MTS-5000 USER's MANUAL

MANTA™
TEST SYSTEMS

MTS-5000

PROTECTIVE
RELAY TEST SYSTEM

USER's MANUAL

Third Edition
March 2006

4060B Sladeview Crescent Unit 1
Mississauga, Ontario L5L 5Y5, Canada
Tel: 905-828-6469 Fax: 905-828-6850
www.mantatest.com e-mail support@mantatest.com

Pay special attention to the warnings and safety instructions that accompany the above symbol wherever it is found within this manual!

MTS-5000 User’s Manual

The information and specifications contained within from Manta Test Systems are believed to be accurate and reliable at the time of printing. However, because of the nature of this product, specifications and features shown in this manual are subject to change without notice.

The features and capabilities described herein reflect those available in MTS-5000 firmware release 1.70

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MANTA TEST SYSTEMS
4060B Sladeview Crescent Unit 1
Mississauga, Ontario L5L 5Y5, Canada
Tel: 905-828-6469 Fax: 905-828-6850
Internet: http://www.mantatest.com e-mail support@mantatest.com
Toll-free technical support (USA & Canada): 1-800-233-8031

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INTRODUCTION

1.1 GENERAL DESCRIPTION

The MTS-5000 Protective Relay Test System is a compact product containing in a single easy to carry package all the facilities required to conduct comprehensive testing of virtually any protective relay device or system. Ease of use was a primary design consideration, to enhance the productivity of even relatively inexperienced users.

Comprehensive manual control features give instant access to simple through advanced functions without the need for an external control computer. A full color VGA graphic display provides intuitive control menus, complete operational status information, detailed help screens, and vector displays of complex polyphase output signals.

Three AC/DC high voltage outputs, three AC/DC high-current outputs and a DC voltage output provide all the high-VA sources needed for testing both modern processor-based relays and older higher burden electromechanical relays. Twelve channels of status inputs and four of digital outputs provide monitoring and stimulation capabilities respectively for the digital outputs and inputs of both complex relays and the systems in which they are incorporated. A full range of conventional PC interfaces including USB and Ethernet provide convenient access to high-speed data exchange with an external computer.

1.2 DISTINCTIVE FEATURES

- Compact easy to carry package, one person can transport a complete test system.
- Comprehensive manual controls including keypad for fast precise setting of any parameter, rotary knob for intuitive continuous modification of any parameter, function buttons for menu selection, and dedicated output state control buttons.
- Bright full color VGA graphic display for intuitive control menus, color coded status and setting information, and polyphase vector displays.
- Extensive built-in help screens with tutorial information on use and applications plus connection diagrams.
- Advanced polyphase control modes provide single-command control of voltage to current phase relationships, current or voltage amplitudes, and rotation of fault relationships to adjacent phase.
- Unique vertical configuration minimizes footprint, maximizes work space in crowded areas and places controls and display at eye level.

- 12 status input channels accept voltage or dry contact inputs, allow multiple relay output monitoring without moving wires, and can provide multichannel analog waveform capture.
- 4 digital output channels provide high voltage rated dry contacts to simulate breaker position switches, permissive trip receive signals, etc.
- 3 high-voltage AC/DC sources for flexible polyphase testing, plus dedicated DC voltage source.
- 3 high-current AC/DC sources for flexible 1/2/3-phase testing, and can be paralleled for extra high current.
- Low-level measurement inputs accept DCV/mA outputs from AC transducers
- Standard GPS inputs accept antenna or external IRIG-B timing signal, for ultra precise synchronizing of end-to-end testing of transmission line protection systems.
- RS-232C, USB, and Ethernet interfaces allow convenient connection to external computer for automated testing, and facilitate high-speed transfer of large data files such as complex waveforms.
- Very high power output, high-compliance-voltage current sources, to allow on-panel testing of high-burden electromechanical protective relay systems without the need to remove or short out portions of the system, resulting in much more realistic fault simulations.

1.3 APPLICATIONS

- Static and dynamic testing and calibration of virtually any protective relay, including:

Timed overcurrent/undercurrent	Under/overvoltage
Impedance/Distance	MHO
Under/overfrequency	Frequency rate-of-change
Directional overcurrent	Line Differential
Synchrocheck	Motor Protection
Transformer Differential	Reverse power
Volts-per-Hertz	Loss of excitation
Out-of-step	DC Timer/Auxiliary
Reclosing/Synchronizing	Negative sequence
Multi-function distance	Pilot wire

- On panel testing of relay systems, in both static and dynamic modes.
- Fault recording: capturing of waveforms and digital output signatures when protective relays operate
- Meter Calibration
- Transducer calibration: 1- and 3-phase voltage, current, phase, frequency, Watt and Var
- Circuit breaker timing

1.3.1 Waveform Playback Applications

- Playback of Comtrade format digital fault records, or relay event reports, into relays and relay systems for fault and misoperation analysis
- Fault simulation, harmonic sourcing, and transient simulation for relay and relay system testing
- Inrush current simulation/testing (including DC offset)
- Ground resistance testing
- Playback of multiple and evolved faults.
- Digital fault recorder testing.
- Playback of EMTP calculated waveforms to relays and relay systems for simulation of hypothetical or predicted system faults.
- Simulation of non-zero source impedance for testing impedance relays. (Performed with the assistance of EMTP simulation output).
- Generation of user-defined power waveforms for relay sensitivity testing. Testing of pilot wire relaying systems.
- Power system modelling.
- Relay qualification and acceptance testing.

1.4 TERMINOLOGY

The following section clarifies terminology defining various approaches to relay testing.

The MTS-5000 Protective Relay Test System is very versatile, and may be used in all these types of relay testing.

1.4.1 Static Relay Testing

Static relay testing refers to testing of relays using very slowly varying inputs to accurately locate pickup points and to perform repeatable measurements.

1.4.2 Dynamic Relay Testing

This form of testing refers to testing of relays using instantaneous steps/ramping of voltage and current inputs.

To closely simulate conditions during in-service operation, the voltages and currents are typically stepped from a nominal level to a pre-determined fault level. The MTS-5000 has the unique ability to perform dynamic testing under manual control.

1.4.3 Waveform Playback

Waveform playback refers to the regeneration of digitized voltage and current waveforms at high power levels. The waveform data may originate from any of the following sources:

a) Fault records from digital fault recorders
b) Digital simulation output e.g. from Electromagnetic Transient Program (EMTP)
c) Event reports from microprocessor-based relays
d) User-defined waveforms
e) Fault record libraries

Playback of these waveforms allow actual and hypothetical fault events to be re-created. Analysis of protective relay system performance can also be carried out as a result of these events. Real-time simulation and analysis of system response to transients and other abnormal conditions is further permitted.

For a more detailed discussion of this application, see the paper “Protective Relay Digital Fault Recording and Analysis” by Elmo Price, Conference of Protective Relay Engineers, Texas A&M University, April, 1998.

1.4.4 On-Panel Testing

This refers to testing of relays and relay systems while they’re installed on panels and equipment racks. This involves injecting voltages and currents directly to the panel to test complete system response, and to verify correct input/output wiring and phasing.

1.5 TECHNICAL SUPPORT

The design of this instrument reflects decades of experience in the electric power industry. Manta Test Systems recognizes, however, that there will be testing situations encountered which were not considered during product design, and we want it to be the product which best serves your specific needs.

Manta Test Systems encourages any user questions, problems or suggestions to be forwarded to us, via the representative through which the product was purchased, or directly to us via the fax numbers provided on the front cover or in the customer support area of our website.

1.6 SAFETY CONSIDERATIONS

This instrument can generate high levels of current and voltage. Incorrect usage may cause personal injury or damage to the instrument.

The user must be qualified to work safely in the intended application environment of this instrument. Non-adherence to the following minimum requirements constitutes misuse of the MTS-5000, and the manufacturer accepts no liability for damages arising from such misuse:

1) The instrument case must always be effectively grounded. The integrity of the power supply cord ground should always be verified before use.

2) All leads and connectors should be in good condition and rated for the appropriate voltage and current carrying requirements. Current outputs must be securely connected with minimum 14 gauge leads.

3) The outputs must not be connected to live outputs or live equipment.

4) All outputs must be turned off before making changes in connections.

5) Never exceed the following maximum ratings:

   (a) 300Vrms to ground on any input (power or control)
   (b) 300VAC/DC differential to external trigger inputs

1.7 LIMITED PRODUCT WARRANTIES

1.7.1 Hardware

Manta Test Systems warrants that its hardware products, and the hardware components of its products, shall be free from defects in materials and workmanship under normal use and service for a period of one year from the date such products are shipped from Manta Test Systems.

Provided that Manta Test Systems receives notice of any defects in materials or workmanship of its hardware products, or hardware components of its products, within such one-year period, Manta shall, at its option, either repair or replace the defective hardware product or hardware component, if proven to be defective.

1.7.2 Software & Firmware

Manta Test Systems warrants that its software products, and the software and firmware components of its products, shall not fail to execute their programming instructions under normal use and service, due to defects in materials and workmanship, if properly installed on intended hardware, for a period of one year from the date such products are shipped from Manta Test Systems.

Provided Manta Test Systems receives notice of such defects within the warranty period, it shall, at its option, either repair or replace the software or firmware media, if proven to be defective.

1.7.3 Separate Extended Warranty for Hardware Products

Aside from the standard warranty set forth above, Manta Test Systems offers a separate extended warranty plan for all hardware products (excluding cables, batteries and accessories) which may be purchased, and extends the standard warranty by one additional year.

The extended warranty is issued under the same terms, conditions and exclusions as the standard warranty set forth herein. Pricing is based upon the cost of the product, and the average cost of servicing and calibration. Refer to the Manta Test Systems price list available from your local representative, or Manta Test Systems, for extended warranty pricing for specific products. The extended warranty must be purchased and paid for within three months from the date the product is shipped from Manta Test Systems.

EXCLUSION OF OTHER WARRANTIES AND LIMITATION OF REMEDIES

1.7.4 Exclusion of other Warranties

THE FOREGOING WARRANTIES ARE EXCLUSIVE, AND ARE IN LIEU OF ANY AND ALL OTHER WARRANTIES (WHETHER WRITTEN, ORAL OR IMPLIED) INCLUDING, BUT NOT LIMITED TO, WARRANTY OF MERCHANTABILITY IN OTHER RESPECTS THAN AS SET FORTH ABOVE, AND WARRANTY OF FITNESS FOR A PARTICULAR PURPOSE.

Limitation of Liability and Remedies

IT IS UNDERSTOOD AND AGREED THAT MANTA TEST SYSTEMS' LIABILITY AND PURCHASER'S SOLE REMEDY, WHETHER IN CONTRACT, UNDER ANY WARRANTY, IN TORT (INCLUDING NEGLIGENCE), STRICT LIABILITY OR OTHERWISE, SHALL NOT EXCEED THE COST OF REPAIR OR REPLACEMENT OF MANTA TEST SYSTEMS' PRODUCTS, AS SET FORTH ABOVE, AND, UNDER NO CIRCUMSTANCES, SHALL MANTA TEST SYSTEMS BE LIABLE FOR ANY SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES, INCLUDING, BUT NOT LIMITED TO, PERSONAL INJURY, PROPERTY DAMAGE, DAMAGE TO OR LOSS OF EQUIPMENT, LOST PROFITS OR REVENUE, COSTS OF RENTING REPLACEMENTS, AND OTHER ADDITIONAL EXPENSES.

FURTHERMORE, IT IS UNDERSTOOD AND AGREED THAT MANTA TEST SYSTEMS SHALL NOT BE LIABLE FOR ANY DAMAGES, LOSSES OR EXPENSES AS A RESULT OF THE PURCHASER'S OR ANYONE ELSE'S:

I. NEGLIGENCE (WHETHER DEEMED ACTIVE OR PASSIVE),

II. MISUSE, ABUSE, OR MODIFICATION OF MANTA TEST SYSTEMS PRODUCTS,

III. USE OR OPERATION OF PRODUCTS NOT IN CONFORMITY WITH THE SPECIFICATIONS AND INSTRUCTIONS FURNISHED BY MANTA TEST SYSTEMS FOR ITS PRODUCTS,

IV. REPAIR OR MAINTENANCE OF MANTA TEST SYSTEMS' PRODUCTS BY PERSONS OR ENTITIES NOT AUTHORIZED BY MANTA TEST SYSTEMS, OR

V. DAMAGE TO, OR DESTRUCTION OF, PRODUCTS, DURING DELIVERY TO MANTA TEST SYSTEMS FOR ANY REASON.

Limitation of Warranty Regarding Software

Manta Test Systems does not warrant that the operation of the software, firmware or hardware shall be uninterrupted or error free.

1.7.5 Extension of Warranty

At the discretion of Manta Test Systems, the warranty may be extended for a product which has been returned for service shortly after its warranty period has expired.

SPECIFICATIONS

NOTE: All specifications are preliminary and are subject to change. All AC quantities are RMS values, except as otherwise noted. Power outputs are specified for nominal 120VAC/60Hz or 240VAC/50Hz power input, and 25°C ambient operating temperature. Derating applies for lower input power voltages and higher ambient temperatures.

For all current outputs, maximum obtainable current will vary inversely with load impedance. For extended operation at high power output levels, ensure adequate cooling (i.e. verify air intakes and exhaust ports are unrestricted).

2.1 INPUTS

Mains Supply
Single phase 110-130VAC @ 15A max (or 220-250VAC @10A max), factory set
Operating Range 100-130 VAC or 210-250 VAC, 47-63 Hz

Status Inputs
12 channels DC/AC voltage sensing, fully isolated
Channels 1-8 also monitor NC or NO wet/dry contact status

- Voltage range 0-300 VAC, ±300 VDC
- Threshold range 3-225 V (Channels 1-8) or 12 V fixed (Channels 9-12)
- Threshold resolution 1V (Channels 1-8)
- Input impedance >25 Kohm
- Programmable contact de-bounce delay, 0.0 - 999.9 msec, 0.1 msec resolution
- Any channel may be programmed for start or stop trigger function, or pulse time measurement
- Waveform capture mode accuracy ±1.0V <±28V signal, ±4.0V >± 28V signal
- Waveform capture mode response time 200 microseconds

Transducer Inputs
Measure low level outputs from AC transducers

- Maximum input level ±20 mA DC or ±10 VDC
- Measurement accuracy greater of 0.05% of full scale or 0.1% of reading

GPS Antenna Input
Active antenna, low gain, BNC connector

IRIG-B Input
AM or TTL level, BNC connector

2.2 OUTPUTS

Voltage

3 channels AC/DC voltage, overload, short circuit and over temperature protected

- 0-150 V rms phase-neutral, direct coupled
- Setting resolution 0.01 V, accuracy greater of 0.5% of setting or 0.03 V rms
- 100 VA AC per phase all phases loaded
- 200 VA AC single phase
- 50 W DC per phase
- 0-50% superimposed harmonic, 2nd to 50th harmonic
- Bandwidth (-3dB point) 3 kHz
- Noise & distortion at maximum power <1%

1 channel DC voltage

- 10-300 VDC
- 85W maximum power
- Surge current 2 A maximum
- Setting resolution 0.1V, accuracy greater of 1% of setting or 0.3V
- Noise & distortion at maximum power <1%

Current

3 channels AC/DC current, overload, open circuit and over temperature protected

- 0-30 A rms per channel phase-neutral, direct coupled
- 0-90 A rms single phase, three channels in parallel
- 0-5 A DC
- Accuracy greater of 0.5% of setting or 0.01 A rms for outputs >1% of range
- Setting resolution 0.001 A rms
- 600 VA maximum per channel
- 1800 VA single phase, three channels in parallel
- 0-5 ADC @ 60W per channel
- Bandwidth (-3 dB point) 3 kHz
- Noise & distortion at maximum power <1%
- 0-50% superimposed harmonic, 2nd to 50th harmonic

AC Outputs Frequency/Phase

- Frequency range DC, 1-3000 Hz
- Frequency resolution 0.001Hz
- Frequency accuracy 10 ppm (GPS synchronized) or 50 ppm (no GPS)
- Capable of generating 2 simultaneous frequencies
- Phase angle range 0-359.9°, resolution 0.1°
- Phase angle accuracy at 50/60 Hz 0.5°

Digital Outputs

4 channels fully isolated form A contacts

Maximum rating 0.4A resistive at 250 VDC, 5 Arms at 240 VAC

Available functions 52A, 52B, unblock, permissive

Programmable transition delay 6.0-9999.9 msec

IRIG-B Output

5V TTL level, BNC connector

2.3 METERING

Time Measurement

Fault timer plus four independent timer channels, measure time interval of fault duration or external start trigger to external stop trigger

0 -99999 sec or 0 - 99999 cycles, autoranging scale

Resolution: 0.1 ms

Accuracy: Greater of 0.2 ms or 0.05% of full scale

Sequence of Events Recording

Records state changes on all contact/voltage inputs, contact outputs, and output state changes.

