" is the harmonic number and "I_h" is the magnitude of the h^{th} harmonic. K-Factor is measured on each of the three phases of amps, however there is no "Total" K-Factor. K-Factor, like THD and PF, does not indicate the actual load on a device, since all three of these measurements are ratios. Given the same harmonic ratio, the calculated K-Factor for a lightly loaded transformer will be the same as the calculated K-Factor for a heavily loaded transformer, although the actual heating on the transformer will be significantly different.

$$K - Factor = \frac{\sum_{h=1}^{63} I_h^2 \times h^2}{\sum_{h=1}^{63} I_h^2}$$

Equation 4 – K-Factor

6.11.6 Displacement Power Factor

Displacement Power Factor is defined as the cosine of the angle (phi) between the Fundamental Voltage Vector and the Fundamental Current Vector. The sign convention for Displacement Power Factor is the same as for Power Factor, shown in Figure 9.

The Total Displacement Power Factor measurement is calculated using the "Power Triangle", or the three-phase Fundamental WATTS divided by the three-phase Fundamental VAs. The per-phase Fundamental VA measurement is calculated from the product of the per-phase Fundamental Amp and Fundamental Volts values. The three-phase Fundamental VA measurement is the sum of the per-phase Fundamental VA values (Arithmetic VAs).

6.11.7 Phase Angles

The M65x measures the Fundamental Phase Angles for all Currents, Line-to-Neutral Voltages, and Line-to-Line Voltages. The Phase Angles are in degrees, and all are referenced to the V_{A-N} Voltage, which places all Phase Angles in a common reference system. Values are from -180 to +180 Degrees. Note that the phase angles are only available in the TUC register set and use calculation type T8 (see Modbus and DNP3 Protocol manuals for more detail). As with other measurements, the Phase angles can be mapped to analogue outputs or used in custom display screens.

6.12 Heartbeat and Health Check

M65x meters provide a Heartbeat State Counter Register that allows the user to determine the time between successive polls. This counter will increment by the number of milliseconds that have elapsed since the last time the data was updated. Another use of this register is as a visual indicator that the data is changing; it allows users of certain MMIs to identify disruption in the polling of the instrument. The Heartbeat State Counter is a full 32-bit counter that rolls over at 4,294,967,295 (4,294,967 seconds). The counter starts at zero on power up, and is NOT stored in non-volatile memory.

M65x meters have several self-tests built in to ensure that the instrument is performing accurately. The results of these self-tests are available in the Health Check register which is a simple 16-bit binary value. Each bit represents the results of a particular self-test, with "0" indicating the test was passed, and "1" indicating the test was failed. If Health status failures occur, the meter may have experienced an operational failure. The table below provides a reference of error codes. The Health Check value shown in the M65x web live data page is a hexadecimal representation of the binary value. For example, a Health Check value of 0000 0014 is the equivalent of the binary value 000000000010100. The “1” shown in bit 2 and bit 4 represents a failed test in those bits which indicates a checksum error for both the gain and phase on the calibration. Contact the factory for further instructions.

Health Check Error Codes	
Bit	Description
0	Checksum error on analogue output (either 0-1mA or 4-20mA) calibration constants
2	Checksum error on gain calibration of inputs
4	Checksum error on phase calibration of inputs
12	Indicates firmware download in progress and measurements are offline

6.13 List of Available Measurements & Settings

Available Measurements	
Amps A, B, C, Residual	Heartbeat
Average Volts AN, BN, CN, AB, BC, CA	K-factor Amps A
Average (Max.) Volts AN, BN, CN, AB, BC, CA	K-factor Amps B
Average (Min.) Volts AN, BN, CN, AB, BC, CA	K-factor Amps C
Average Watts A, B, C, Total	K-factor Amps Residual
Average (Max.) Watts A, B, C, Total	Meter Type
Average (Min.) Watts A, B, C, Total	Phase Angle Amps A, B, C
Average VARs A, B, C, Total	Phase Angle Volts A, B, C
Average (Max.) VARs A, B, C, Total	Phase Angle Volts AB, BC, CA
Average (Min.) VARs A, B, C, Total	Power Factor A, B, C, Total
Average VAs A, B, C, Total	Protocol Version
Average (Max.) VAs A, B, C, Total	PT Scale Factor
Average (Min.) VAs A, B, C, Total	PT Scale Factor Divisor
Class 0 Response Setup	TDD Amps A, B, C, Residual
CT Scale Factor	TDD Denominator A, B, C,
CT Scale Factor Divisor	THD Volts AN, BN, CN, AB, BC, CA
Demand (Max.) Amps A, B, C, Residual	VA-Hrs
Demand (Max.) Fund. Amps A, B, C, Residual	VAR-Hrs Lag
Demand Amps A, B, C, Residual	VAR-Hrs Lead
Demand Fundamental Amps A, B, C, Residual	VARs A, B, C, Total
Displacement Power Factor A, B, C	VAs A, B, C, Total
Displacement Power Factor Total	Volts AN, BN, CN, AB, BC, CA
Factory Version Hardware	Volts Aux
Factory Version Software	Watt-Hrs Net
Frequency	Watt-Hrs Normal
Fund. Amps A, B, C, Residual	Watt-Hrs Reverse
Fund. Volts AN, BN, CN, AB, BC, CA	Watts A, B, C, Total
Health	

6.14 Calibration

Routine re-calibration is not recommended or required. A field calibration check every few years is a good assurance of proper operation.

6.15 Instantaneous Measurement Principles

The M65x measures all signals at an effective rate of 64 samples/cycle, accommodating fundamental signal frequencies from 45 to 65Hz. Samples of all bus signals are taken using a 16-Bit A/D converter, effectively creating 64 "snapshots" of the system voltage and current per cycle.

6.15.1 Sampling Rate and System Frequency

The sampling rate is synchronized to the frequency of any of the bus voltages prioritized as follows: $V1_{A\text{-}N}$, $V1_{B\text{-}N}$, $V1_{C\text{-}N}$. This is the frequency reported as the "System Frequency". The sampling rate is the same for all channels.

7.0 ANALOGUE OUTPUT OPTION

7.1 Introduction

The Analogue Output options (0 -1 mA or 4-20 mA) feature 3 separate outputs each with two terminals, one of which is common to all three outputs and which provides a unique return path for each output.

7.2 Specifications

Outputs: 3 bi-directional, 0-1mA (active) or 4-20mA (loop powered, passive)

0 – 1mA Current Range

Output Range:	0 to +/-1mA into 10K ohms or less; Overload to +/-2.1mA into 5K ohms or less.
Resolution:	0.22uA
Output Resistance:	500 ohm

4 – 20mA Current Range

Output Range:	4 to 20mA
Resolution:	1.1uA
Max Loop Voltage:	40Vdc
Max Voltage Drop:	2.3V @ 20mA

4 – 20mA Internal Loop Supply

Max Output Voltage:	6V @ 60mA,

Accuracy: 0.25% of Full Scale Input

Data Update Rate (poll rate): 100ms minimum

Input Capacitance, any Terminal to Case: 470pF

7.3 Connections

The connections for the 0-1 mA output option are shown in figure 10 while the connections for the 4-20 mA with external and internal loop are shown in figure 11.