Resolution 0.1 ms

2.4 COMPUTED VALUES

Impedance (positive sequence 3-phase, phase-phase, or phase-ground)

% slope for current differential relays (3 methods)

% harmonic current

V0, V1, V2

I0, I1, I2

2.5 STATE SEQUENCING

Available states include Off, Prefault, Fault 1-8, and Postfault

State duration infinite or 0-9999.9999 seconds

State change control infinite, fixed duration, or dynamic based on contact/ voltage input

Point-on-wave programmable from 0-359° for Prefault-Fault 1 transition

DC offset exponentially decaying, user controllable

2.6 RAMPING

Independent linear ramps programmable for each state

AC current each channel 0- ± 100,000 A/s
AC voltage each channel 0- ± 100,000 V/s
Phase angle each channel 0- ± 9,000.0°/s
Frequency each frequency source 0- ± 20 Hz/sec

2.7 WAVEFORM PLAYBACK

Programmable from IEEE C37.111 COMTRADE format files, 1991 or 1999 standard

Reproduces analog and digital waveforms
Channel assignment and scaling performed on front panel user interface
Maximum duration 1 minute from internal memory
Peak output levels: ±226 V for voltage channels
±42.4 A for current channels

2.8 PHASE/FREQUENCY SYNCHRONIZATION

Ability to synchronize phase, frequency and time of multiple instruments

Synchronize reference is internal clock (in master-slave mode), internal GPS receiver, or external IRIG-B signal (AM or TTL)
Internal receiver requires external active low gain antenna (provided)
IRIG-B output type TTL
Internal GPS accuracy ± 1 microsecond subject to selective availability
Synchronous start of Prefault or Fault 1 in non-waveform playback mode, or start of file in waveform playback mode
2 frequency sources for synchrocheck and islanding condition tests

2.9 DATA INTERFACES

All interfaces are fully isolated from AC/DC inputs and outputs, and digital inputs and outputs. Ground where present such as BNC ground is connected to frame ground.

RS-232 Serial Port
Standard 9 pin male DB-9 wired as DTE (Data Terminal Equipment)
Standard baud rates from 4800 to 115.2k baud

Ethernet Port
10Base-T/100Base-TX, complies with Ethernet IEEE 802.3 standards
Connector: Standard RJ45 connector
Speed: 10/100 Mb per second

USB Ports

Connector: Standard 4 pin USB series “A” receptacle
Data Format: Standard USB 1.0
Speed: Standard USB 1.0 (12 Mbps)

2.10 ADDITIONAL STANDARD FEATURES

- Numerical plus phasor graph display of all output parameters
- Independent direct adjustment of all output amplitudes and phase angles
- All output parameters may be adjusted off-line
- Adjustment by numeric keypad or rotary knob
- AC output amplitudes, phase angles and frequencies controllable in simultaneous multi-phase fashion
- Single-input control of phase-to-phase and 3-phase voltage, current and phase angles
- Single-action rotation of fault parameters to next phase
- Parameter display active and updated while under computer control
- Internal clock/calendar
- Audible feedback tone
- User programmable default output voltages, frequency, phase rotation, DC voltage, and communications settings
- Single-button auto configuration for synchronizing, current differential, instantaneous overcurrent, and impedance relay tests

2.11 ACCESSORIES INCLUDED

- Front panel cover
- Shipping/transport case with rollers and telescoping handle
- Users manual
- Outdoor use GPS antenna with 100 foot cable
- AC power cord
- RS-232 null modem cable
- Ethernet crossover cable
- MTS-2100 Graphical Monitoring Software

2.12 APPLICATION SOFTWARE

- MTS-2150 Monitoring and Control Software
- MTS-2170 Power System Model
- MTS-2800 MPower: Protection test management, execution, reporting, and analysis

2.13 PHYSICAL CHARACTERISTICS

- 9.9”W x 16.4”H x 15.6”D (25.1cm W x 41.7cm H x 39.5cm D)
- Weight: 49.2 lbs (22.5 kg) without front protective cover
- Display 6.5 inch diagonal TFT, VGA resolution (640 X 480 pixels)
- Operating temperature 32° to 122°F (0° to 50°C)
- Storage temperature -13° to 158°F (-25° to 70°C)

OPERATION SUMMARY

3.1 FRONT PANEL LAYOUT

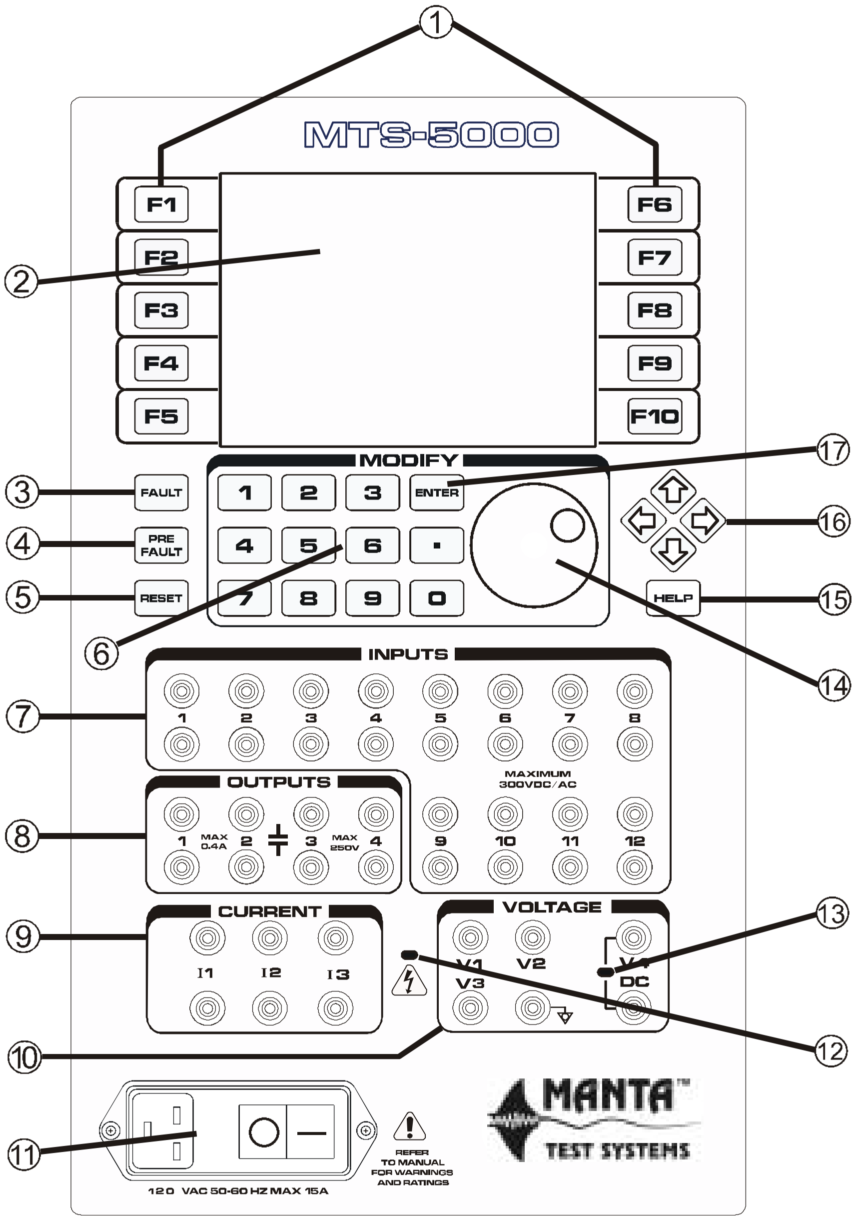


FIGURE 3.1 FRONT PANEL LAYOUT

1. FUNCTION BUTTONS

These ten pushbuttons are used to activate menu options that appear adjacent to the pushbuttons, on the display screen. The option labels change according to the active submenu.

2. DISPLAY SCREEN

All user information and menus appear here. The 640 X 480 color VGA screen is an active matrix format with high intensity backlighting for good visibility in high ambient light conditions.

3. FAULT BUTTON

This pushbutton activates the Fault 1 state. A momentary press (less than 300 msec) latches the AC current and voltage outputs into Timing fault mode, where they will remain until the user presses RESET, or an operation of an external device sensed by one of the INPUT channels causes a transition to another Fault state or Postfault state. Pressing and holding the button for more than 300 msec will activate the Pickup fault mode, where the outputs remain active only as long as the button is held, and will not be tripped off by any transitions sensed at the INPUT channels. Presence of an active Timing mode output is indicated on the display by a rapidly flashing red background and the text *Generating Fault* in the fault status box, at the bottom left edge of the display. See page 3-8. Presence of an active Pickup mode is indicated by a steady red background in the fault status box, plus the text *Generating Static Fault*. An active output from either fault type will also illuminate the AC Output Warning LED, see item 12 below.

4. PREFAULT BUTTON

This pushbutton activates the Prefault state, typically used when it is desired to establish a specific stable state prior to the appearance of a programmed Fault state. If pressed, any voltages and/or currents that have been programmed for Prefault state will appear at the outputs. Presence of an active Prefault state is indicated on the display by a slowly flashing red background and the text Generating Prefault in the fault status box, at the bottom left edge of the display. See page 3-8. A Prefault output will also illuminate the AC Output Warning LED, see item 12 below.

5. RESET BUTTON

This pushbutton aborts a dynamic test in progress. The first press will turn off all AC outputs, and freeze the readings of all output parameters plus elapsed time(s), the second press will reset the timer(s) and output readings. If the outputs have already been tripped off, and readings frozen, as the result of a trip signal sensed by the INPUTs during a dynamic fault, the first press will reset the timer(s) and output readings. It will also turn off Prefault state if pressed when that state is active.

6. MODIFY KEYPAD

This numeric keypad may be used to input the desired value of amplitude, phase, or frequency of any output source. It is also used for numeric input that may be required for advanced menu options.

7. STATUS INPUT TERMINALS

These terminals are used to monitor the operation or status of dry contacts (Channels 1-8 only) or AC/DC voltage signals (Channels 1-12) in the device(s) under test. Each input pair is high impedance, and galvanically isolated, allowing connection into live equipment. They are programmable for debounce time and function, and may also be used to capture analog waveform signals. See section 4.4 page 4-17 and 4.11 page 4-39 for details.

8. DIGITAL OUTPUT TERMINALS

These terminals provide programmable normally open or normally closed dry contact outputs, whose action can be slaved to the operation of the main AC outputs, or operated at specified times in a fault sequence. See section 4.6 page 4-25 for further details.

9. CURRENT OUTPUTS

The programmable AC/DC current outputs appear at these terminal. Current output channels may be paralleled to increase the amount of current available.

10. VOLTAGE OUTPUTS

The programmable AC/DC voltage outputs appear at these terminals. By default channels V1, V2, and V3 are AC. V4 is DC only.

11. MAINS POWER INLET/POWER SWITCH

The mains power cord is connected to the input socket on this component. The AC power switch incorporates a circuit breaker, so an overload will cause the switch to automatically trip to the off position. This eliminates the need for replaceable fuse protection.

12. AC OUTPUT WARNING LED

This red warning LED flashes whenever any current or voltage output channel is active or armed for GPS activation. Output wiring must never be handled when this LED is illuminated.

13. V4 WARNING LED

This warning LED is illuminated whenever voltage channel V4 is active. V4 will commonly be used to power DC operated devices under test. It will often be in continuous use independent of the operation of the AC output channels. Output wiring on channel V4 must never be handled when this LED is on.

14. MODIFY KNOB

This rotary knob is used both for continuous variation of output parameters, and for selection of menu items. Turning the knob slowly makes fine adjustments. Turning the knob at a moderate speed and high speed makes medium and coarse adjustments respectively.

15. HELP PUSHBUTTON

This button brings up Help text on the display with information relevant to the operation being executed at the time.

16. CURSOR CONTROL PUSHBUTTONS

These pushbuttons move the cursor to the location of a parameter the user wishes to change with the MODIFY controls.

17. ENTER PUSHBUTTON

This button is pushed to lock in a numeric setting which has been programmed by the MODIFY keypad or MODIFY knob.

3.2 AUXILIARY INPUT-OUTPUT PANEL

This panel is located under the latched cover on the right hand side of the instrument. Technical information on the GPS and data interfaces is available in Sections 6 GPS OPERATION and Section 5 DATA INTERFACES respectively.

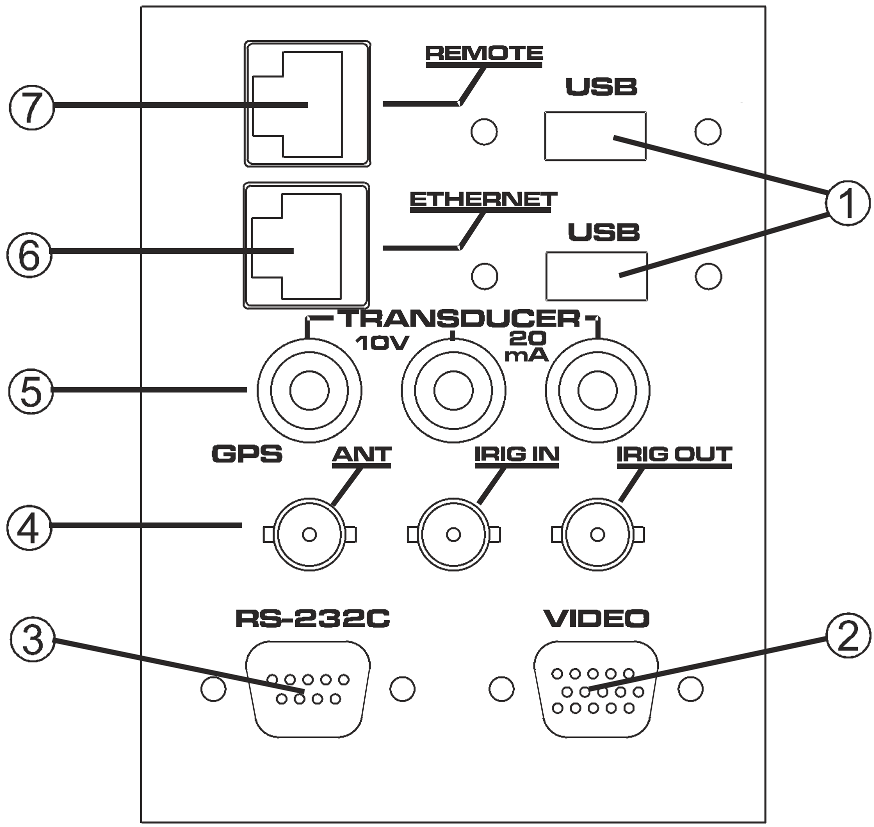


FIGURE 3.2 AUXILIARY I/O PANEL LAYOUT

1. USB CONNECTORS

Standard USB peripherals such as a USB data storage drive may be connected to these ports.

2. VIDEO CONNECTOR

A standard computer monitor may be connected to this output for a larger view of the display data. This can be useful in training situations where several people wish to simultaneously view the information.

3. RS-232 SERIAL PORT

This standard DTE connected serial port provides a communication facility for older computers which do not have Ethernet or USB capability.

4. GPS CONNECTORS

The ANT input is for connection of an external antenna for the on-board Global Positioning Satellite receiver. This facilitates precise timing of testing sequences at physically separate locations, such as end-to-end testing. The IRIG IN input allows connection to a standard IRIG-B encoded serial data stream, when a permanently installed GPS receiver signal is available at the testing location. The IRIG OUT output allows the MTS-5000 to be inserted into the middle of an existing TTL format IRIG-B loop without disabling downstream devices, or provide a synchronizing signal to a second MTS-5000 when doing very high current testing.

5. TRANSDUCER INPUTS

A transducer signal of up to ±10 VDC or ±20 mADC may be connected to these measurement inputs. This feature provides high accuracy measurement of the output of transducers, whose inputs are driven by the AC outputs of the MTS-5000.

6. ETHERNET CONNECTOR

This standard T10 network jack allows connection to an external computer. Typical applications are remote control of the MTS-5000, and high-speed data downloading for complex waveform generation.

7. REMOTE CONNECTOR

This T10 jack enables connection to a second MTS-5000, for master/slave remote control of one by the other. Typical applications are providing 6-current capability, and very high 3-phase or single-phase currents.

3.3 BASIC APPLICATIONS

3.3.1 Getting Started

- Connect mains power to mains power inlet.
- Turn on the Power switch.

Following the initialization sequence, the startup display shown below will appear.

Selection of any menu item is done by pressing the pushbutton immediately to the left or right of the menu item. To select Manual Test for example, the user would press the F1 button.

Throughout this manual, the screen displays will not include the graphic illustration of the accompanying pushbuttons, but will refer to them in the written description. Text which appears on the display will be in italics to distinguish it from text in the manual. In the example just given therefore, the instruction would read “Press *Manual Test* [F1]”

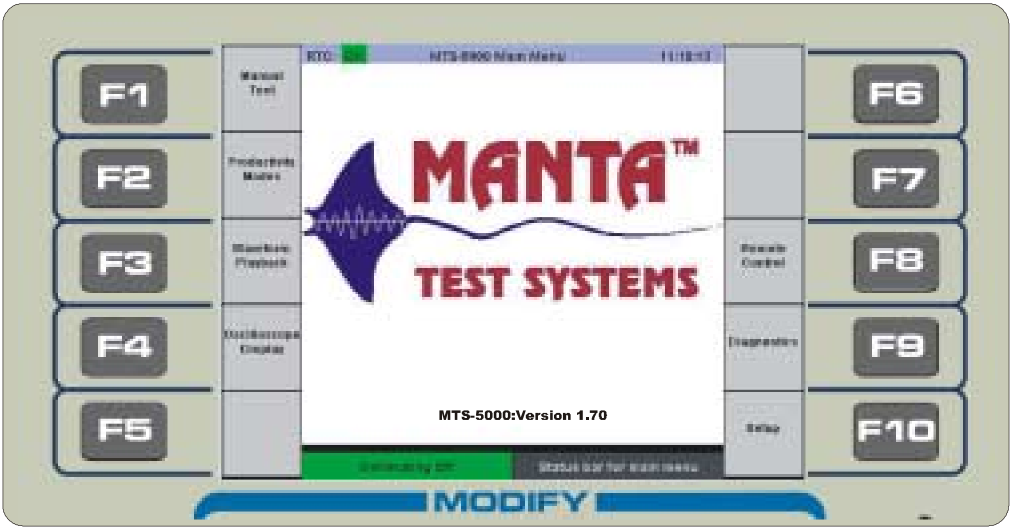


FIGURE 3.3 STARTUP DISPLAY

Note that the installed firmware version is displayed on the lower portion of the display. Certain operating features described in this manual may only be available with the same or later firmware version as listed on the reverse side of the first page of this manual.

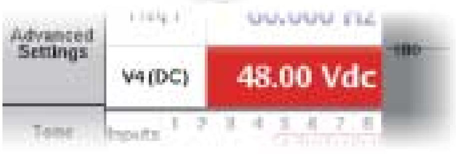
3.3.2 Safety & other precautions

3.3.2.1 SAFETY.

- The red AC Output Warning LED between the AC voltage and current output terminals indicates when any V1-V3 or I1-I3 voltage or current outputs are potentially live. It will flash to warn that the outputs are enabled.

- Whenever the Fault Status Box at the bottom left side of the display is flashing red, there are potentially live AC outputs.

- The DC voltage output may be live at all times. This is indicated by the red LED beside the V4 voltage output terminals, and red background of the DCV data.



- <u>NEVER</u> contact an exposed metallic part of the output circuit with bare hands when it is connected to any output of the test system!

UNDER NO CIRCUMSTANCES ATTEMPT TO ALTER OUTPUT WIRING WHEN ANY OF THE ABOVE LIVE OUTPUT INDICATORS ARE ACTIVE!

3.3.2.2 ISOLATION.

- All AC/DC outputs are isolated from the AC input supply and case/earth ground to a maximum of 300 VAC/DC. All voltage neutrals are connected together but are isolated from case/earth ground. All current terminal neutrals are common, but are isolated from case/earth ground.
- The Status Inputs and Outputs are isolated from each other, from the AC input supply, from the AC/DC outputs, and from the case/earth ground.

3.3.2.3 PROTECTION.

- The AC voltage outputs are protected from short circuits, overloads and over temperature.
- The AC current outputs are protected from open circuits, overloads and over temperature.

3.3.2.4 PRECAUTIONS.

- <u>DO NOT CHANGE CONNECTIONS WHILE OUTPUTS ARE ENERGIZED!</u> Turn outputs off before making current and voltage connection changes. Connections from the MTS-5000 to the device(s) under test should always be the last made and first disconnected.
- DO NOT OPEN/CLOSE A CURRENT CIRCUIT WHILE OUTPUTS ARE ENERGIZED!
- <u>NEVER</u> contact an exposed metallic part of the output circuit with bare hands when it is connected to any output of the test system!

3.3.3 Manual Test Menu

Most manual testing will be controlled from the Manual Test Menu. At the Startup Menu shown in Figure 3.3 above, press *Manual Test* [F1] and the Manual Test Menu as shown in Figure 3.4 below will appear.

NOTE: Only data displayed in blue may be directly modified. Dark grey signifies computed or automatically generated data, such as the Fault Timer reading in the figure below.

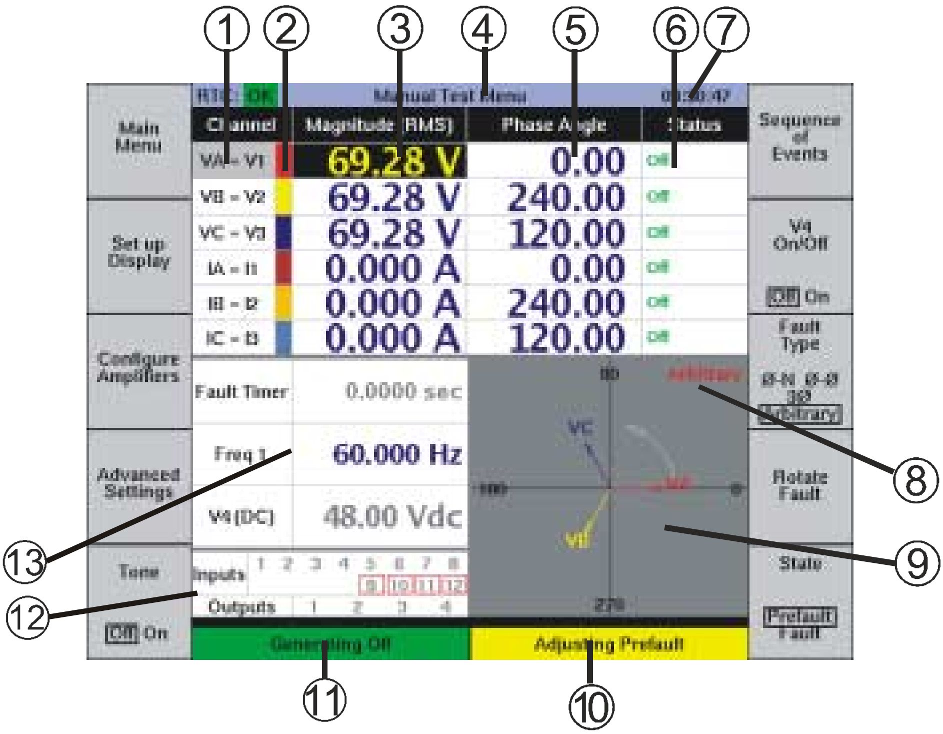


FIGURE 3.4 MANUAL TEST MENU

1. OUTPUT CHANNELS

Lists the number and type of output channels available in the present configuration. The length of this list will vary depending on configuration.

2. OUTPUT CHANNEL COLOR BAR

Identifies the color assigned to the corresponding channel on the Vector Display, see item 9.

3. OUTPUT CHANNEL VALUE

Lists the present setting of the output channel in volts or amps RMS.

4. MENU IDENTIFICATION BAR

Identifies the currently selected menu, in this example Manual Test Menu.

5. PHASE ANGLE VALUE

Lists the phase angle setting of the current or voltage on that channel.

6. STATUS DATA

Lists information on active status, and abnormal conditions such as over temperature, open circuit output, ramping, etc. Messages include *Off, On, Clip, Overload,* and others. See Appendix A for a full listing of messages.

7. TIME/GPS INFORMATION

This shows the current time in 24-hour or UTC format, depending on whether the system is selected for internal, or external (GPS) timing source respectively. The time will only be precise when the internal GPS receiver is locked on to a number of satellites, as indicated by the lock status information at the left edge of the Menu Identification Bar (*OK* or *NO*), or an external IRIG-B signal is supplied to the IRIG IN input. Refer to Section 6 GPS Operation for further information.

8. FAULT TYPE/PHASE

Lists the currently selected fault mode, as controlled by the *Fault Type* button [F8], and the fault phase, controlled by the *Rotate Fault* button [F9].

9. VECTOR DISPLAY

This display shows graphically the amplitude and phase relationships of all the active output AC voltage and current channels. The color of the individual vectors identifies the channel, as noted in item 2 above. Voltage vectors have an open-ended arrow, and current vectors have a closed-end arrow. By default the individual vectors are all identified by text labels as well. Phase rotation is indicated by the light grey curved arrow and the relative position of the phase vectors. In the illustration, the direction arrow is counterclockwise, so an observer on the x-axis/ 0-degree line would see the phasors go by in an A-B-C sequence. The display also contains in the upper right corner information about the fault mode selected for adjustment, including fault type and phase. For information on modifying colors in this display see section 3.8.1. Customize on page 3-43.

10. SELECTED FAULT BOX

This color-coded box identifies which of the available Prefault, Fault, or Postfault states is currently selected for modification. The color of the box changes according to the fault selection, which is controlled by the *State* button [F10].

11. FAULT STATUS BOX

This color-coded box identifies the output status of the selected fault, labelled in the Selected Fault Box and shown graphically in the Vector Display. A green background accompanied by the text *Generating Off* always means the fault is not enabled to the outputs, a red background always means that a fault output is enabled to the outputs and that hazardous voltages may therefore be present on them. Text identifying the fault mode currently active at the outputs will accompany the red background, for example *Generating Static Fault*, *Generating Fault 2*, etc.

12. DIGITAL INPUT/OUTPUT STATUS

This area provides information on the on/off status and configuration of all inputs and outputs.

13. DYNAMIC DISPLAY AREA

This area provides data from an extensive range of user selectable displays, which may be programmed in the Display Setup Menu, entered via the *Set Up Display* button [F2]. See Section 4.9 ADDITIONAL DISPLAY INFORMATION on page 4-33 for more information.

3.4 RELAY TESTING

3.4.1 Quickstart Procedure

The following procedure illustrates the minimum steps required to test basic types of protective relays.

ENSURE YOU ARE FAMILIAR WITH THE SAFETY PRECAUTIONS 3.3.2.1 TO 3.3.2.4 ON PAGES 3-8 AND 3-9 BEFORE PROCEEDING!

The factory default settings which appear on the instrument when selecting *Manual Test* [F1] from the Startup Display (Fig 3.3) are:

VA = V1 = 69.28V @ 0.0 Deg
VB = V2 = 69.28V @ 240.0 Deg
VC = V3 = 69.28V @ 120.0 Deg
IA = I1 = 0.0A @ 0.0 Deg
IB = I2 = 0.0A @ 240.0 Deg
IC = I3 = 0.0A @ 120.0 Deg
V4 = 48VDC
Fault Type = Arbitrary
Fault Phase = A
Frequency 1 = 60.00Hz
Channels 1-6 Status Inputs selected for tone operation, trip output mode.

Note that custom user default settings may be applied to the instrument, but this discussion assumes factory default settings including phase rotation A-B-C.

<u>Connections</u>:

- Connect the relay AC inputs to the appropriate voltage and current outputs.
- Connect the relay output contact(s) to the Status Input(s). By default Inputs 1-8 sense dry contact operation, and 9-12 sense voltage presence.

<u>Output Adjustments/Selections:</u>

- Press *State* [F10] to select Fault mode, as indicated by a box around *Fault*, and *Adjusting Fault* in the Selected Fault box.

- The ‘cursor’, indicated by a darker background color and yellow text as shown below, will be initially be located on the Magnitude cell of VA channel.

The position of the cursor indicates which parameter may be adjusted by the MODIFY controls. In the above example it would be the voltage amplitude of AC output V1.

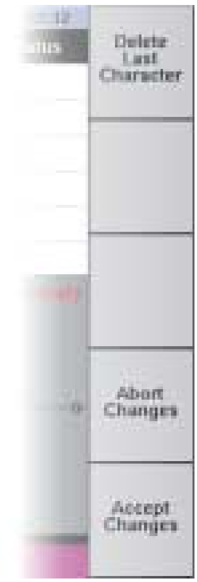
- Move the cursor to the desired parameter cell by pressing the cursor control keys,

  and use the MODIFY keypad and/or rotary knob controls to enter the desired setting. NOTE: only cells containing blue text may be selected via the cursor controls, and modified.

- For large or precise numeric parameter changes enter the desired value on the MODIFY keypad, and press ENTER when complete, or move to another cell via the Cursor Controls.

- For small or incremental changes to a numeric parameter, rotate the MODIFY knob; clockwise increases the value, counterclockwise decreases it. The rate of change is velocity sensitive, so rotating it faster makes larger changes, rotating it slower makes smaller changes.

- Note that if any key on the MODIFY keypad is pressed, new function keys appear until the keypad sequence is completed. These include *Delete Last Character* [F6], *Abort Changes* [F9], *Accept Changes* [F10], and when appropriate +/- [F3]. This adds the ability to modify an entry on the fly without having to re-enter the complete number, and enables the entry of negative numbers.



- Some cells permit the selection of a parameter rather than modifying a numeric quantity, for example selecting Frequency 1, 2 or DC as described in section 3.5.2 Frequency Control on page 3-20. In this case, rotate the MODIFY knob. A selection list drops down, and moving the knob scrolls through it. Leaving the cursor on the desired selection a few seconds, or pressing ENTER, locks it in.

- If it is desired to have an audible tone accompany sensing of relay operation via a status input, press *Tone On/Off* [F5].

<u>Energizing Outputs</u>

<u>DC Voltage</u>

If DC voltage is required to power a relay being tested, the V4 voltage output may be switched on independent of the AC channels status by pressing *V4 On/Off* [F7]. The red warning LED between the V4 output terminals will illuminate whenever the output is live, and the background of the DCV data cell will turn red.

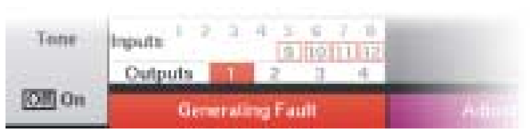
By default the DC voltage level is locked to the value specified in the Setup Menu accessible by pressing *Setup* [F10] in the Startup display, see Fig 3.3. Control of the DC voltage level may be unlocked at any time however without altering the default value, by pressing *Configure Amplifiers* [F3] in the Manual Test Menu, then *Allow V4 Adjustment* [F6] in the Amplifier Adjustment Menu. The *V4(DC)* amplitude figures in the Manual Test Menu will change from gray to blue, and may be adjusted with the Modify controls, as described in the previous section.

<u>AC Voltage/Current</u>

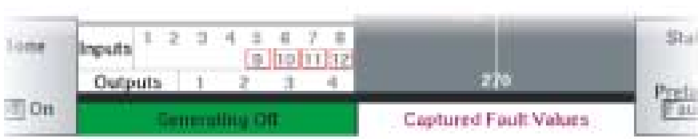
Once all parameters have been set, press the red FAULT button to initiate the test. The programmed fault levels will be applied to the outputs, and the timer is started. If the FAULT button is just pressed momentarily (<300 mSec) the outputs will latch on and stay energized until a trip signal is sensed on a Status Input, or the RESET button is pushed. This state is referred to as Timing mode. See Section 4.2.2 TIMING Fault Mode on page 4-7 for more details.

If the FAULT button is held on, the outputs will remain energized until the button is released, and any trip signals on the Input(s) will have no effect on the AC outputs. This state is referred to as Pickup mode. See Section 4.2.1 PICKUP Fault Mode on page 4-7 for more details.

When the AC outputs are energized, the red AC Output Warning LED will flash, the text in the Fault Status Box will read *Generating Fault*, and the background of the box will flash red. If Pickup mode is engaged as described in the previous paragraph, the Fault Status Box will read *Generating Static Fault* and its background will turn red.



If Timing mode was engaged, when the relay under test operates the status input(s) will be activated, the trip tone will sound briefly, the outputs will switch off, and the timing, voltage, phase, and frequency readings will be frozen. The label below the vector display will state *Captured Fault Values*. The Fault Status box on the display will turn green, display *Generating Off*, and the AC Output Warning LED will turn off.



To restore the instrument to (de-energized) Fault state and clear the frozen readings, press RESET.

3.5 ADDITIONAL FEATURES

3.5.1 Paralleling Currents

Some applications will require more current than can be produced by a single AC current channel. To increase the amount of current available by paralleling channels, it is necessary to set the amplitude, phase angle and frequency of each current to be identical to that of the others in its group. The MTS-5000 can automatically make these adjustments so that only a single amplitude, phase angle, and frequency need to be specified for all paralleled channels. To enter the appropriate menu, press *Configure Amplifiers* [F3] in the Manual Test Menu (Fig 3-4). This will bring up the Amplifier Configuration Menu.

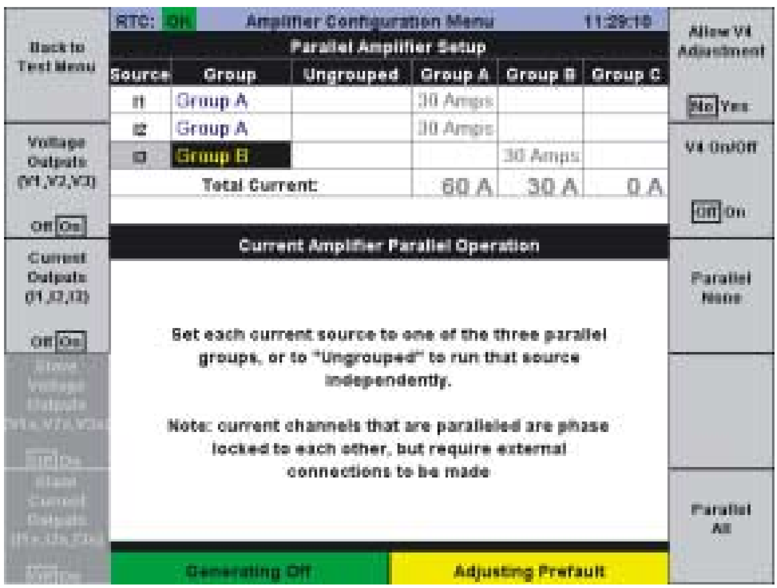


FIGURE 3.5 AMPLIFIER CONFIGURATION MENU

Any combination of parallel channels is possible, for example the configuration shown above could be used to increase the current available for a current differential relay test, see Figure 3.7 on page 3-18.