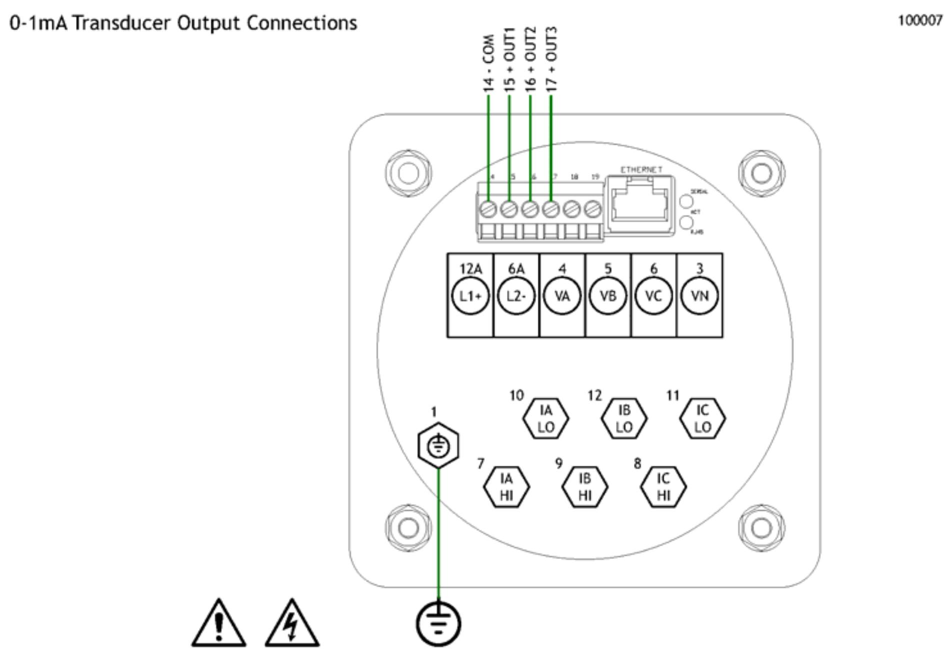
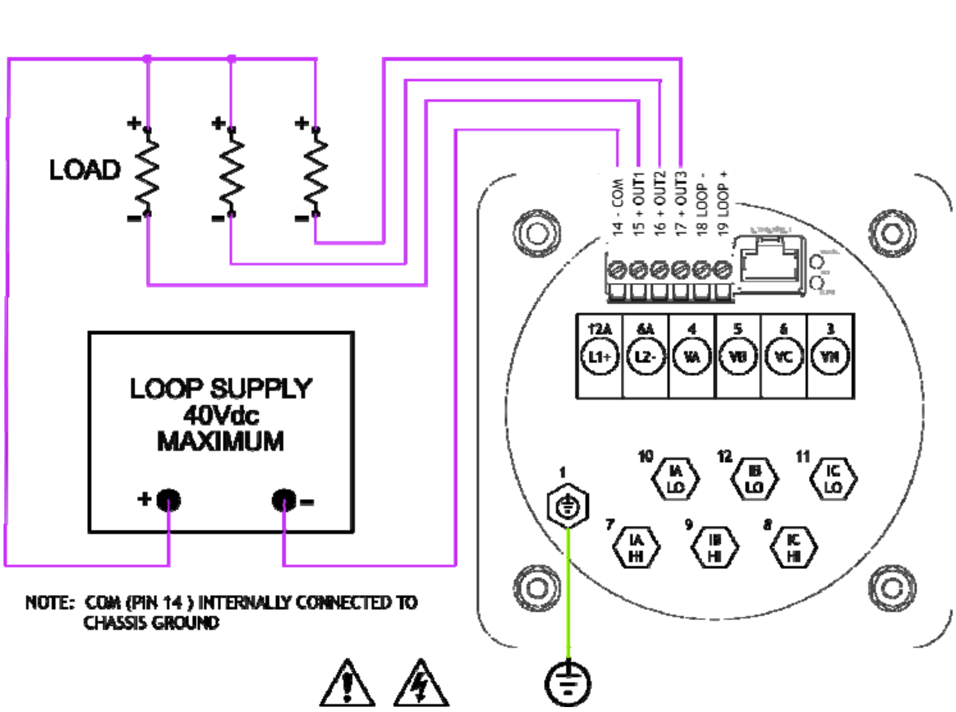


Figure 10 – 0-1mA Transducer Output Connections

4-20mA Transducer Output Connections - External Loop Supply

100010R1



4-20mA Transducer Output Connections - Internal Loop Supply

100009R1

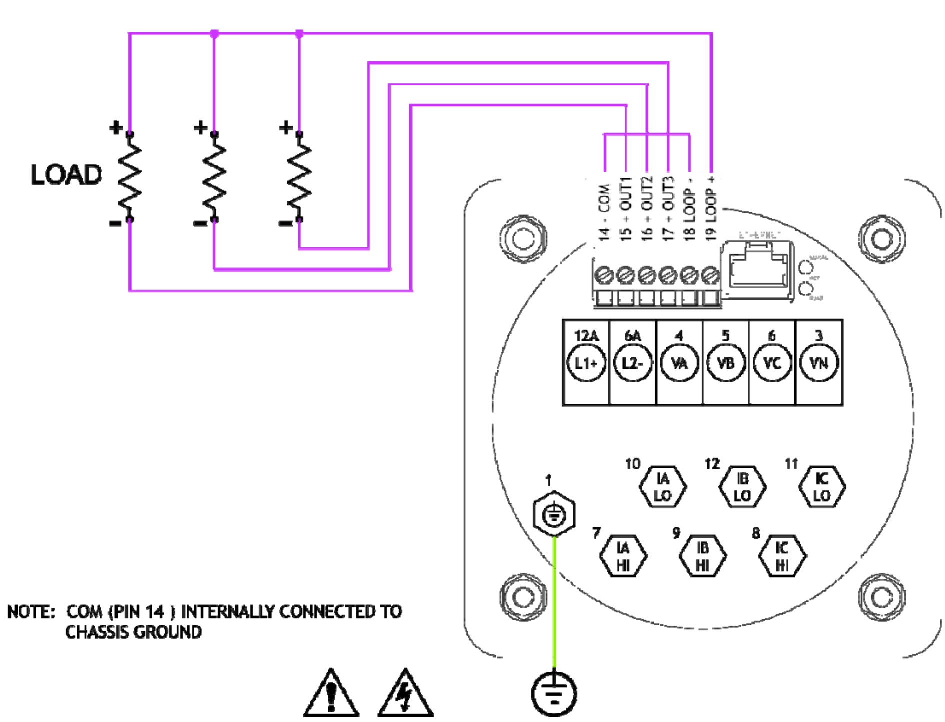


Figure 11 – 4-20mA Transducer Output Connections

8.0 SPLIT-CORE CT INPUT OPTION

8.1 Introduction

A version of the M65x can be supplied with split-core CTs for monitoring the 5A secondary wiring of an installed CT. This M65x version is customised to operate with the supplied split-core CTs and **cannot** be connected to standard 1A or 5A CT outputs, doing so will result in damage of the M65x.

The split-core CTs are only for installation on the secondary wiring of an installed CT, which are energized to no more than 600Vac, they **cannot** be mounted on a load current carrying conductor (primary). The split-core CTs are designed for monitoring a 5A nominal current with a maximum current of 10A with rated accuracy. The split-core CTs are not suitable for monitoring CTs with a 1A secondary.

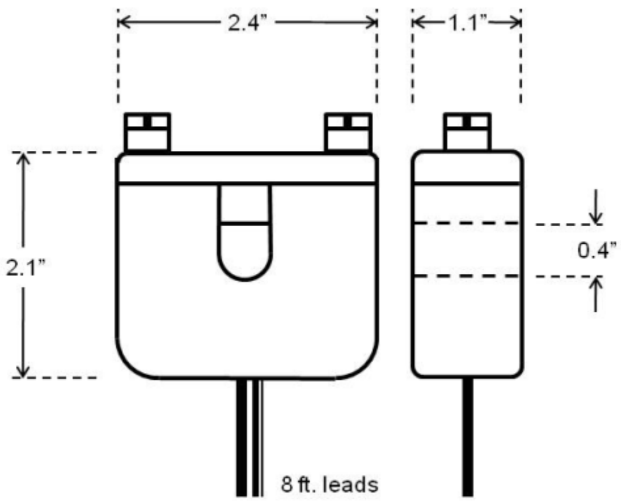
The split-core CT output is 0 – 10mA and the output is protected by zener diodes to ensure that it is safe to operate with the secondary leads open circuit.

During manufacture each split-core CT is calibrated to linearise both the amplitude and phase angle response. The split-core CTs are supplied labelled with the serial number of a specific M65x and the specific phase on that unit. They must be connected to the specified phase on the specific M65x unit if the defined accuracy specification of the measurements is to be achieved.

8.2 Mounting

The M65x supplied with the split-core CTs is mounted in the same way as the standard M65x, as defined in section 2.

The split-core CTs have the following dimensions.