A dedicated selection *Parallel All* [F10], is available to quickly parallel all 3 channels. On returning to the Manual Test Menu, there will be a single row of cells for adjusting the current of all three channels simultaneously, see Figure 3.8 on page 3-19. To restore individual channel control, press *Parallel None* [F8] in the Amplifier Configuration Menu.

Although the system automatically makes the individual amplitude, phase, and frequency adjustments to each current channel, the outputs of all three channels must physically be paralleled externally, as shown below.

NOTE: ONCE A CURRENT SOURCE IS ASSIGNED TO A PARALLEL GROUP, IT MUST BE CONNECTED IN PARALLEL WITH THE OTHERS OF ITS GROUP OR SHORT CIRCUITED. THE TOTAL CURRENT SETTING APPLIED TO A PARALLEL GROUP IS DIVIDED EQUALLY AMONG THE SOURCES IN THE GROUP, AND ANY SOURCE NOT CONNECTED WILL OVERLOAD (CLIP).

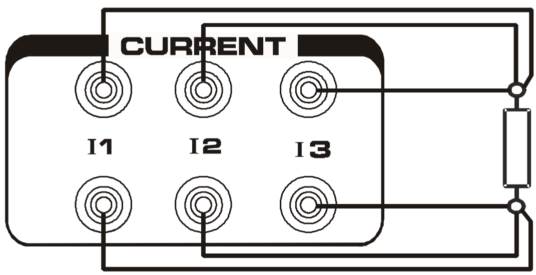


FIGURE 3.6 SINGLE PHASE HIGH CURRENT PARALLEL CONNECTIONS

This connection is used when the highest possible current is required, for example when testing instantaneous overcurrent elements. Note that the compliance voltage available is equal to that of a single current channel only, so if the V=IR voltage drop across the relay at the desired current level exceeds the compliance voltage clipping will occur, and an alarm warning *Clip* will appear in the Status cell of the affected channels.

To maximize compliance voltage available at the relay terminals, i.e. to maximize the current available without clipping, use the largest gauge wiring possible and ensure all connections from the wiring to the relay inputs are firmly tightened.

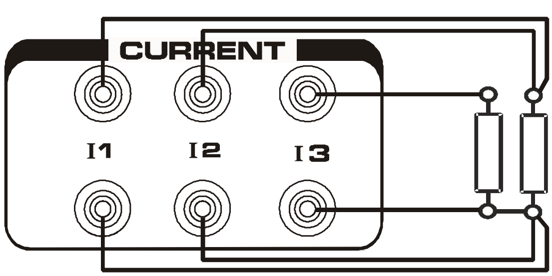


FIGURE 3.7 TWO CHANNEL MEDIUM CURRENT PARALLEL CONNECTIONS

In any of the possible parallel current connection combinations, the amplitude, phase angle and frequency within each group will automatically be matched. Press *Manual Test Menu* [F1] to return to the Manual Test display. There will be a single row of information presented about each group as shown below.

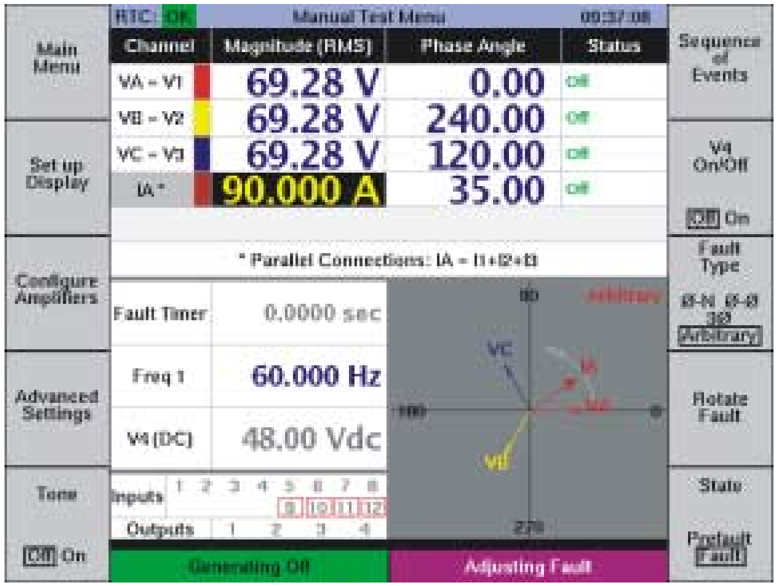


FIGURE 3.8 PARALLELED CURRENT MANUAL TEST DISPLAY

The current amplitude setting will equal the sum of the currents available from all the paralleled sources in each group, and the listing in the source column will show all the sources connected in that group. Any amplitude setting applied with the MODIFY controls will automatically be divided among the sources so the total current available equals the setting. Any phase angle setting applied with the MODIFY controls will be applied to all sources in the group.

3.5.2 Frequency Control

By default all AC output channels are synchronized to the same frequency, whose value is shown in the *Freq 1* cell in the Dynamic Display area, see Fig 3-4 on page 3-10. To change the frequency, move the cursor to the *Freq 1* cell, and enter the desired value with the Modify controls.

To display and control two different frequencies and/or DC, enable the Frequency column on the manual test display by pressing *Advanced Settings* [F4], then the *Show Frequency Column* button [F10] on the Advanced Settings Menu, see Fig 4.20. For synchrocheck relay testing there is a convenient automatic setup mode, refer to section 3.6.2 on page 3-27.

FIGURE 3.9 FREQUENCY CONTROL

Once the frequency column is turned on, move the cursor to the smaller left hand box in the *Frequency(Hz)* column of the channel whose frequency you wish to set differently than the others, and turn the Modify Knob to select Frequency 2 or DC. In the screen above Va has been set to Frequency 2, and Ic is being selected for DC. Moving the cursor to the larger right hand box under the *Frequency (Hz)* column will now allow all channels set to the same frequency number to be adjusted simultaneously by the MODIFY controls.

3.5.3 Multiple Frequencies

The most common application for two frequencies is for testing synchrocheck relays, so a dedicated Productivity Mode is provided to configure the system for this application. See Section 3.6.2 on page 3-27 for further information.

3.5.4 DC Current

The most common application for DC current is to verify the operation of current-activated trip indicators found in some older electromechanical relays. Any current source can be allocated to this function. In Figure 3.9 on the previous page, Ic is being selected for DC operation, as described in the underlying text.

3.5.5 Increasing Voltage Output

The standard 0-150 VAC range of the voltage output channels is sufficient for most AC testing, which typically lies in the range of 0-120 VAC. For applications requiring three phase voltages up to 260 VAC, it is only necessary to connect the device under test phase-to-phase rather than phase-to-neutral. By default, the voltages in Prefault and Fault mode are in a balanced three phase configuration, 120 degrees apart and 69 VAC phase to neutral. By setting any two adjacent phases to an equal amplitude, the phase to phase voltage resulting will be 1.732 (square root of 3) times the phase to neutral voltage.

For single phase voltage up to 300 VAC, connect the load across the ‘hot’ outputs of two channels. Set the phase angle of the second channel to 180 degrees different from the other channel to which it is connected. The total voltage will then be the arithmetic sum of the amplitudes set on each channel.

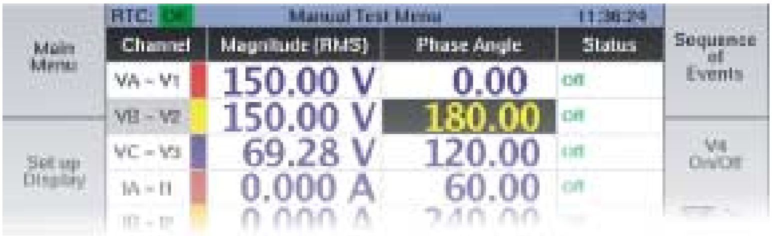


FIGURE 3.10 HIGH VOLTAGE CONFIGURATION

In the configuration shown above, the maximum voltage available would be 300 VAC. The figure on the next page shows how the output connections are made.

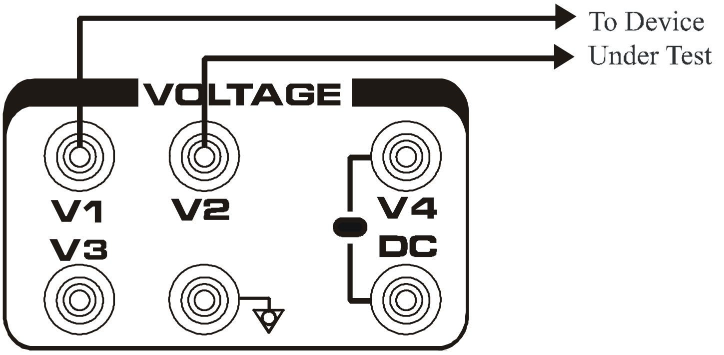


FIGURE 3.11 HIGH VOLTAGE OUTPUT CONNECTIONS

CAUTION!! USE EXTREME CARE IN HIGH VOLTAGE TESTING
NEVER CONTACT ENERGIZED WIRING
DISABLE OUTPUTS BEFORE CONNECTING WIRING
INATTENTION CAN KILL!!

3.6 PRODUCTIVITY MODES

Productivity Modes are special built-in routines that automatically configure the MTS-5000 for the unique requirements of a number of common relay testing applications. Revised displays presenting only the AC output parameters required for the test, connection wiring diagrams, special vector displays, automatic computing of of settings and results, and pushbutton selection of multiple test modes, can dramatically simplify and speed up performance of these tests.

To access Productivity Modes from the Manual Test Menu, press *Advanced Settings* [F4] in the Manual Test Menu, then *Select Productivity Mode* [F4] in the Advanced Settings Menu. Productivity Modes are also available directly from the Main Menu via the *Productivity Modes* button [F2], see Fig 3.3 on page 3-7.

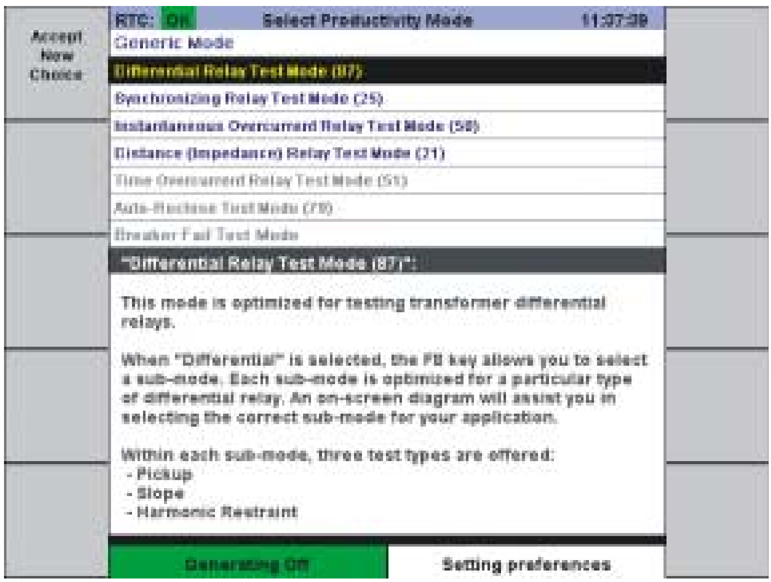


FIGURE 3.12 SELECT PRODUCTIVITY MODE MENU

3.6.1 Differential Relay Testing

The Productivity Mode selection for differential relay testing contains both generic and device-specific options. To access it, go to the Select Productivity Mode Menu as described above.

Move the cursor to the *Differential Relay Test Mode (87)* option with the MODIFY knob and press *Accept New Choice* [F1]. This returns you to the Manual Test Menu, which will now be reconfigured for differential relay testing, see Figure 3.13 on the following page.

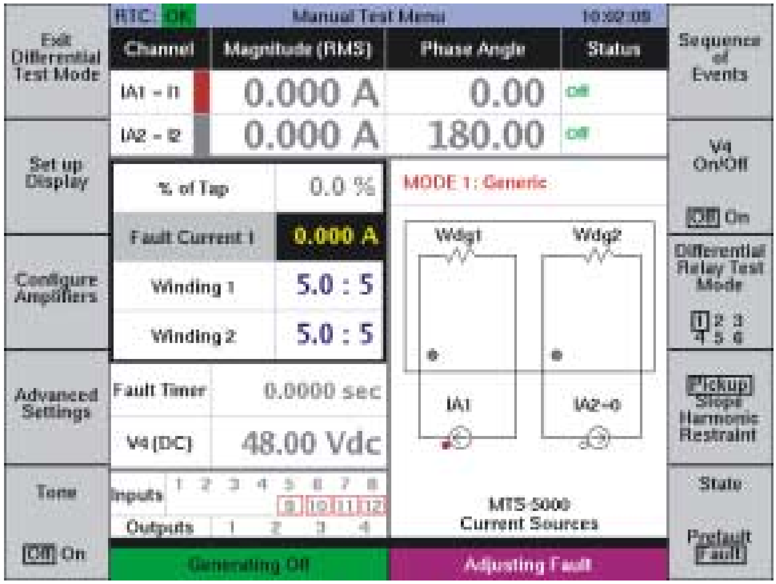


FIGURE 3.13 DIFFERENTIAL RELAY TEST CONFIGURATION

The default screen is for Generic differential test mode, but a number of additional specific test modes are available via the *Differential Relay Test Mode* button [F8]. At the time of this edition, selections are available for the Basler B87T (*2*), GE BDD (*3,4*), and ABB HU (*5,6*) differential relays. Additional information about the test modes is available at any time by pressing the HELP key, see section 3.7 for details.

There are also dedicated screens for the three standard test sequences, controlled by button F9, namely *Pickup*, *Slope*, and *Harmonic Restraint*. A dedicated button *Exit Differential Test Mode* [F1] clears the special setup mode and returns the standard Manual Test Menu.

3.6.1.1 Pickup Mode

Refer to Figure 3.13 above. Adjust the *Winding 1* and *Winding 2* ratios to match the ratio matching tap settings on the relay being tested. Then select the *Fault Current 1* cell, press FAULT, and increase the current with the MODIFY controls until the relay operates. Pickup is often specified in % of tap value, so this percentage value is automatically calculated from the current and winding settings.

The BDD and HU specific screens have provision for winding 1 > winding 2 and winding 2 > winding 1 tests, as well as the actual relay terminal numbers on the diagram. Current should be injected to the winding with the higher setting to ensure the correct test results.

3.6.1.2 Slope

Press F9 to select *Slope* mode as shown.

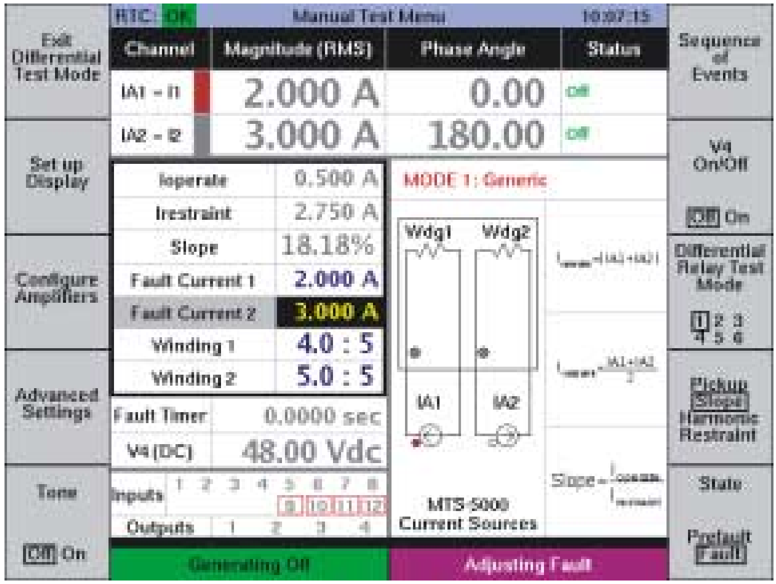


FIGURE 3.14 DIFFERENTIAL RELAY SLOPE TEST MODE

The Winding 1 and Winding 2 current taps set in *Pickup* mode will be carried over, and the phase angle relationship of the two currents automatically set to 180°, as required to simulate an external fault with current sources sharing a common neutral. Note that an additional +/-30° may be necessary if the transformer is a Wye-Delta configuration. Typically one current will be fixed to a value recommended by the manufacturer, and the second current varied until the relay operates. The % slope will be automatically calculated based on the Ioperate and Irestraint values, and displayed in the Dynamic Display Area.

The BDD and HU specific screens selected by the F8 button have provision for winding 1 > winding 2 and winding 2 > winding 1 tests, as well as the actual relay terminal numbers on the diagram. Current should be injected to the winding with the higher setting to ensure the correct test results. The formula for calculating slope changes depending on the mode selected, but the right formula is automatically selected and displayed, and the calculated result shown in the Dynamic Display Area.

As in the previous test, additional information is available at any time by pressing the HELP key.

3.6.1.3 Harmonic restraint

Press F9 to select *Harmonic Restraint* mode as shown.

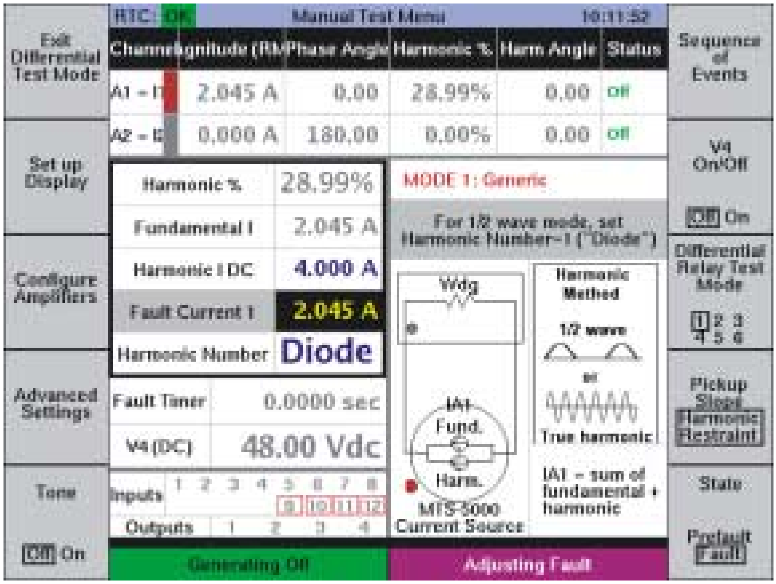


FIGURE 3.15 DIFFERENTIAL RELAY HARMONIC RESTRAINT TEST MODE

There are two methods offered to perform this test. The classical 'Diode' method originally employed with electromechanical relays uses half wave rectified DC current via a series diode, combined with pure AC current, to produce current of variable 2nd harmonic content according to a specific formula. The *Diode* selection in the *Harmonic Number* cell produces a current waveform identical to this approach.

The other method uses combined fundamental plus 2nd (or 5th) harmonic frequency to simulate the distorted inrush current that the harmonic restraint feature is designed to recognize. A different formula is used to calculate % harmonic content. The desired harmonic number can be selected in the *Harmonic Number* cell.

For the Diode method, cursor to *Harmonic I DC* to set the required level, then move to *Fault Current 1* and alter the level to cause relay operation or blocking, as specified by the manufacturer's test procedure. For BDD and HU relays using the Diode method set the harmonic current to 0.8X tap setting; press the HELP key for further information.

As in the other differential test modes, the BDD and HU screens offer additional options and terminal connection information.

3.6.2 Synchronizing Relay Testing

Select *Synchronizing Relay Test Mode (25)* on the Select Productivity Mode Menu; from Manual Test Menu press *Advanced Settings* [F4], then *Select Productivity Mode* [F4], see Figure 3.12 on page 3-23. Specific help is available via the HELP key.

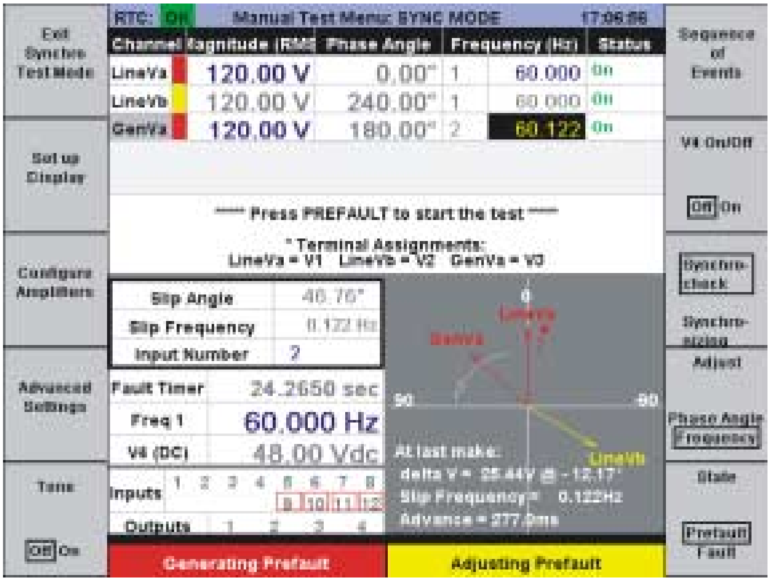
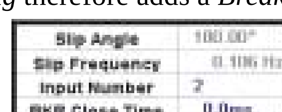


FIGURE 3.16 SYNCHROCHECK RELAY TEST MODE

Note that two types of relays may be selected in this mode via the F8 button, namely *Synchro-check* relays and *Synchronizing* relays. The former are typically used to supervise reclosure operations where different static phase angles or slowly changing parameters between two power systems may be present, the latter to supervise or automatically control the closure of a generator breaker, where variable voltage, frequency, and/or phase angles are usually present. Since generator breakers are normally closed with the generator frequency slightly exceeding system frequency (to ensure outgoing power flow) it is important that the breaker operate time is considered to ensure that all parameters will still be within acceptable limits when the breaker closes. Selecting *Synchronizing* therefore adds a *Breaker Close Time* input cell.



Once a breaker close time has been specified, it will be included in the *Advance* time data captured in the Vector Display, see Fig 3.16 above.

The vectors in the Vector Display function as a synchroscope. The *LineVA* and *LineVB* vectors remain fixed, and the *GenVA* rotates clockwise or counterclockwise depending on the relative frequency and/or phase angle of the two vectors. The slip angle and slip frequency data in the Dynamic Display Area are updated continuously.

Each time the contact of the relay under test operates, there will be a ‘lollipop’ marker left on the display showing where closure of the relay contact (or breaker in *Synchronizing* mode) occurred, and specific data about the voltage difference, slip frequency, and advance time in milliseconds at that time are recorded on the bottom of the Vector Display. Advance time is the time that it would take from the relay contact closure (or breaker closure in *Synchronizing* mode) to reach 0 degrees phase difference at the present slip frequency rate. In other words, for a given closure phase angle, the higher the frequency slip rate, the closer the (advance) time is to 0 degrees.

Synchro-check tests are all conducted in Prefault state. Generator synchronizing relays however in some cases monitor conditions following output contact closure to ensure that the breaker closed successfully and that generator parameters are now locked to line parameters. When *Synchronizing* is selected therefore, the test is initiated in Prefault mode but following contact closure and the specified breaker close time delay, the system automatically switches to Fault state and locks the Generator parameters to the Line VA parameters, simulating successful synchronizing. See Section 4.1 page 4-1 for more information on fault states.

For either test, connect V1 (and V2 if required) to the bus voltage inputs of the relay under test, and V3 to the generator voltage inputs of the relay. Connect the relay close contact to Status Input 2 which is configured to prevent the AC outputs tripping off when the relay operates.

3.6.2.1 Phase Angle Limit Check

Ensure *Synchro-check* mode [F8] is selected. Select *Phase Angle* on the *Adjust* key [F9]. Verify that LineVA and GenVA voltage levels are identical. Do not change the default frequency. All frequencies are set to F1, and the cursor will be located on the *Phase Angle* cell of *GenVA*. Set it to 45°, which will place the GenVA vector leading the LineVA reference vector by 45°, outside the operation setpoint of most synchrocheck relays. Press PREFAULT and decrease the phase angle slowly (rotate the MODIFY knob counterclockwise) until the relay operates. The message at the bottom of the display will record *Delta V* in terms of xV @ y°, see Figure 3.16 on the previous page. Record the phase angle value and continue to rotate the MODIFY knob until the relay drops out. The captured phase angle value at this point is the second of the two phase angle limit points.

3.6.2.2 Voltage Limit Check

Set the GenVA phase angle to 0° with the MODIFY controls, then select the *GenVA Magnitude(RMS)* cell with the cursor keys. Raise the voltage with the MODIFY knob until the relay drops out, and record the captured *Delta V* voltage. Lower the voltage until the relay picks up again, and continue lowering it until it drops out a second time.The captured voltage at this point is the second of the 2 voltage limits.

3.6.2.3 Slip Frequency Limit Check

Adjust the *GenVA* voltage back to the same value as the *LineVA* voltage with the MODIFY controls, then select *Frequency* on the *Adjust* button [F8]. The cursor will move to the *Frequency (Hz)* cell of *GenVA* which is now set to F2. Raise the frequency with the MODIFY knob so the *Slip Frequency* reading in the Dynamic Display Area remains less than the setting of the relay, and verify that as the rotating GenVA vector passes through 0° and within the phase angle limits observed above, the relay contact operates. Increase the frequency for a *Slip Frequency* reading of just over the expected value and verify that the relay no longer operates within the nominal phase angle limits around 0°. Decreasing the frequency to slightly below the expected slip operate point while within the phase angle limits should cause the relay to operate again, confirming the operate point value.

3.6.2.4 Breaker Advance Time Check

As noted above, in *Synchronizing* mode the MTS5000 can simulate a generator successfully synchronizing to a power system. A synchronizing relay must be able to accommodate the fixed close time delay of a generator breaker across a significant range of frequency slip rates to ensure breaker closure at or close to 0 degrees phase difference. If the relay is functioning correctly, and the *Breaker Close Time* value in *Synchronizing* mode is set equal to the relay's breaker advance time setting, the captured Delta V results in the Vector Display should always be close to 0 degrees, and never exceed the phase angle limits determined above.

To measure the relay's advance time setting directly, simply set the *Breaker Close Time* to zero in *Synchronizing* mode. Initiate the test by pressing Prefault with a frequency slip rate within the operate range, and the captured *Advance* reading, i.e. the time to reach 0 degrees, should equal the relay setting.

To restore the Manual Test Menu display to normal after completing the synchrocheck tests, press *Exit Synchro Test Mode* [F1].

3.6.3 Instantaneous Overcurrent Relay Test Mode

Select *Instantaneous Overcurrent Relay Test Mode (50)* on the Select Productivity Mode Menu; from Manual Test Menu press *Advanced Settings* [F4], then *Select Productivity Mode* [F4], see Figure 3.12 on page 3-23. Press HELP for information.

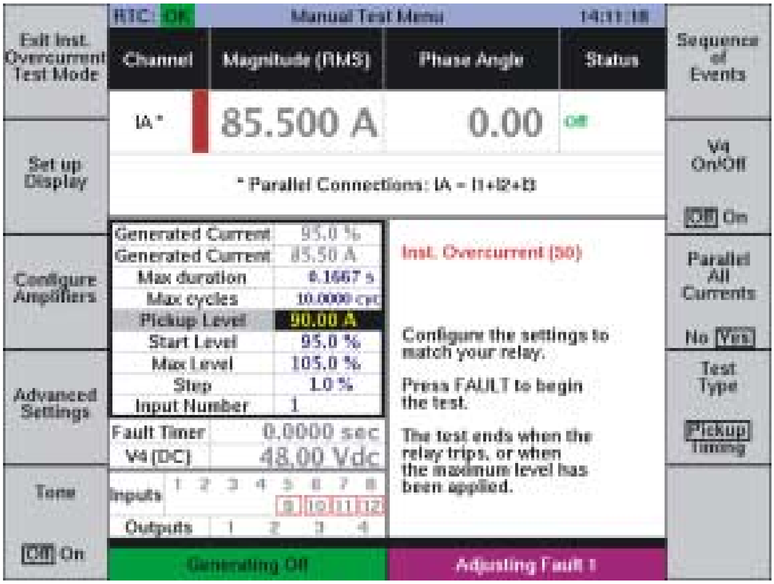


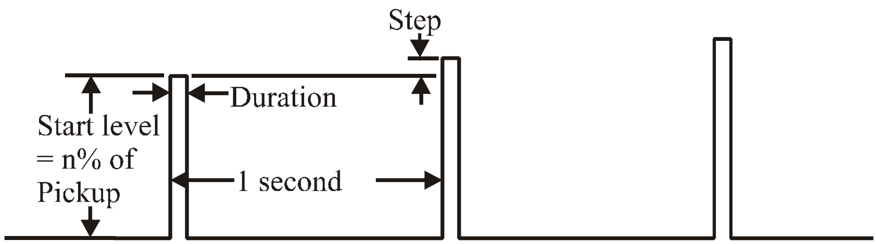
FIGURE 3.17 OVERCURRENT RELAY TEST MODE

The Instantaneous Overcurrent selection can generate short pulses of high current which ramp through a specified range to quickly identify the operate point and operate time of the instantaneous element. Since these elements usually operate at high levels, on-screen provision is made for paralleling all current sources, *Parallel All Currents* [F8].

The default settings of 10 cycles/0.1677 seconds per current pulse, a 95% to 105% of nominal setting span of current output, and a 1% step increase of current after each 1-second delay interval, are suitable for most applications but all can be modified in their respective cells of the Dynamic Display area. Duration should exceed the expected pickup time, and the *Start Level/Max Level* values should be less than and more than respectively the expected pickup level.

Select the *Pickup Level* cell and enter the expected operate value for the relay being tested. If the value is more than a single current source can provide, the system will not accept the value until *Parallel All Currents* [F8] is pressed. Note that if the currents are paralleled in this manner, it is important to ensure that all current sources are externally paralleled, or unused sources are short circuited. See Section 3.5.1 on page 3-17 for more information.

Press FAULT, and the current will be applied in a series of brief increasing pulses until



the relay operates, the specified Maximum level is reached, or the RESET button is pushed. If relay operation is sensed during the sequence, the current level and timing values, and error, are captured as shown below and the sequence stops.

FIGURE 3.18 FROZEN OVERCURRENT TEST RESULTS

If the relay being tested is electromechanical, the operate time of the instantaneous element is usually slower just at the threshold of operation than it is for a value 5-10% above that level. If it is desired to further check timing, press *Test Type* [F9] to select *Timing* mode. This automatically configures a single current pulse set 10% above the nominal operate value. Press FAULT to initiate the test, and once again the captured value will be displayed on the screen as in Figure 3.18 above. Remember to reset the target before each new test, as the effort to trip the target has some influence on the timing.

3.6.4 Distance (Impedance) Relay Test Mode

Select *Distance (Impedance) Relay Test Mode (21)* on the Select Productivity Mode Menu; from Manual Test Menu press *Advanced Settings* [F4], then *Select Productivity Mode* [F4], see Figure 3.12 on page 3-23.

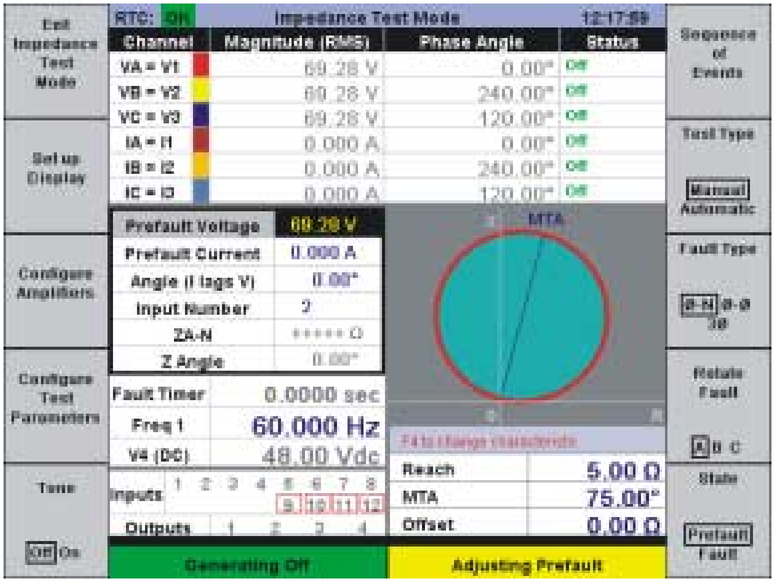


FIGURE 3.19 IMPEDANCE RELAY TEST MODE

As indicated by the *Test Type* button [F7] there are both manual and automatic test modes available for impedance relays. There is also a *Fault Type* button [F8] to select one of the three standard fault modes, depending on the type of relay to be tested.

By default the system is configured for Generic test mode, but additional specific test modes for popular electromechanical and microprocessor based relays are also available. This description of the testing process will assume a **Φ-Φ** KD-4 electromechanical relay is to be tested. Reference will be made at times to other options, and the HELP key will provide additional information as appropriate. Test connections vary depending on relay type, but all use input #2 to sense operation.

3.6.4.1 Manual Test

Press *Fault Type* [F8] to select **Φ-Φ** test mode. Next press *Configure Test Parameters* [F4] to bring up the Configure Test Parameters menu, then *Settings Format* [F3] to bring up the KD-4 option (item *3*) as shown on the next page. This option will accommodate KD-4, KD-10, and KD-11 type relays.

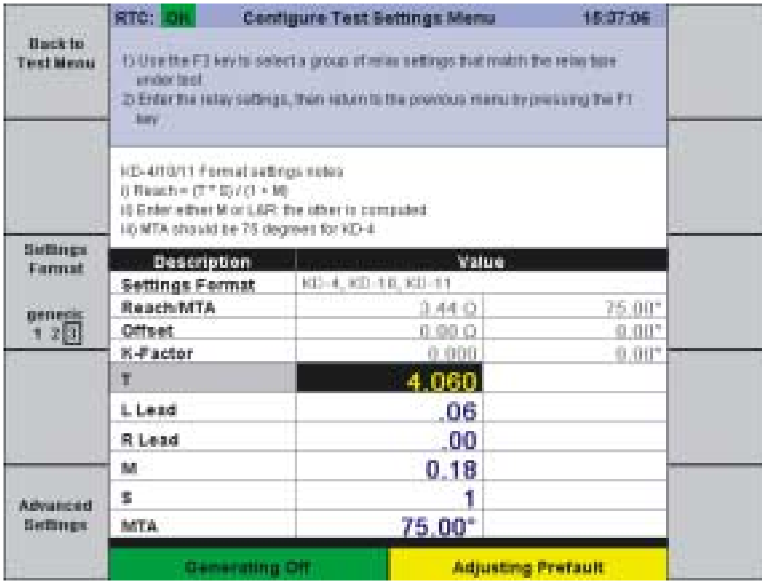


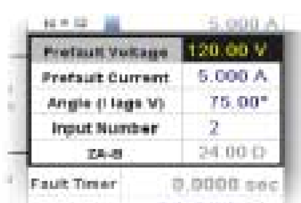
FIGURE 3.20 CONFIGURE TEST SETTINGS MENU

As indicated in the *settings notes* area of the menu, it is only required to enter tap setting data taken directly from the relay under test, and the resulting impedance setting is then calculated automatically. The default values are valid KD-4 tap settings, but ensure the actual in-service settings are entered.