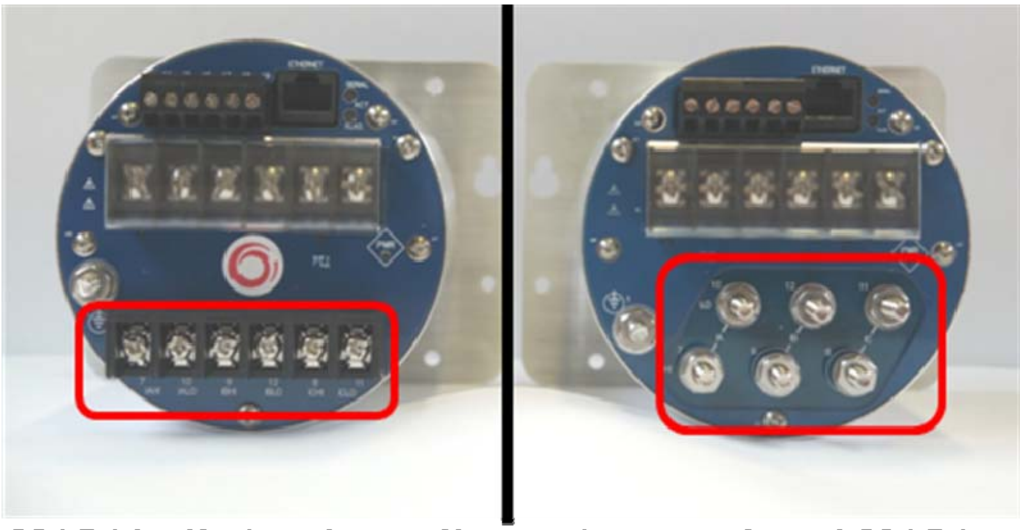
The split-core CTs can be mounted in optional brackets, side and end mounted versions are available, they are held in the bracket by 2 screws. The brackets can be mounted on any flat surface.


End Mounting


Side Mounting

8.3 Rear Panel and Wiring

The M65x version for use with split-core CTs is fitted with screw terminals for the current connections rather than the studs fitted on the standard version. All other wiring details are the same as the standard M65x and are defined in section 3. See Appendix A1 for the detailed wiring diagrams of the split-core version.



M651 built for the split core option:
Connects to split cores CTs
0-10mA into screw terminals

Conventional M651:
Connects to substation CTs
0-10A+ into 6 x 10-32 studs

The split-core CTs are fitted around the secondary cabling of the installed CT as shown below,

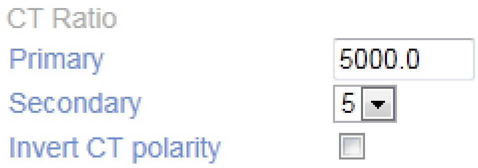
The gate of the core is fastened using 2 bolts which should not be overtightened. It is important that the mating faces of the core are free on any dirt or debris which could prevent the lapped faces of the CT mating correctly.

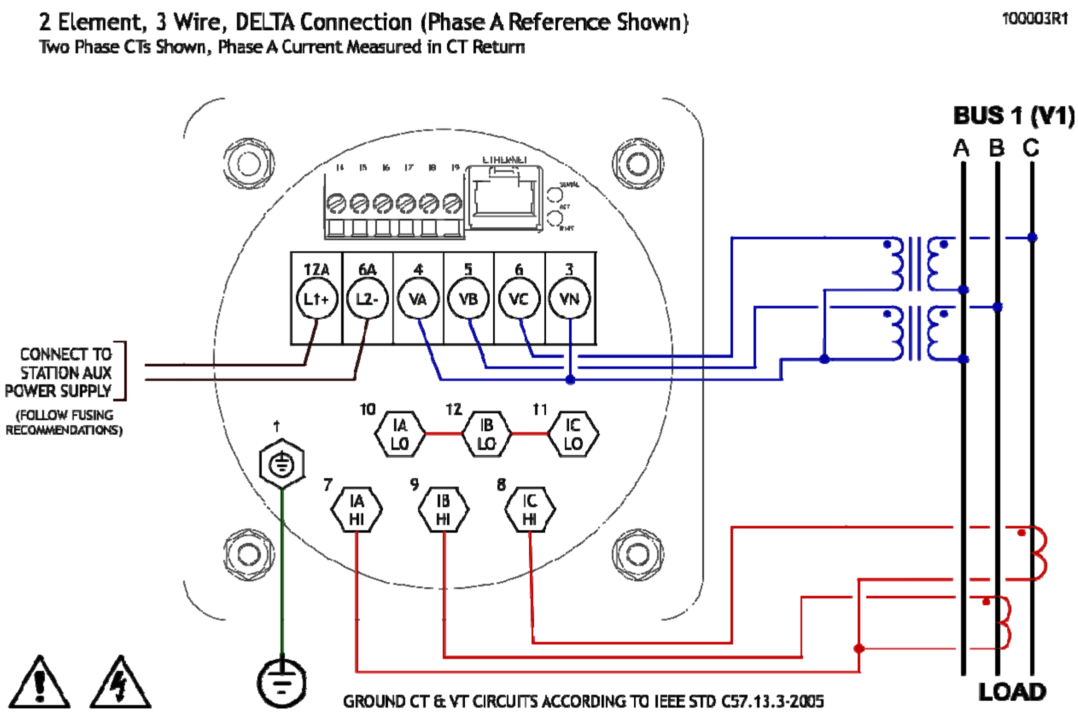
The split-core CT is supplied as standard with 2.4m (8ft) of cable attached, this can be extended during installation by a reasonable amount. Any length of wire that adds less than 1.0 Ohm to the total loop resistance from the split-core CT to the M65x can be added without degrading the accuracy. For example: Remember, there are **two** leads for each CT. So if you want to add 20m to the distance between the M65x and the CT, you are adding the effect of two 20m lengths of wire, or 40m to the loop resistance. Therefore use a wire gauge and composition that has less than 1.0 Ohm resistance per 40m.

APPENDIX

A1 CT/VT Connection Diagrams

Please note that there is an option on the Settings/Input page to invert the CT Polarity (see screen shot clip below). This option is the equivalent of swapping the connections in the connection diagrams below at the HI and LO terminals for each CT input, that is, swapping 7 and 10, 8 and 11, 9 and 12. The effect is a 180 degree phase shift in the current signals.





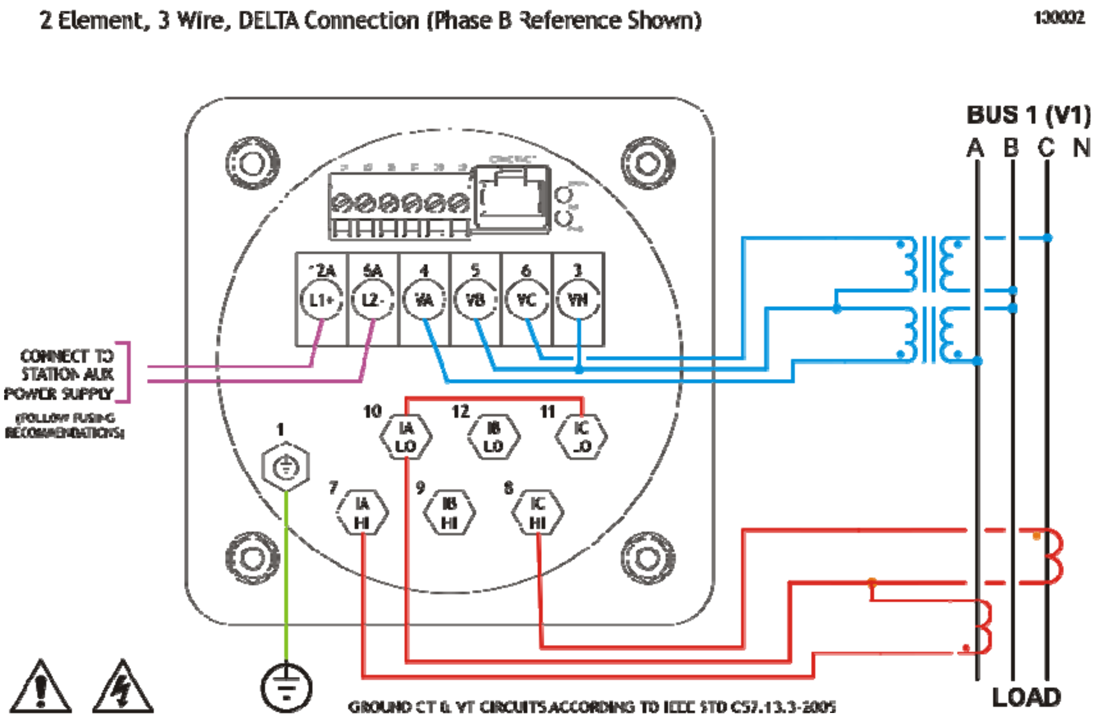
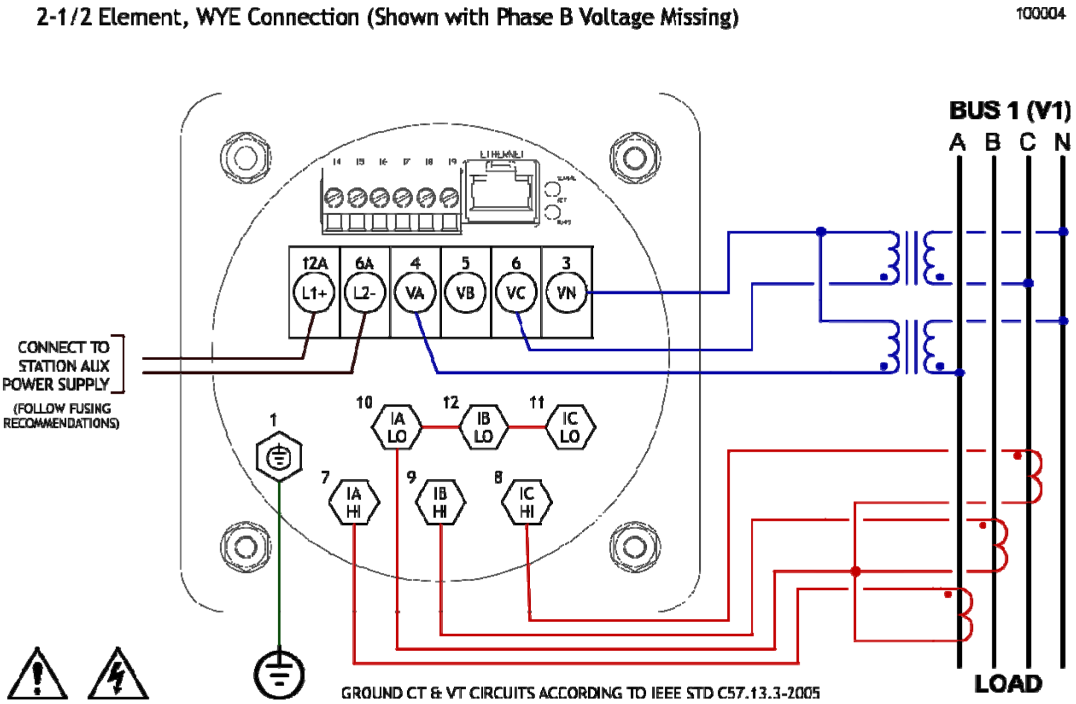


Figure 12 - Signal Connections – M65x

2-1/2 Element, WYE Connection (Shown with Phase B Voltage Missing)



3 Element, 4 Wire, WYE Connection

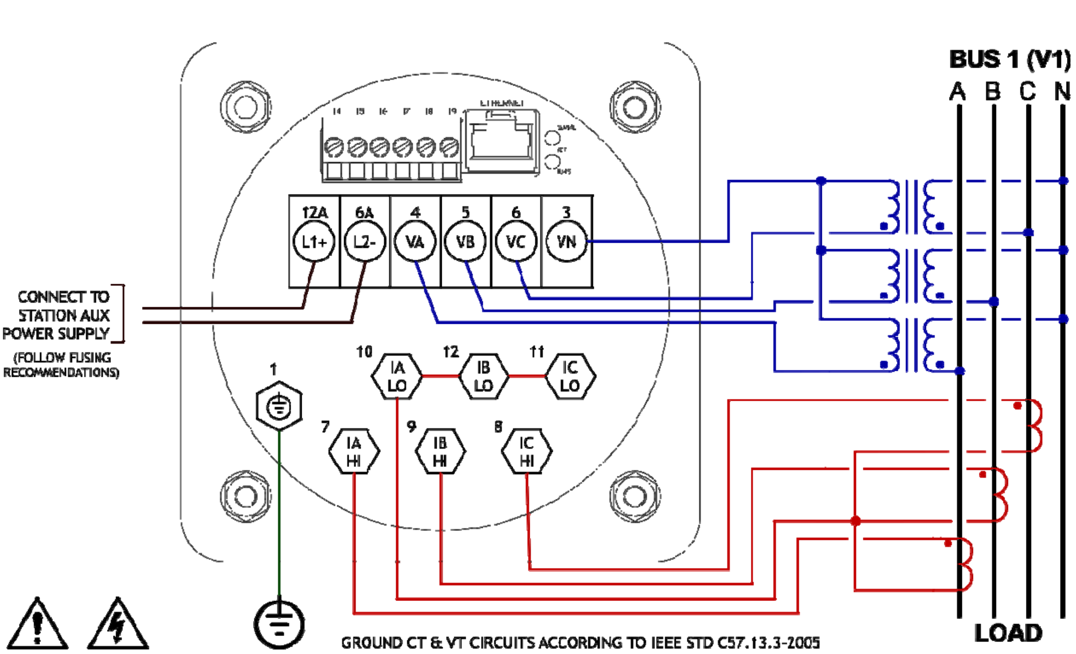
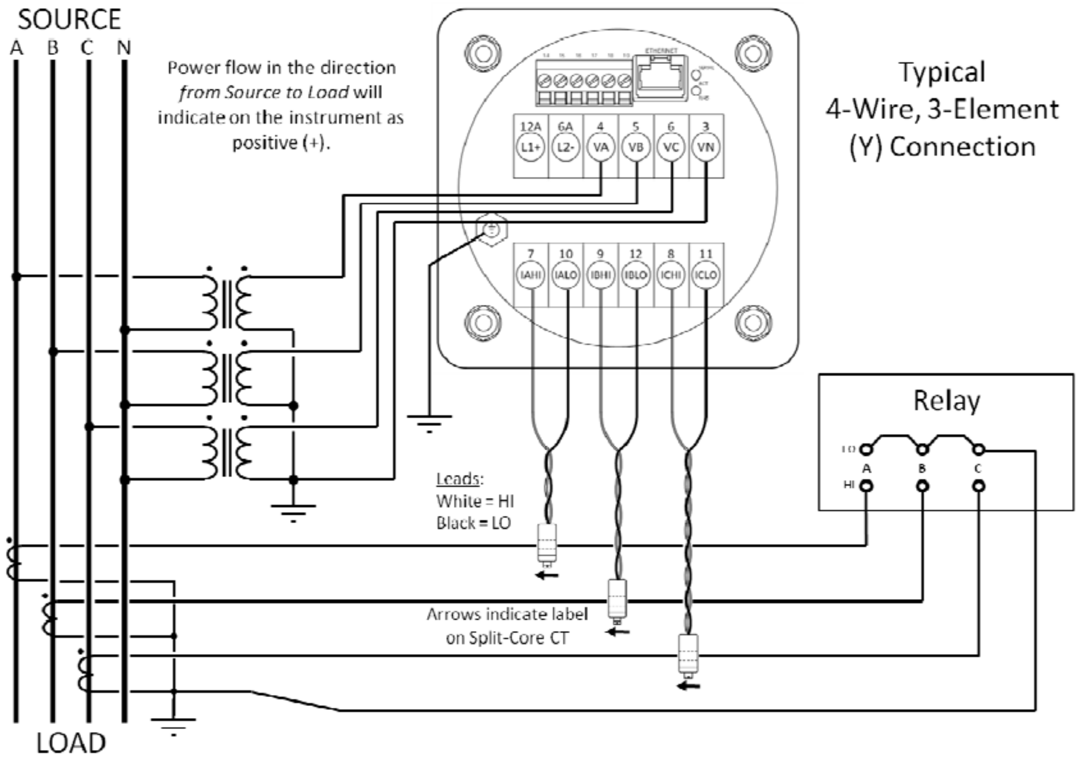