Settings Format [F3] items *1* and *2* generate factory default settings for SELx21 and SEL3xx relay families respectively. If testing these devices, you must also ensure the actual in-service settings are entered, as directed by the *settings notes*.

When finished, press *Back to Test Menu* [F1]. The computed reach, MTA and offset values will appear beneath the impedance diagram, see Fig. 3-19 on the previous page.

Press *State* [F10] to select *Fault* state. In the Three Phase Parameters box (see at left),



set the current to a safe continuous value (typically 5 amps), the phase angle to the expected Maximum Torque Angle (MTA), and return the cursor to the *Fault Voltage* cell. Press FAULT, and lower the voltage with the MODIFY controls until the relay operates. This will be the reach at the MTA. The computed reach *ZA-B* in the bottom of the box should be close to the theoretical reach shown below the impedance circle display. The three phase current and voltage vectors are automatically set up for this simple one-control-input test method. See Section 4.3 page 4-9 for a full explanation of this three phase control process.

The most effective way to determine the operate point is to make a rapid initial adjustment of the voltage with the MODIFY knob to bring the computed reach within about 10% of the expected operate point, and then more slowly lower the voltage until a relay trip is detected, freezing the readings. To verify the frozen reading, press and hold FAULT while slowly passing back and forth through the operating point. See section 4.2 Fault Modes: Pickup & Timing, page 4-7, for a description of this process. Note that the border of the impedance circle on the display changes from red to green as the relay enters the operate area.

To continue the reach at MTA tests, select the next phase via *Rotate Fault* [F9] and repeat the above process. Repeat this step for the third phase.

To verify the reach at points other than the MTA, set *Angle (I lags V)* to the desired value and repeat the above steps.

Note that it is possible to achieve the same test results by setting the voltage at a reduced level and increasing the current until the relay trips. The drawback to this approach is that it may require very high currents, especially for short reach settings and phase angles farther away from the MTA, which increases the risk of overheating the relay. The variable voltage method is inherently a safer process.

To check the MTA, lower the voltage 5-10% below the trip point, move the cursor to the *Angle (I lags V)* cell, and while pressing FAULT, modify the phase angle down and then up with the MODIFY knob to the points where the relay drops out. The MTA is the average of these two points. Repeat for the remaining two phases via selections on the *Rotate Fault* button [F8].

3.6.4.2 Automatic Test

The MTS-5000 is capable of performing the above test sequences automatically, typically much faster and more consistently than can be done manually. In addition, this mode can generate a formatted report of the results, which can be saved internally or imported directly to an external computer.

There are a few additional test parameters which must be specified to define the auto procedures, though in many cases the default settings of these will be adequate.

This description of the process assumes testing of a Φ-Φ element of a KD-4 relay.

Press *Test Type* [F7] to select *Automatic*. As shown on the following page, this will generate some additional menu selections: *Test Report* [F6], an *All* selection under *Test Phase(s)* [F9], and three test functions via *Auto Test* [F10]. Note that the cells in the Three Phase Parameters box where adjustments are made in manual mode are now greyed out, the test outputs that are generated are based on settings specified on the Configure Test Settings Menu.

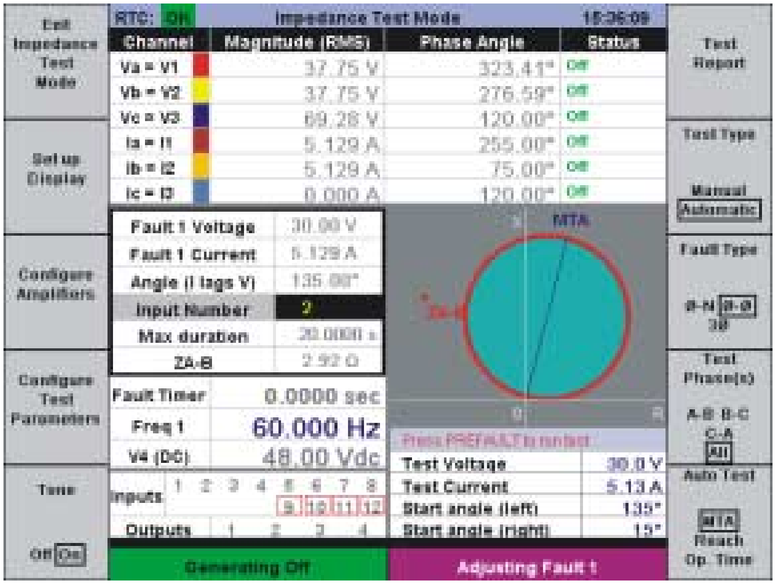


FIGURE 3.21 AUTOMATIC MODE IMPEDANCE TEST

Select Φ-Φ fault [F8], *Reach* [F10], then press *Configure Test Parameters* [F4].

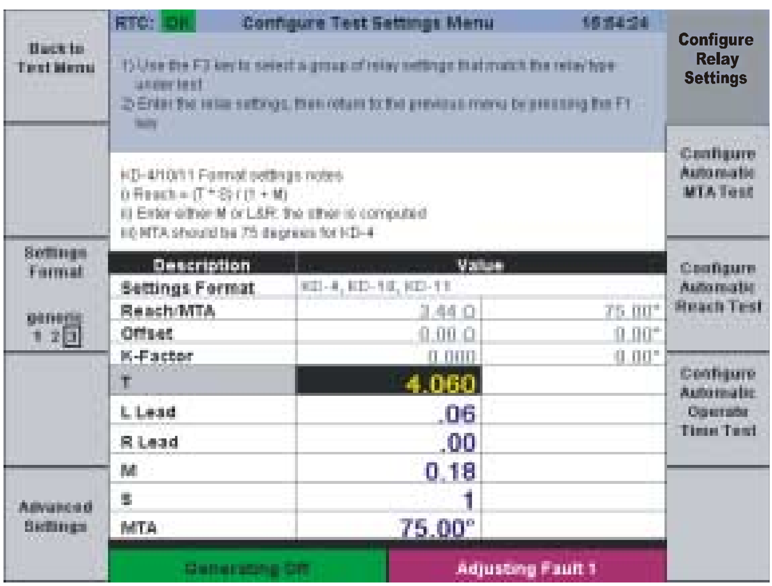


FIGURE 3.22 AUTOMATIC MODE CONFIGURE TEST SETTINGS

Note that additional options are now available on F6 to F9. As described in Section 3.6.4.1 select relay KD-4 via *Settings Format* [F3] and enter the actual tap settings.

To check the auto test settings press *Configure Automatic Reach Test* [F8].

FIGURE 3.23 AUTOMATIC MODE REACH CONFIGURATION

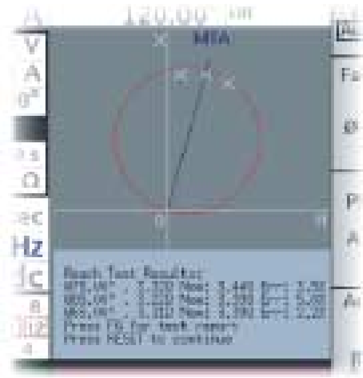
Note that additional options are now available on F2 and F3. The latter, *Value to Vary*, permits the test to be conducted with variable current (i.e. fixed voltage), but as detailed in the previous section variable voltage is the inherently safer and recommended choice. Based on this selection, the reach computed from the relay settings in the previous step, and the *Fault Type* specified, the system calculates a maximum test value for the variable parameter, as well as a value for the fixed parameter. Often the default settings will be adequate, and no adjustments will be required.

Note that the default calculated value for the fixed parameter can be modified, for example in the above screen the fixed current could be set lower, and this will automatically adjust the maximum variable parameter value.

Some electromechanical relays like the KD series recommend voltage be applied throughout the test process to keep the relevant internal coils warm, and some processor-based relays require the presence of a healthy prefault voltage, so the default *Prefault Voltage* setting is usually appropriate.

The *Max. Operate Time* can be important if multiple impedance zones output to the same trip signal point, since for example Zone 2 relays typically pick up for all Zone 1 faults but their trip outputs are time delayed. The default 0.1 second value cuts off the applied fault before a typical Zone 2 could trip. Conversely, if testing a Zone 2 element, this time can be adjusted to exceed the expected Zone 2 delay, ensuring the fault is applied long enough to allow operation.

Press *Back to Test Menu* [F1] when finished.



Press PREFAULT to start the test. The system begins applying a series of short pulsed outputs to the relay under test, and reports progress on the test in the area beneath the RX diagram. **To abort the test at any time press RESET**. It runs on all three phases in turn, and when complete presents the as-found results below the RX diagram. The as-found points are also plotted graphically for comparison to the theoretical values. To view a formatted version of the report press *Test Report* [F6].

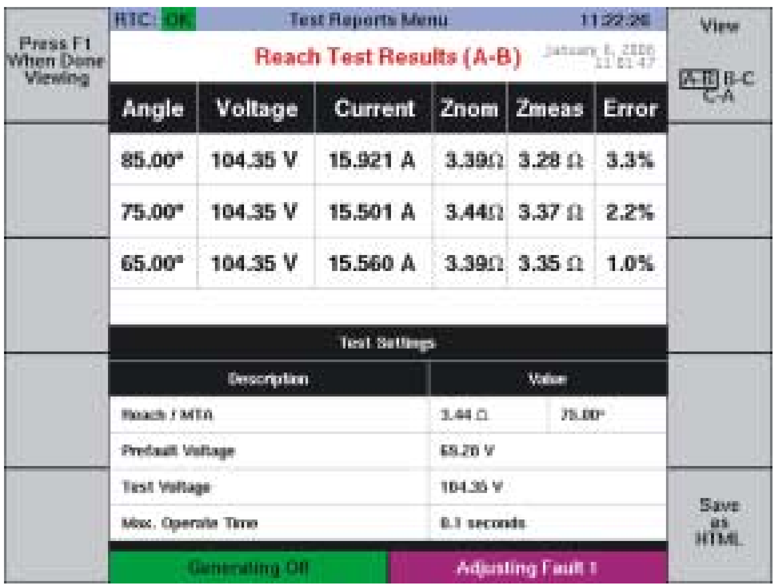


FIGURE 3.24 TEST REPORTS MENU

The *View* button [F6] selects each of the three pages of the report. It is also possible to save an HTML (Hypertext Formatted Markup Language) format report to either the MTS-5000 internal memory, or an external USB drive from this menu, via the *Save as HTML* button [F10]. Files saved to internal memory can be transferred at a later time to an external USB drive. HTML files on a USB drive can be directly imported into a word processing program such as Word. For a detailed explanation of internal file storage and retrieval see Sec. 7.7 File Storage/Retrieval page 7-11, and for USB file handling see Sec. 5.2 USB page 5-4.

Distance Relay Test Report		
Test Mode	Distance (Impedance) Relay Test Mode (21)	Location
Type of Test	Reach (Z<Z)	Relay Type
Time of Test	January 6, 2006 13:01:47	Relay Serial#
Test Equipment	Manta Test Systems Inc. MTS-5000	Tested by

Reach Test Results (A-B)

Angle	Voltage	Current	[illegible]	[illegible]	Error
85.00°	104.35 V	15.923 A	1.39Ω	1.28 Ω	2.3%
75.00°	104.35 V	15.501 A	1.44Ω	1.37 Ω	2.2%
65.00°	104.35 V	15.960 A	1.39Ω	1.35 Ω	3.0%

Reach Test Results (B-C)

Angle	Voltage	Current	[illegible]	[illegible]	Error
85.00°	104.35 V	16.571 A	1.39Ω	1.15 Ω	7.1%
75.00°	104.35 V	15.733 A	1.44Ω	1.31 Ω	1.7%
65.00°	104.35 V	15.505 A	1.39Ω	1.32 Ω	2.0%

Reach Test Results (C-A)

Angle	Voltage	Current	[illegible]	[illegible]	Error
85.00°	104.35 V	16.214 A	1.39Ω	1.22 Ω	1.0%
75.00°	104.35 V	15.712 A	1.44Ω	1.32 Ω	1.5%
65.00°	104.35 V	15.701 A	1.39Ω	1.31 Ω	1.2%

Test Settings

Description	Value	
Reach / MTA	1.44 Ω	75.00°
Prefault Voltage	69.28 V	
Test Voltage	104.35 V	
Max. Operate Time	0.1 seconds	

FIGURE 3.25 HTML TEST REPORT

As shown above, the HTML file contains information on settings, theoretical and as-found results, type of test, date and time. Since it can be directly imported into Word in this format, the only additional work necessary for a complete final report is to enter the location, relay specifics and tester's identity in the upper right corner via the computer's keyboard. If additional data such as a company logo is desired, just import the file into a preformatted template file containing this data.

The MTA test is similar but has fewer parameters, and the default settings rarely need to be altered. In the Impedance Test Mode screen (Fig 3.21) press *Auto Test* [F10] to select *MTA*. To check the auto test settings, press *Configure Test Parameters* [F4], then *Configure Automatic MTA Test* [F7], then *Back to Test Menu* [F1].

Press PREFAULT to initiate the test. As will be seen on the RX diagram, this test is executed by smoothly ramping the phase angle, instead of applying pulsed test signals. It will be necessary to block the trip signal from any out-of-zone elements that may be in parallel with the element under test during this sequence. **Press RESET to abort the test sequence at any time**. As above, the test results appear below the RX diagram, and a formatted report may be viewed or saved.

The Operate Time test is selected and run in a similar manner. By extending the maximum operate time to >Zone 2 delay (if present) the latter time can be verified.

3.7 HELP SYSTEM

There is extensive on-board help available to describe many of the operating features of the MTS-5000, accessible at any time by pressing the HELP button below the cursor controls. The information which appears is specific to the menu which is in use at that time. Pressing HELP when in the Manual Test Menu for example will produce the help screen below.

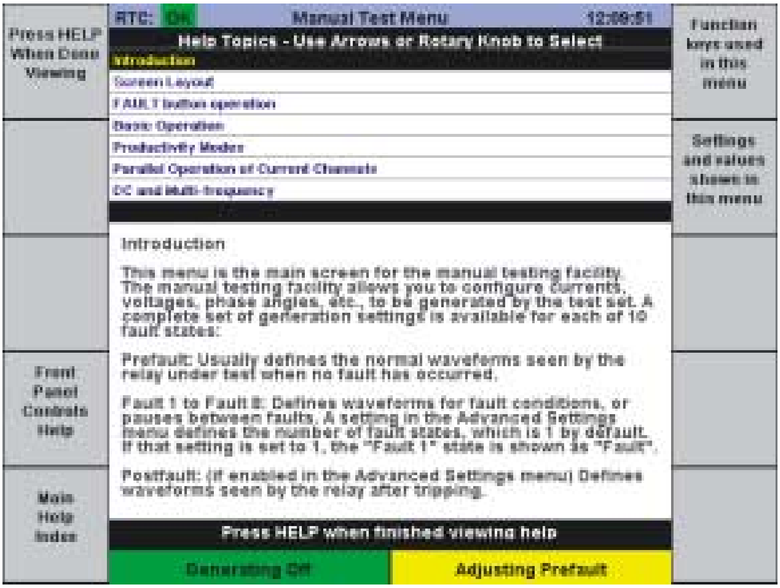


FIGURE 3.26 MANUAL TEST MENU HELP SCREEN

This layout is typical of the Help screens. The *Main Help Index* [F5] brings up an overview of the Help system itself, product specifications, lists phone and Internet contact information for Manta, and details the changes that comprise the current and preceding firmware releases.

The *Front Panel Controls Help* [F4] brings up an overview of the front panel controls, and pressing any of the latter brings up additional information as below. There is even an animated overview of the rotary knob use available.

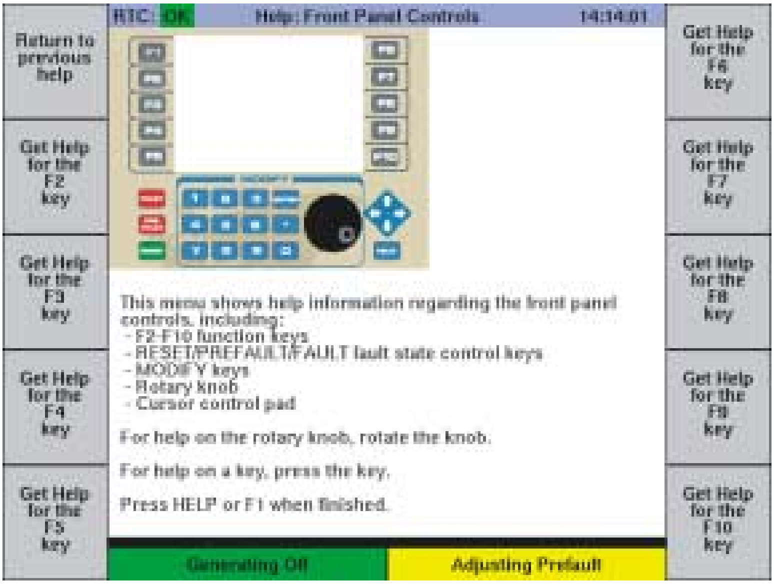
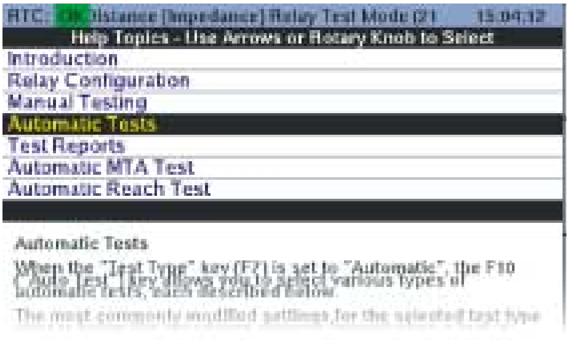


FIGURE 3.27 FRONT CONTROLS HELP SCREEN

In the initial help screen (Figure 3.26) there are also two buttons available for explanations of the controls and settings within the originating menu. Press *Function keys used in this menu* [F6] for example. A written description is given for all the function keys, whose operations are typically unique to that menu. Moving the cursor over a function key listing with the rotary knob or cursor control buttons will bring up the desired information.

Settings information is available via *Settings and values shown in this menu* [F7].

The HELP system can be particularly useful when using the Productivity Modes described in the previous section, since there may be multiple tests, and multiple configurations and settings for a given test, depending on the specific relay selected. See the Impedance Relay test HELP to the right. Use HELP to provide context-sensitive information as required.



3.8 SETUP MENU

A number of significant but infrequently modified functions are accessed through the Setup Menu. These settings are stored in nonvolatile memory and will be applied each time the MTS-5000 is powered up. To access it from the Manual Test Menu press *Main Menu* [F1], then in Main Menu press *Setup* [F10].

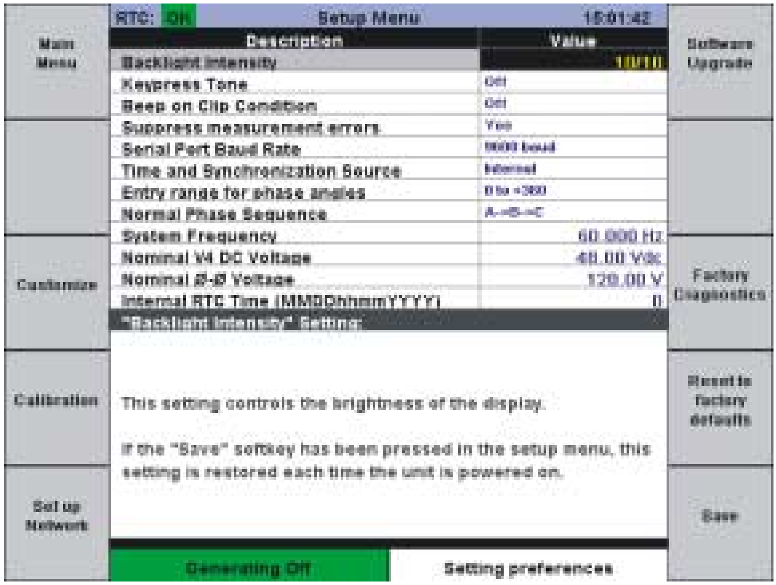


FIGURE 3.28 SETUP MENU

Selecting any item on the list with the cursor controls will provide additional information about the selection in the lower part of the display. If a new selection of any parameter is made and you then return directly to the Main and Manual Test menus, the new selection will be active only until the instrument is powered down. To make a selection the new default upon powerup, it is necessary to press *Save* [F10] before leaving the Setup Menu.

Backlight Intensity controls the brightness of the display.

Keypress Tone enables a beep upon each operation of the manual controls, if additional feedback is desired.

Beep on Clip Condition provides additional warning beyond the visual *Status* column warnings of a clipping condition, usually due to an open current circuit or too high current burden for the current output specified.

Suppress measurement errors: This selection will suppress the error message *MeasError* that can appear in the *Status* column of the current amplifiers under certain abnormal operating conditions such as high frequency operation

Serial Port Baud Rate: for further information see Section 5.1 RS-232C SERIAL on page 5-1.

Time and Synchronization Source: for further information see Section 6.2 USING AN EXISTING GPS SIGNAL on page 6-3. When the default *Internal* Time/ Synchronizing Source is selected, the time and date may be adjusted if desired via the *Internal RTC Time* selection near the bottom of the list. The other selections available are *GPS Receiver* and *Ext. IRIG-B.*

Entry range for phase angles permits phase angles to be specified either in 0-360° format (default) or ±180° format.

Normal Phase Sequence permits the default A>B>C sequence to be reset to A>C>B.

System Frequency allows the default system frequency to be specified.

Nominal V4 DC Voltage sets the default voltage which will be available from the V4 DC voltage output terminals. This voltage setting will appear in the Dynamic Display area of the Manual Test Menu. It can be set to any voltage level desired, however the safest option is to set it for the lowest DC voltage level normally encountered in your testing work, and manually raising it via this option as required, without saving it, to prevent inadvertent application of high voltage to a low voltage system.

Nominal Φ-Φ *Voltage* sets the default level for all Φ-Φ voltage levels. The individual Φ-N levels that appear as the amplitude setting of voltage channels in the Manual Test Menu correspond to the Φ-Φ setting divided by the square root of 3.

“Internal RTC Time (MMDDhhmmYYYY)” setting allows manual adjustment of the internal Real Time Clock setting, in the format month, day, hour, minute, year, as indicated by the alphabetic characters. When the MTS-5000 is connected to a valid GPS or IRIG-B signal, the time setting will automatically be extremely accurate. The internal clock setting however, in the absence of these references, can drift slowly over time. The present system time is shown in the upper right corner of most displays, and can be adjusted via this selection if necessary.

In addition to the selections above, there are a number of pushbutton selections giving access to additional setup screens.

3.8.1 Customize

Customize [F3] enables control over some aspects of the data and colors used on the Manual Test and other displays.

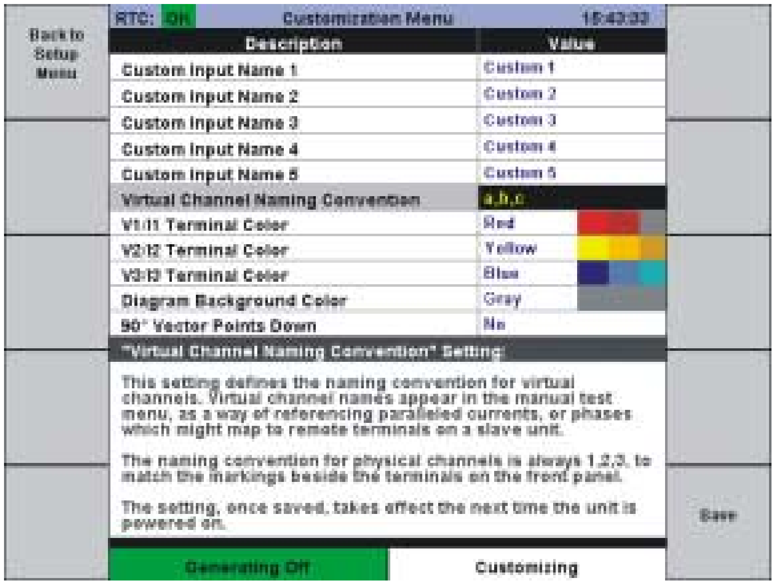
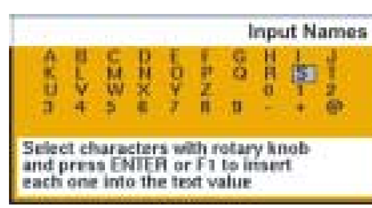


FIGURE 3.29 CUSTOMIZATION MENU

The *Custom Input Name* selections refer to the names which may be assigned to input channels 1 through 12 when activity on those inputs is recorded in the Sequence of Events recorder text or graphic displays. If one of these five cells is selected, an *Edit Text* [F6] pushbutton becomes available. Press the pushbutton to bring up the edit window as shown, and enter the desired name as indicated. For more information on the Sequence of Events Recorder, see section 4.11 on page 4-39.



Virtual Channel naming is described in Figure 3.29 above. The *Terminal* and *Background* selections control the colors of the vectors and background respectively of the vector display.

3.8.2 Calibration

This selection gives access to calibration constants used in the equipment, and is provided primarily for factory service use. It is password protected to prevent inadvertent changes to the calibration data.

3.8.3 Set Up Network

This selection is provided to give access to data used to configure the Ethernet connection to an external computer. For more details refer to Section 5 DATA INTERFACES, item 5.3 on page 5-6.

3.8.4 Software Upgrade

This selection is provided to give access to files which upgrade the firmware revision of the instrument. For further details see Application Note 1.

3.8.5 Factory Diagnostics

This is a password protected area used for factory diagnostics and servicing.

3.8.6 Reset to factory defaults

Pressing *Reset to factory defaults* [F9] will return the instrument to a known state, which can be useful if a number of custom settings are causing confusion in operation of the instrument.

3.8.7 Save

If adjustments are made in some of the settings in the Setup Menu, and *Save* [F10] is pressed before exiting via *Main Menu* [F1], these new settings will be saved, and thus present the next time the instrument is powered up. If settings adjustments are made but not saved in this manner, i.e. the user goes directly to *Main Menu*, the new settings will be active as long as the instrument is powered up, but will revert to the original settings at the next power up.

3.9 REMOTE CONTROL MENU

This menu gives access to the various remote control mechanisms for controlling the MTS-5000 by an external PC. From the Main Menu press *Remote Control* [F8].

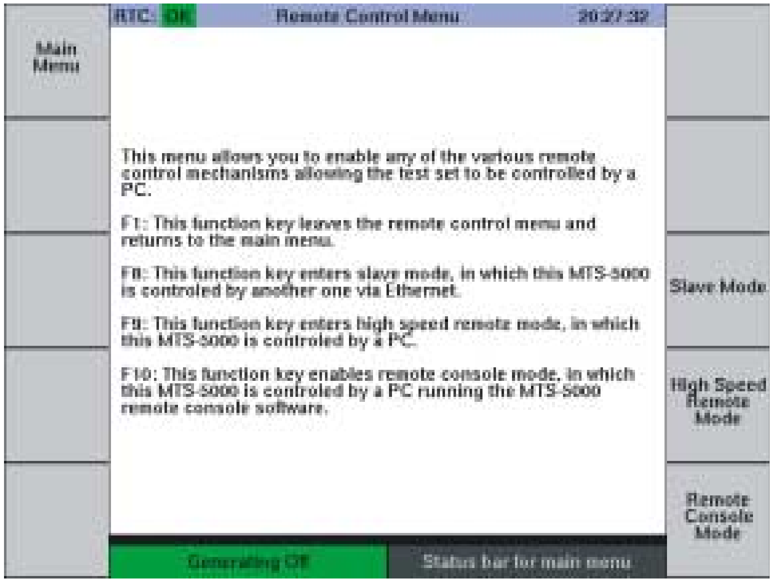


FIGURE 3.30 REMOTE CONTROL MENU

Slave Mode allows two MTS-5000 systems to run in a master-slave configuration where the master controls the operation of both systems. See Section 8 Master-Slave Operation for further details.

High Speed Remote Mode enables near-real-time control of AC outputs via high-speed Ethernet data. It is used only in specialized testing applications.

Remote Console Mode is used in conjunction with Manta's MTS-5050 Remote Console software, an emulation of the MTS-5000's control panel, display, and I/O status indicators which can be run on a desktop or laptop computer. The emulation can run in stand-alone mode, or when connected to an MTS-5000 via Ethernet it can control most of the latter's functions from the computer's keyboard and mouse.

Installation of the software requires an encryption key number, which is available from Manta sales or support staff. The first time the program is run, you will be prompted to enter this number, which will be provided to you by Manta based on another number displayed on the same screen which is unique to your computer.

Once installed, running the program brings up a preliminary instruction screen from which may be selected the stand-alone simulation mode, or remote control mode for a connected MTS-5000. The operation of these 2 modes is virtually identical, except that some functions requiring features such as file loading/saving, are not available on the simulation. When connected to an MTS-5000, settings may be modified, and outputs turned on/off, etc., just as from the actual manual interface.

To enable the latter mode on the MTS-5000, first establish a functional Ethernet link and record the IP address of the MTS-5000; see Section 5.3 Ethernet, page 5-4 for details. Enter the IP address on the instruction screen where prompted, and click the Connect to MTS-5000 button. This will bring up the Remote Console display.

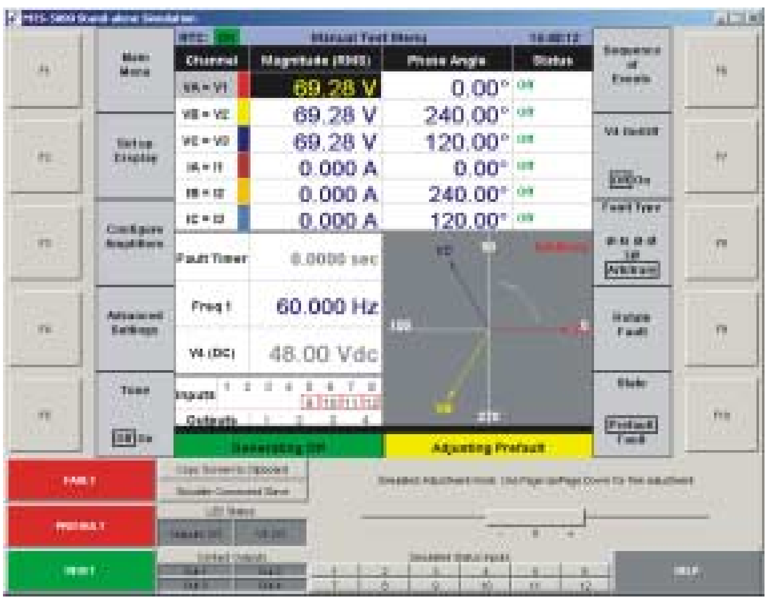


FIGURE 3.31 REMOTE CONSOLE SCREEN

The display on the MTS-5000 will not change from the previous state except that the message on it will read "*Connected to a remote console. Press F1 to exit*." The display on the PC as shown above however will respond to commands as the MTS-5000 does, by mouse clicking on the appropriate buttons. The physical PC keyboard F1-F10 keys also control the respective F1-F10 display buttons.

The display LED output status indicators follow the status of the actual LEDs. Similarly, the Contact Output indicators follow the status of the actual contact outputs.

Clicking and dragging the Simulated Adjustment Knob bar will modify parameters on a continuous basis, the speed of adjustment depending on how far to the left or right it is dragged. Numeric adjustments can also be made directly via the PC's numeric keys. Cursor movement may be controlled by the physical PC cursor keys, or by clicking in the desired cell.

The stand-alone emulation can be a useful aid to training, or previewing more complex configurations and operating sequences, without having to power up an MTS-5000 system. It can also be used to control the MTS-5000 in situations such as when the instrument is on the floor in a crowded location, out of easy reach. Note that there is an optional support stand to permit floor operation, while tilted backwards to improve visual and manual access to the front panel.

The Copy Screen to Clipboard button can be useful in developing illustrations for written training material or test instructions, as it copies what would appear on the MTS-5000 display (at the time the button is clicked) directly to the Windows Clipboard, from where it may be pasted into Paint, Word, or other Windows programs.

DETAILED OPERATION

4.1 FAULT STATES: PREFAULT, FAULT, POSTFAULT

Up to 10 independent fault states may be programmed into the MTS-5000 to simulate the states and dynamic transitions between them found in a real-world power system. These are Prefault, Fault 1 through 8, and Postfault, as indicated by the Selected Fault box on the lower right portion of the Manual Test Menu display.

As indicated below, the transition from Prefault to Fault will usually be initiated by a control input to the MTS-5000, and the transition from Fault to another Fault state or Postfault will usually be initiated by the MTS-5000 sensing operation of the equipment under test.

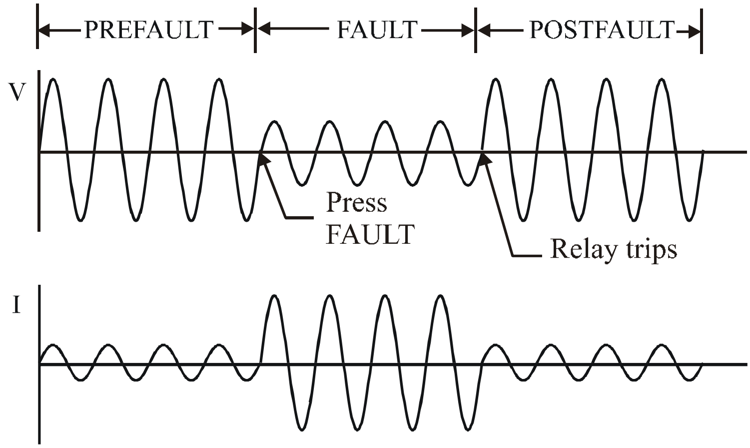


FIGURE 4.1 PREFAULT TO FAULT TO POSTFAULT TRANSITIONS

4.1.1 Prefault State

Prefault state is used to simulate healthy power system conditions prior to the occurrence of a fault. Typically, balanced three-phase voltage and current conditions are found during the prefault period. Many modern protective relays monitor and use these prefault conditions to determine the type and location of fault. When testing certain aspects of these types of protective devices, it is not sufficient to simply switch from a no-AC condition to a fault condition. Conversely, some types of testing require that no AC be present during the prefault state. Pressing the PREFAULT button at any time will turn on the AC outputs, generating the programmed Prefault values.