Figure 12 - Signal Connections – M65x



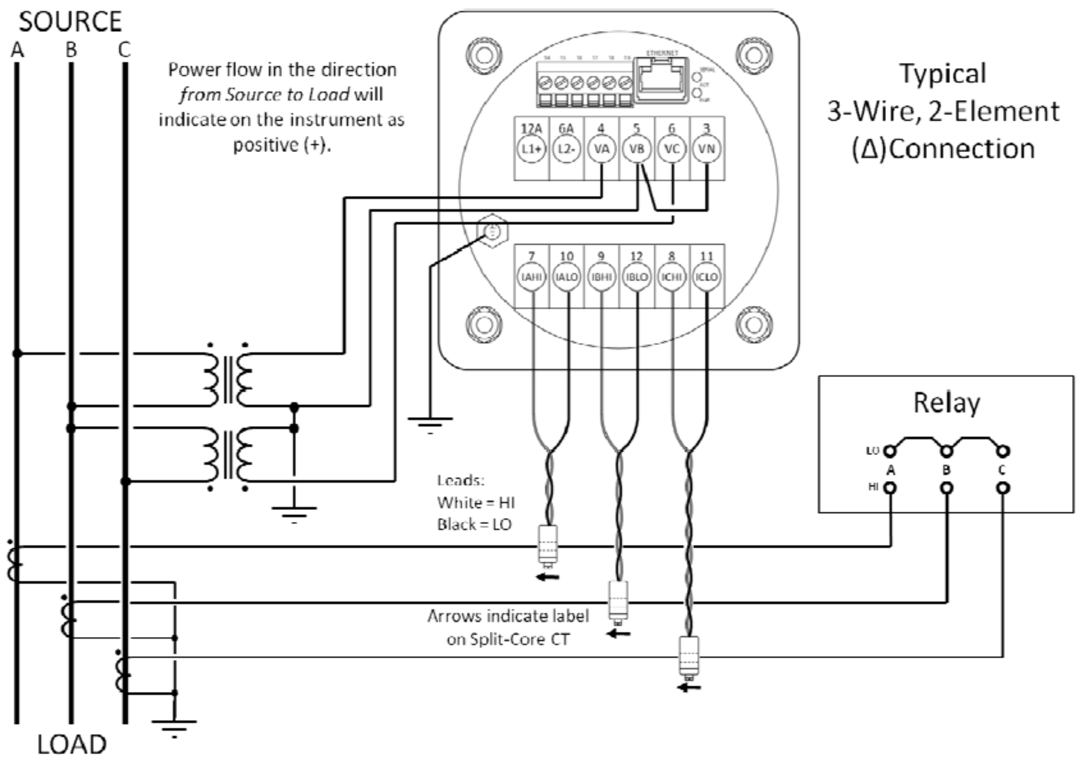


Figure 13 – M65x External Split-Core Signal Connections

A2 Ethernet Troubleshooting

If the Link LED fails to illuminate, this is an indication that there is trouble with the connection and communication will not proceed without solving the problem. If a copper connection is used between the M65x and the hub/switch, check the following items:

1. Verify that the connectors are fully engaged on each end.
2. Verify that the cable used is a "straight-through" cable connected to a "normal" port. Alternatively, a "cross-over" cable *could* be connected to an "uplink" port (this could later cause confusion and is not recommended).
3. Verify that both the M65x and hub/switch are powered.
4. Try another cable.
5. If a long CAT-5 cable is used, verify that is has never been kinked. Kinking can cause internal discontinuities in the cable.

If a copper connection is used to an external fibre converter:

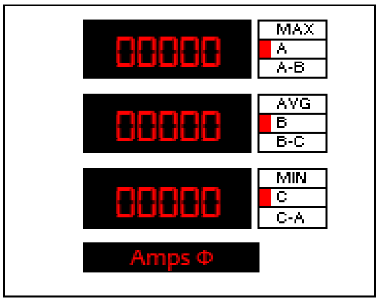
1. Verify that the LINK LED on the converter is lit on at least one side. Both sides need to be lit for a valid connection to be established.
2. At least one brand of converters will not output an optical idle unless it receives a forced 10 Mb copper link pulse (for some reason, auto-negotiation pulses confuse it). Some hubs/switches will not output an optical idle unless they receive an optical idle. This then inhibits the converter from outputting a copper link pulse enabling the M65x to link. In this condition, no device completes the link.
3. Verify that the fibre converter(s) and/or fibre hub/switch are matched for the same type of fibre connections. A 100BASE-FX port will NEVER inter-operate with the 10BASE-FL port (fibre auto-negotiation does not exist).
4. On the fibre connection, try swapping the transmit and receive connector on one end.
5. Verify that the fibre converter(s) and/or fibre hub/switch use the proper optical wavelength (100BASE-FX should be 1300nm).

A3 Display Screens – Visual Representations

Screen

Amps A, B, C

1



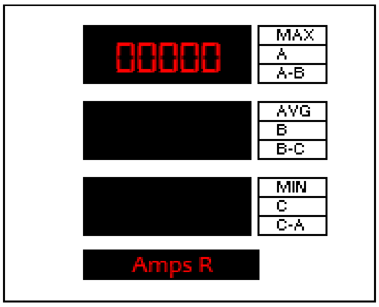
Phase A Amps

Phase B Amps

Phase C Amps

Amp Residual

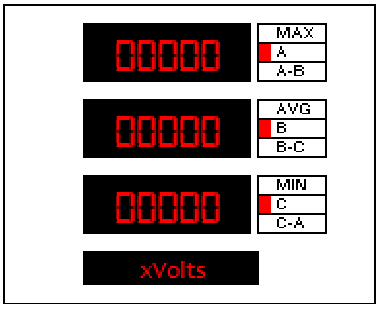
2



Amps Residual

Volts AN, BN, CN

3



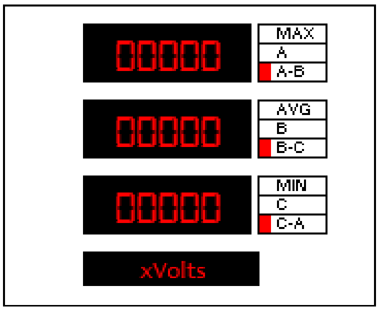
Volts A

Volts B

Volts C

Volts AB, BC, CA

4



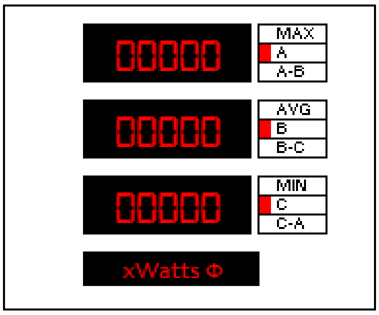
Volts AB

Volts BC

Volts CA

Watts A, B, C

5

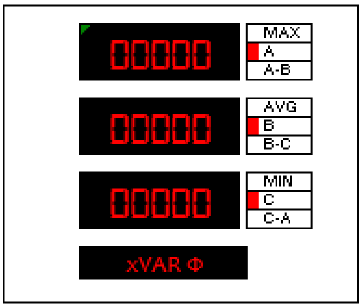


Watts A

Watts B

Watts C

6 VARs A, B, C

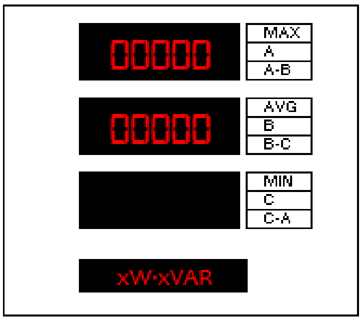


VARs A

VARs B

VARs C

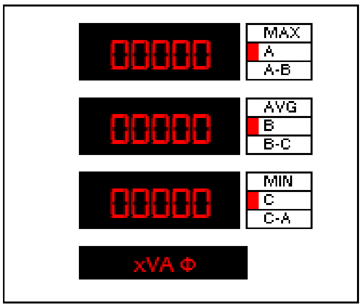
7 Total Watts · Total VARs



Total Watts

Total Vars

8 VAs A, B, C

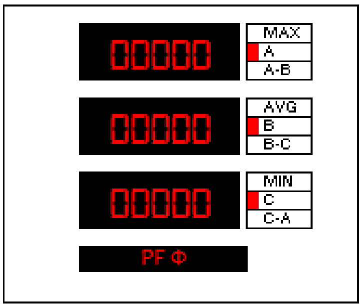


VAs A

VAs B

VAs C

9 Power Factor A, B, C

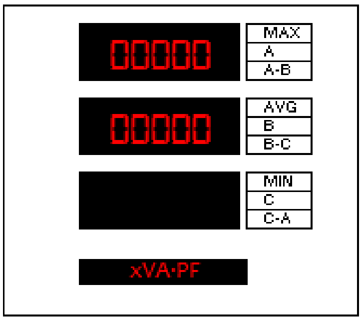


PF A

PF B

PF C

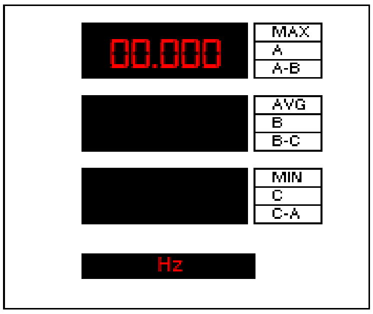
10 Total VAs · 3Φ PF



VAs Total

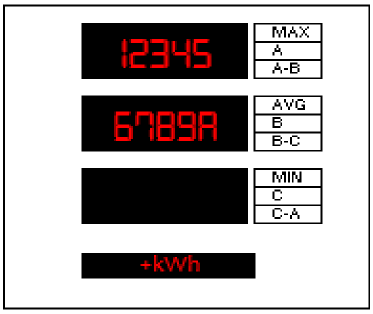
3Φ PF

11 Frequency



Frequency

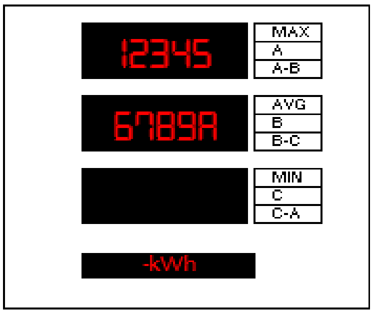
12 Watt Hrs Normal (+)



Most significant half

Least significant half

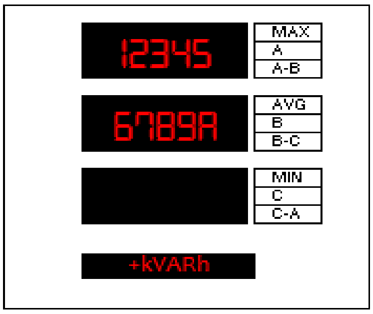
13 Watt Hrs Reverse (-)



Most significant half

Least significant half

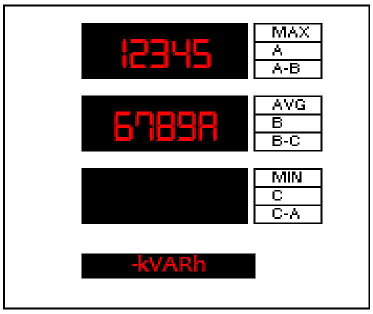
14 VAR Hrs Lagging (+)



Most significant half

Least significant half

15 VAR Hrs Leading (-)

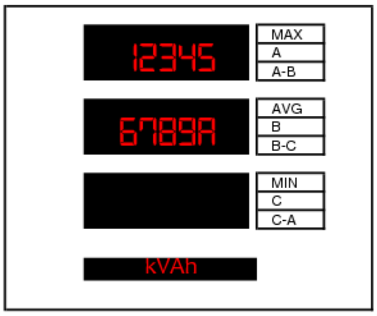


Most significant half

Least significant half

kVA Hrs

16

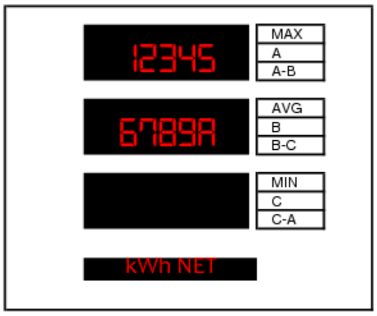


Most significant half

Least significant half

kWatt Hrs Net

17

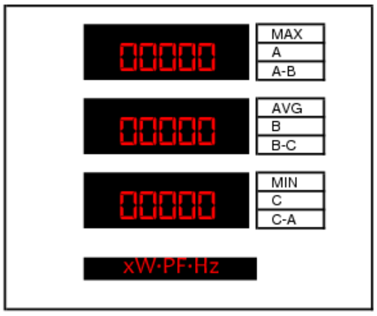


Most significant half

Least significant half

Total Watts · 3Φ PF · Frequency

18



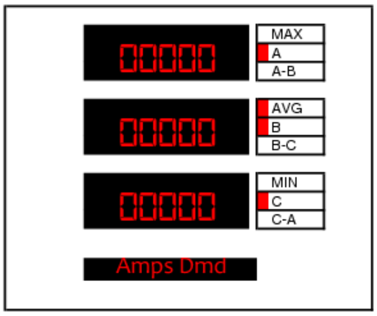
Total Watts

3Φ PF

Frequency

Demand Amps A, B, C

19



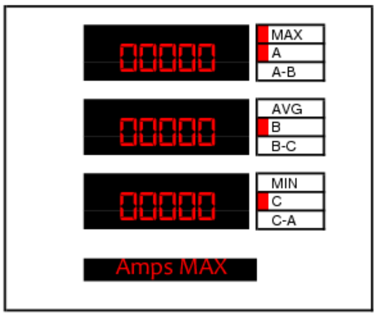
Demand Amps A

Demand Amps B

Demand Amps C

Max Dmd Amps A,B,C

20



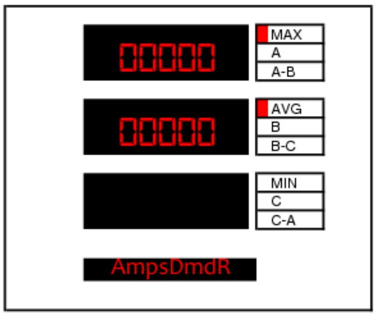
Dmd Amps A Max

Dmd Amps B Max

Dmd Amps C Max

Demand Amps Residual

21

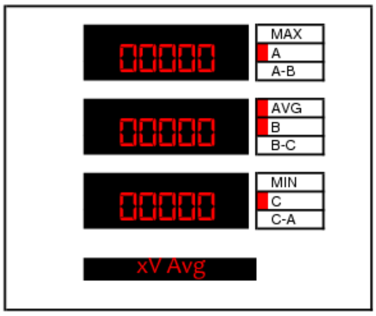


Demand Amps R MX

Dmd Amps R

Average Volts AN, BN, CN

22



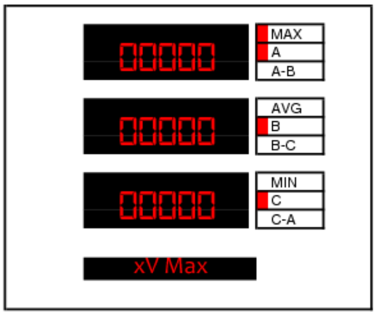
Volts A

Volts B

Volts C

Max Average Volts AN, BN, CN

23



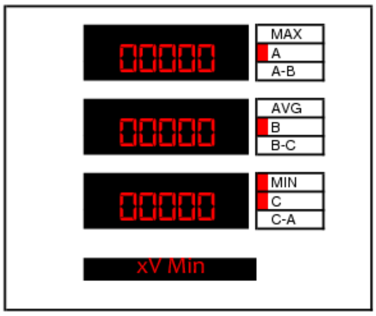
Volts A

Volts B

Volts C

Min Average Volts AN, BN, CN

24



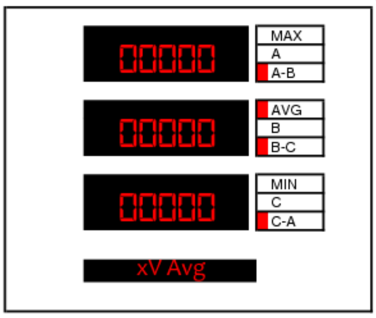
Volts A

Volts B

Volts C

Average Volts AB, BC, CA

25

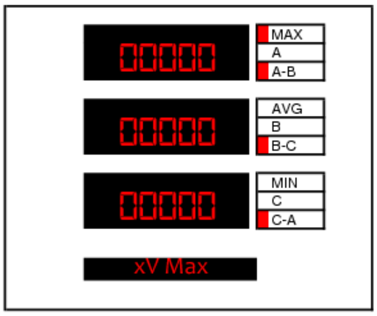


Volts AB

Volts BC

Volts CA

Max Average Volts AB, BC, CA

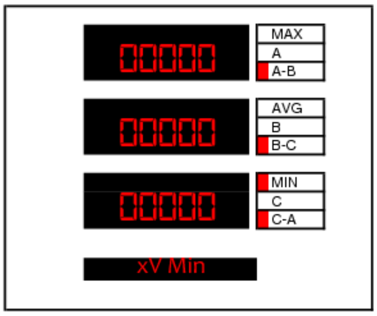
26


Volts AB

Volts BC

Volts CA

Min Average Volts AB, BC, CA

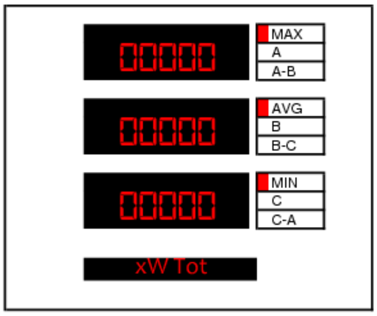
27


Volts AB

Volts BC

Volts CA

Total Watts Max · Avg · Min

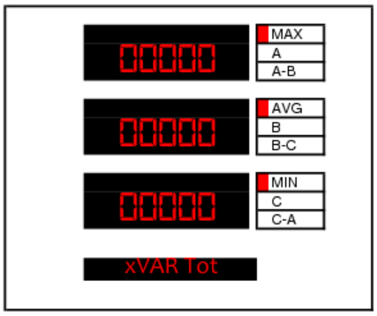
28


Average Watts Max

Average Watts Avg

Average Watts Min

Total VARs Maxl · Avg · Min

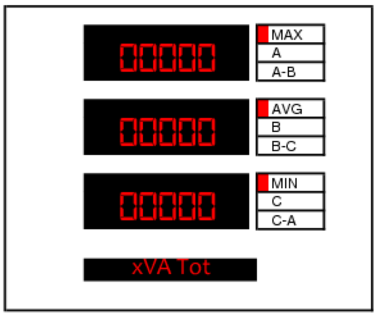
29


Average VARs Max

Average VARs Avg

Average VARs Min

Total VAs Max· Avg · Min

30


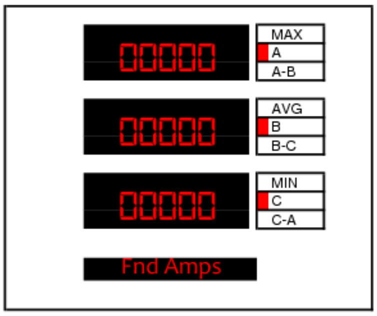
Average VAs Max

Average VAs Avg

Average VA Min

Fundamental Amps A, B. C

31



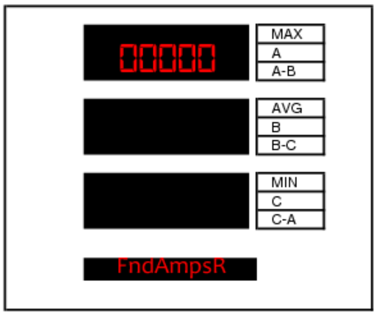
Fnd Amps A

Fnd Amps B

Fnd Amps C

Fundamental Amps Residual

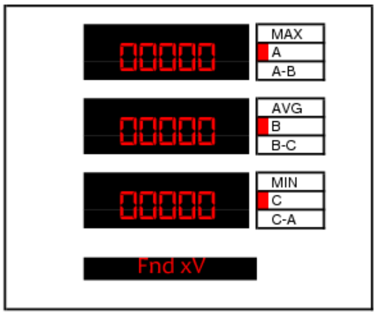
32



Fnd Amps Residual

Fund. Volts AN, BN, CN

33



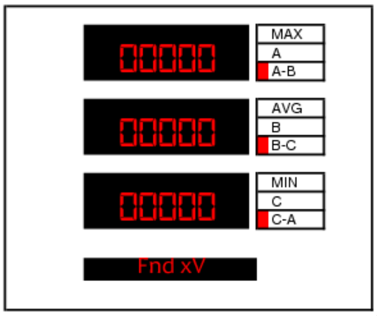
Fnd Volts A

Fnd Volts B

Fnd Volts C

Fund. Volts AB, BC, CA

34



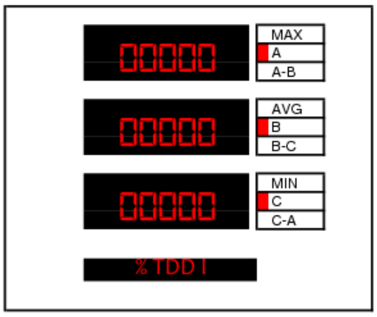
Fnd Volts AB

Fnd Volts BC

Fnd Volts CA

TDD Amps A, B, C

35

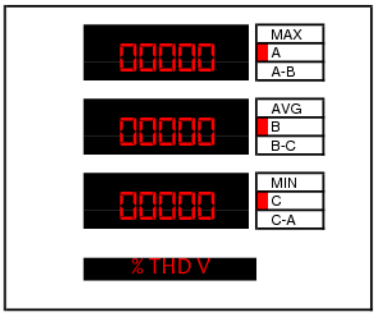


TDD Amps A

TDD Amps B

TDD Amps C

THD Volts AN, BN, CN

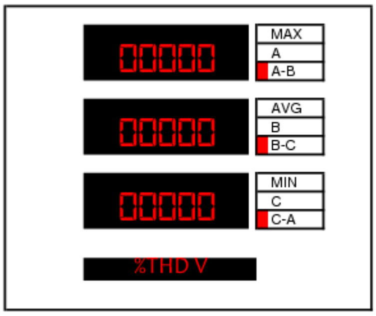
36 

THD Volts AN

THD Volts BN

THD Volts CN

THD Volts AB, BC, CA

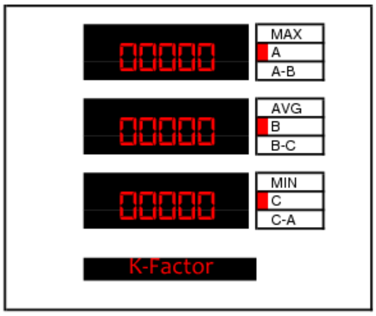
37 

THD Volts AB

THD Volts BC

THD Volts CA

K-Factor Amps A, B, C

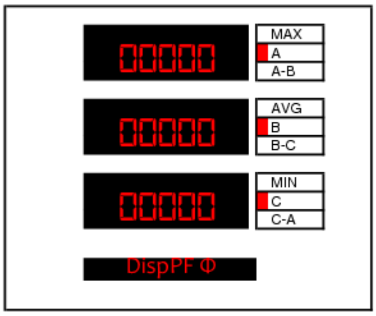
38 

K-Factor A

K-Factor B

K-Factor C

Displacement Power Factor A, B, C

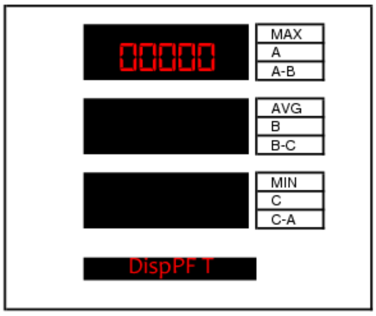
39 

Displacement PF A

Displacement PF B

Displacement PF C

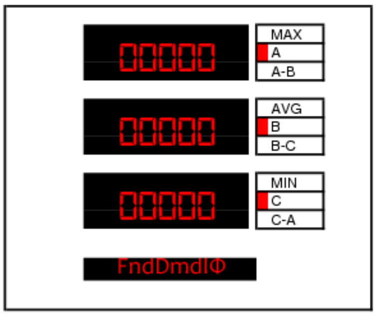
Displacement Power Factor Total

40 

Displacement PF T

Fund. Demand Amps A, B, C

41



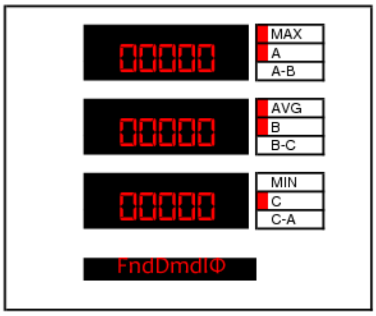
Fnd Dmd Amps A

Fnd Dmd Amps B

Fnd Dmd Amps C

Max Fund. Demand Amps A, B. C

42



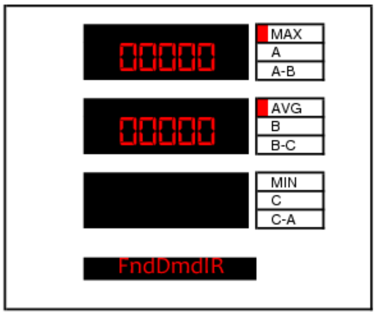
Fnd Dmd Amps A

Fnd Dmd Amps B

Fnd Dmd Amps C

Max Fund. Demand Amps Residual

43

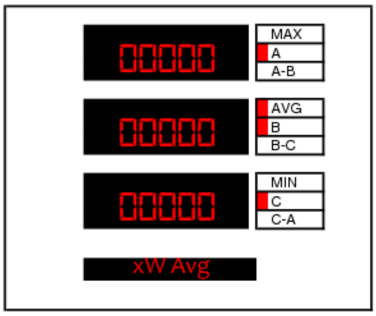


Fnd Dmd Amps R

Fnd Dmd Amps R

Average Watts A, B, C

44



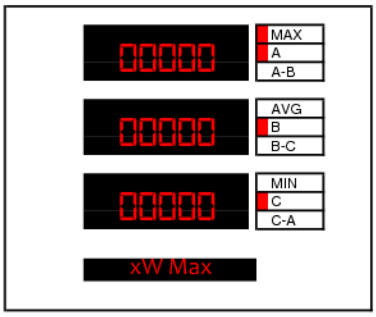
Watts A

Watts B

Watts C

Max Average Watts A, B, C

45



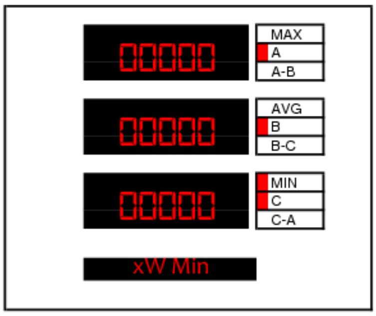
Watts A

Watts B

Watts C

Min Average Watts A, B, C

46



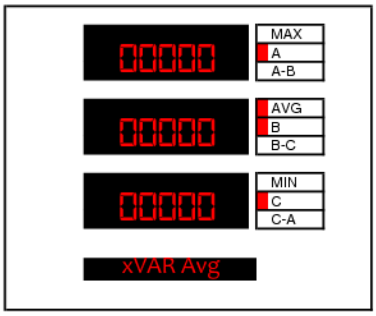
Watts A

Watts B

Watts C

Average VARs A. B, C

47



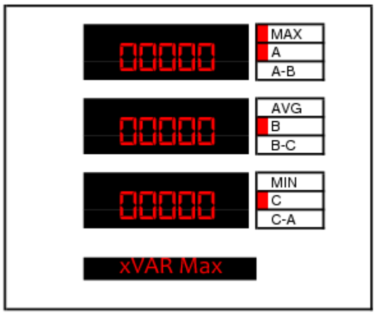
VARs A

VARs B

VARs C

Max Average VARs A. B, C

48



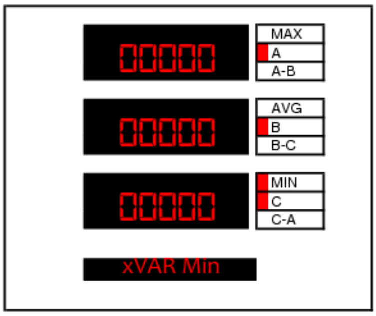
VARs A

VARs B

VARs C

Min Average VARs A. B, C

49



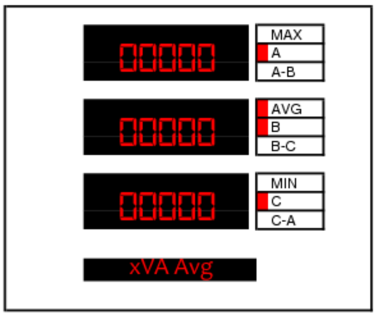
VARs A

VARs B

VARs C

Average VAs A, B, C

50



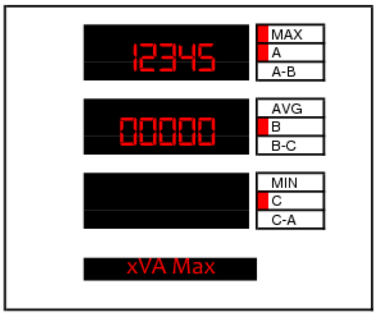
VAs A

VAs B

VAs C

Max Average VAs A, B, C

51



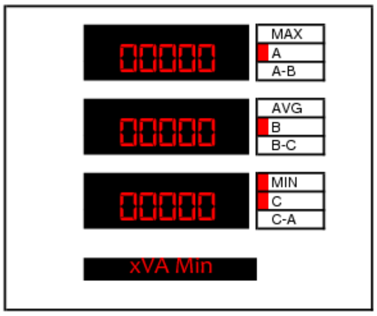
VAs A

VAs B

VAs C

Min Average VAs A, B, C

52



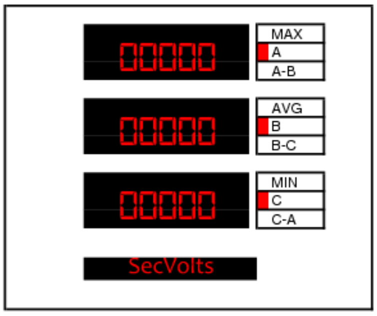
VAs A

VAs B

VAs C

Secondary Volts AN, BN, CN

53



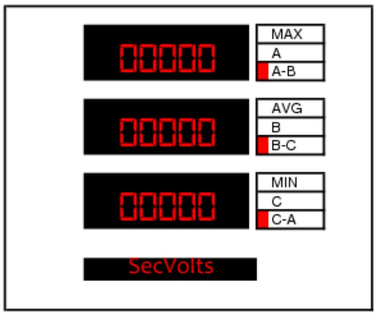
SecVolts A

SecVolts B

SecVolts C

Secondary Volts AB, BC, CA

54



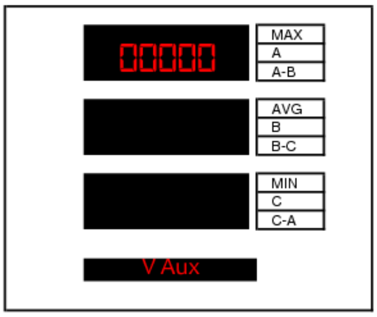
SecVolts AB

SecVolts BC

SecVolts CA

Volts Aux

55



V Aux

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