To program values offline for the Prefault state, press the *State* button [F10] in the Manual Test Menu until *Adjusting Prefault* appears in the Selected Fault box, and *Prefault* is highlighted on the *State* label.

By default there is 120V phase-to-phase balanced three phase voltage and no current. Enter any desired current, voltage, and phase parameters with the MODIFY controls.

To turn on Prefault state AC outputs, press the red PREFAULT button. The text in the Fault Status box will change from *Generating Off* to *Generating Prefault*, the background color of the box will change from green to slowly flashing red, and the AC Output Warning LED will flash.

Subsequently pressing the FAULT button will transition the AC outputs to the programmed Fault values. Pressing the RESET button when in Prefault state will turn off the programmed Prefault AC output values.

4.1.2 Fault State

This is used to simulate power system conditions during a fault. Typically one or more phases of the voltage will decrease while the current increases, and the phase angle between the voltage and current may change during the fault period.

To program values offline for the Fault state, press the *State* button [F10] in the Manual Test Menu until *Adjusting Fault* appears in the Selected Fault box. By default there is 120V phase-to-phase balanced three phase voltage and no current. Enter any desired current, voltage and phase parameters with the MODIFY controls.

To turn on Fault state AC outputs, press the red FAULT button. The text in the Fault Status box will change to *Generating Fault*, the background color of the box will change to rapidly flashing red, and the AC Output Warning LED will flash. By default, the timer will begin running.

4.1.3 Multiple Faults

It is possible to configure multiple fault states, to simulate for example evolving faults or post-reclosure faults, using programmable features provided for the status inputs. Any input may be programmed to switch the AC outputs to any one of n possible fault configurations, where n is the maximum number of fault states specified in the Advanced Settings Menu, accessible by pressing *Advanced Settings* [F4] in the Manual Test Menu.

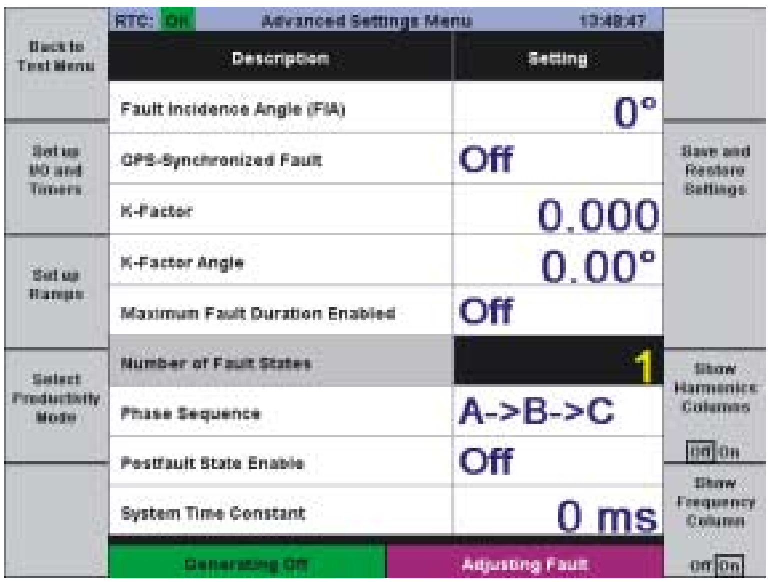


FIGURE 4.2 ADVANCED SETTINGS MENU

Select *Number of Fault States* with the cursor controls and enter the desired number with the MODIFY controls. For detailed information on programming the status inputs, see Section 4.4 on page 4-17. A given input can be programmed to be active only during a specified fault state, and to initiate a different fault state upon being triggered, so a sequential progression of multiple faults may be programmed.

To select each additional fault state for programming, press *State* [F10] until the desired fault is indicated in the Selected Fault box and on the *State* label.

When all faults, and the status inputs controlling their initiations, have been programmed, the entire sequence may be initiated by pressing the FAULT button.

4.1.4 Fault Duration

While still in the Advanced Settings Menu you may wish to enable the Maximum Fault Duration feature. This can be useful in preventing continuous application of fault values if for any reason the device under test fails to operate, especially when high current levels have been specified. It will determine the maximum interval a fault is applied before the next fault state is automatically initiated. Select *Maximum Fault Duration Enabled* to *Seconds*, *Cycles*, or *Both* with the cursor and MODIFY controls. This will add an additional cell or cells to the Dynamic Display area as shown below, allowing independent duration times to be specified for any Prefault, Fault or Postfault state.

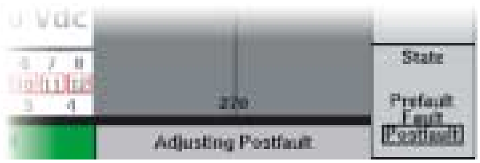
FIGURE 4.3 MAXIMUM DURATION SETTING

Note that if the duration for a given fault state is left at the default setting (0.000), that fault state once initiated will remain energized until either the status input programmed to trip that state off is triggered, or the RESET button is pressed. Once a time is specified however, for example the 350 milliseconds shown above, once that amount of time has elapsed within that fault state without the sensing of an appropriate external trip signal, the system automatically advances to the next fault state if any is specified, or turns off the outputs if there are no further fault states.

This one additional setting applied during the programming of individual fault states can therefore automate a complete sequence, initiated by pressing PREFAULT.

4.1.5 Postfault State

Postfault state is used to simulate power system conditions after a fault has been cleared from the faulted section of the power system, for example to simulate a successful reclosure. By default Postfault state is disabled. To enable it from the Manual Test Menu press *Advanced Settings* [F4], then use the cursor controls to select the *Postfault State Enable* option, and set it to *On* with the MODIFY knob. See Figure 4.2 on page 4-3. Press *Back to Test Menu* [F1] and note that *Postfault* is now listed as an available state on the *State* [F10] label. To program Postfault conditions, press *State* [F10] to select it as shown.



The default Postfault conditions are no voltage and no current. Enter any desired voltage, current and phase values with the cursor and MODIFY controls.

Entry into Postfault state is usually controlled by the status input channels. By default most of these are active in Fault states 1-8 but numerous options are available, see section 4.4 on page 4-17 for more details. Triggering of any active status input channel programmed *Go To Postfault* will then force the transition to Postfault state. The system will also automatically switch to Postfault state if a *Maximum Duration* fault time has been specified for the preceding fault state and that time expires. See section 4.1.4 Fault Duration on the preceding page for details.

It is possible to delay the appearance of a programmed Postfault state for a specified time after the appearance of a trip signal, to simulate the 'dead time' which is often included in reclosure protection systems. Program the system for one additional fault state beyond that required in the test application, program that fault for no current or voltage outputs, and set the *Maximum Duration* time for the desired 'dead time'. See sections 4.1.3 and 4.1.4 on the preceding pages for details. Now initiate the fault sequence, and when the final fault (zero-output dead time) reaches the Maximum Duration time, Postfault will be initiated.

4.1.6 Frozen Readings

In most testing work the user is interested in the AC, DC and time parameters present at the moment the device under test operated, so any event as described above that causes a transition to Postfault state will freeze the timer and displayed output values where they were at the moment of transition, even though the programmed Postfault values are now being generated. These values may of course be very different from the values present at the trip point.

The Fault Status box on the Manual Test Menu will indicate *Generating Postfault* with a slowly flashing red background, and the AC Output Warning LED will flash, as a warning that live output values are present. The Selected Fault box however will indicate *Captured Fault Values*, and the AC values and timer reading shown are frozen values captured at the moment a status input sensed the signal causing the transition to Postfault state.

FIGURE 4.4 FROZEN READINGS

The Postfault values will continue to be generated until the RESET button is pressed, unless an input signal programmed to clear Postfault appears. In the example above, a maximum 5 second duration Fault cleared in just 0.207 seconds, but the frozen Fault values remain on the screen until the RESET button is pushed or another fault is initiated.

4.2 FAULT MODES: PICKUP & TIMING

For a majority of testing applications, only a single Fault state and sometimes a Prefault state will be sufficient to accomplish most tests. In this type of application, there are two Fault modes available, Pickup and Timing. Use of these modes is determined by the nature of the testing being performed, static or dynamic respectively.

4.2.1 PICKUP Fault Mode

PICKUP Fault Mode refers to the operation mode used when determining the pickup or operate level of the Device Under Test (DUT), i.e. Static Testing. When the FAULT button is depressed and held for more than 300 msec, the system exits Prefault state (if energized) and enters into Fault state. The system remains in Fault state only as long as the FAULT button is held depressed. Any trip signals from the DUT will be annunciated on the Digital Input/Output Status box of the display, but will not trip off the AC outputs nor freeze the timer reading. This permits the operator to pass through the pickup/dropout points repeatedly to verify operation without the need to keep resetting the AC outputs. As soon as the FAULT button is released, the system returns to Prefault state (if enabled) or turns the AC outputs off.

If performing extensive pickup testing, using a foot switch to control the MTS-5000 will free the operator’s hands to make adjustments. Status input channels 1-8 can control the system remotely in PICKUP mode by selecting the *FOOT* option. See Sec. 4.4.1.2 Contact Type on page 4-19 for details. By default input channel 8 is configured for FOOT operation. A foot operated switch plugged into that input will then have the same effect as pressing the FAULT button.

4.2.2 TIMING Fault Mode

TIMING Fault Mode refers to the operation mode used to perform timing tests or automated fault sequences, i.e. Dynamic Testing. Pressing the FAULT button momentarily (<300 msec) initiates TIMING fault mode. The AC outputs latch on until the DUT operates, as detected by a status input channel, or until RESET is pressed. The timer is started at the moment the Fault AC outputs appear.

Detection of a trip signal from the DUT freezes the timer and all AC readings, trips off the Fault AC outputs, and either leaves the outputs de-energized or forces the system into Postfault state (if enabled). Any subsequent trip signal detected will be annunciated by the input channel status indicator, but will not change the AC output status. Once the frozen readings have been recorded, pressing RESET will reset the timer and frozen readings, and restore normal operation of the fault buttons. If the DUT fails to trip, pressing RESET will turn off the Fault AC outputs.

TIMING fault mode can be remotely controlled by any status input, by programming that input's *Enable In* and *Go To* modes, see section 4.4.2.1 and 4.4.2.2 on pages 4-20 and 4-21 for details. Any status input configured for *Go To Postfault* will trip the fault off as described above.

The following table summarizes the key functional aspects of these two fault modes.

Action/Result	**Pickup mode**	**Timing Mode**
Press Fault button	Press and hold	Momentary press <300mSec
Timer runs, AC Outputs alive until...	Fault button released	Trip Signal sensed or Press RESET
Response to trip signal	Visual/Audible status indication	Status indication, trips AC outputs off, freezes readings and timer
Application	Manual pickup checks	Timing Checks Automatic fault sequences

FIGURE 4.5 PICKUP AND TIMING MODE CHARACTERISTICS

4.3 FAULT TYPES: THREE PHASE PRODUCTIVITY SHORTCUTS

The descriptions of AC output control covered so far have focussed on individual current, voltage and phase adjustments using the default *Arbitrary* adjustment mode. A very significant portion of protective relay testing work however involves testing of three phase devices, which can require multiple amplitude and phase adjustments to check a single operating point.

Although the voltage outputs are by default set to emulate a balanced three phase system, there can still be for example 15 additional amplitude and phase adjustments necessary to set up the Prefault and Fault current and voltage relationships of a three phase-to-ground fault. In addition, in some tests such as phase-to-phase faults, parameters including the fault voltage and current amplitudes, and voltage-to-current phase angle, must be computed from calculations based on the individual phase-to-ground output levels generated by the MTS-5000.

Further adjustments are also required when for example the phase-to-phase configuration referred to above must be transferred to the adjacent phase pair, say from A-B to B-C. This could require either a physical rotation of the AC output leads, or adjustments to nearly all the amplitude and phase settings.

The *Fault Type* and *Rotate Fault* selections available on the MTS-5000 offer a major productivity boost for this type of work, with the following benefits:

- Automatic configuration of outputs for all major 3-phase fault types
- Simultaneous adjustments of multiple parameters with single MODIFY controls input
- Direct control of phase-to-phase parameters, with automatic adjustment of relevant phase-to-ground outputs
- One-button transfer of fault configuration to adjacent phases

To engage the three-phase fault modes from the Manual Test Menu, press *Fault Type* [F8]. The figure below shows a Phase-to-Phase fault selection.

FIGURE 4.6 THREE PHASE FAULT CONTROL

Note that when any fault type except *Arbitrary* is selected, a 3-cell Three Phase Parameter box appears above the data cells of the Dynamic Display area. The V/I/Φ parameters in the box are blue, indicating they may be adjusted by the MODIFY controls. The cells above, where individual channel adjustments are made in *Arbitrary* mode, are now greyed out, and cannot be modified directly with the MODIFY controls.

Notice below the effect on these readings of pressing *Rotate Fault* [F9].

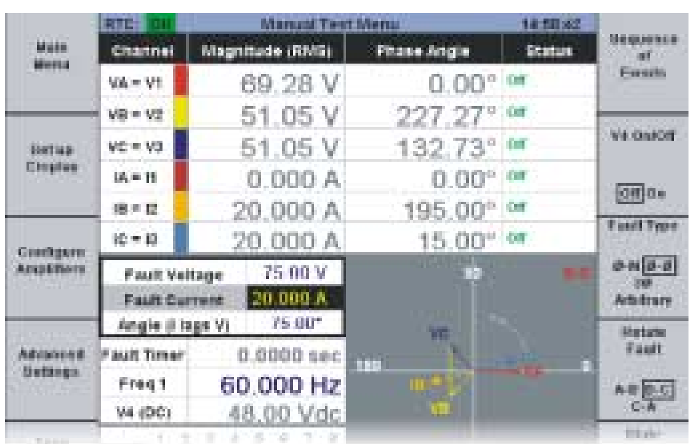


FIGURE 4.7 ROTATE FAULT CONTROL

4.3.1 Φ-N Fault Type

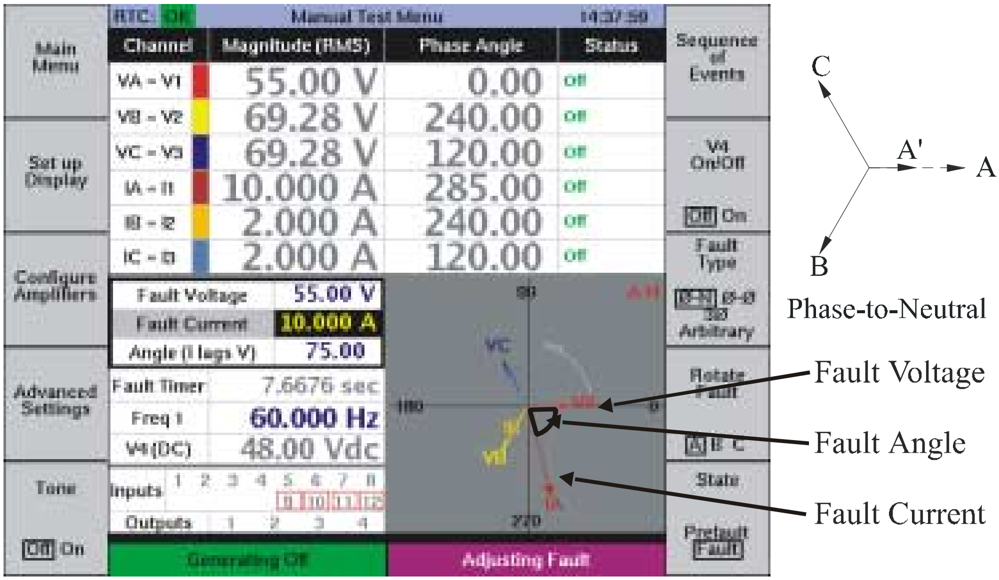


FIGURE 4.8 PHASE-TO-NEUTRAL FAULT

The Φ-N Fault type sets up display and convenient adjustment of any single Φ-N voltage and current, for simulation of single phase faults. Note that any settings applied in Prefault mode will be the default setting in Fault mode on non-faulted phases; in the above figure for example the Prefault currents were set to 2.000 amps.

Once the fault Φ-N voltage, current, and phase relationships are set, they can be applied to any desired phase (A-N, B-N, or C-N) by pressing the *Rotate Fault* [F9] button. The faulted voltage and current, plus the programmed phase angle between them, will rotate to the next phase. Figures 4.6 and 4.7 on the preceding page illustrate this effect in a phase-to-phase fault.

The fault selected at any time is indicated by text in the upper right corner of the phasor display, as well as the highlighted selections on the *Fault Type* and *Rotate Fault* labels, in the above illustration *A-N*, *Φ-N*, and *A* respectively.

This fault mode can also be very useful for single-phase testing when identical relays are installed in each of the three phases. By connecting the wiring for all phases at the start, once tests are completed on the first phase’s devices, it is only necessary to press *Rotate Fault* [F9] to transfer the test settings and active outputs to the next phase.

4.3.2 Φ-Φ Fault Type

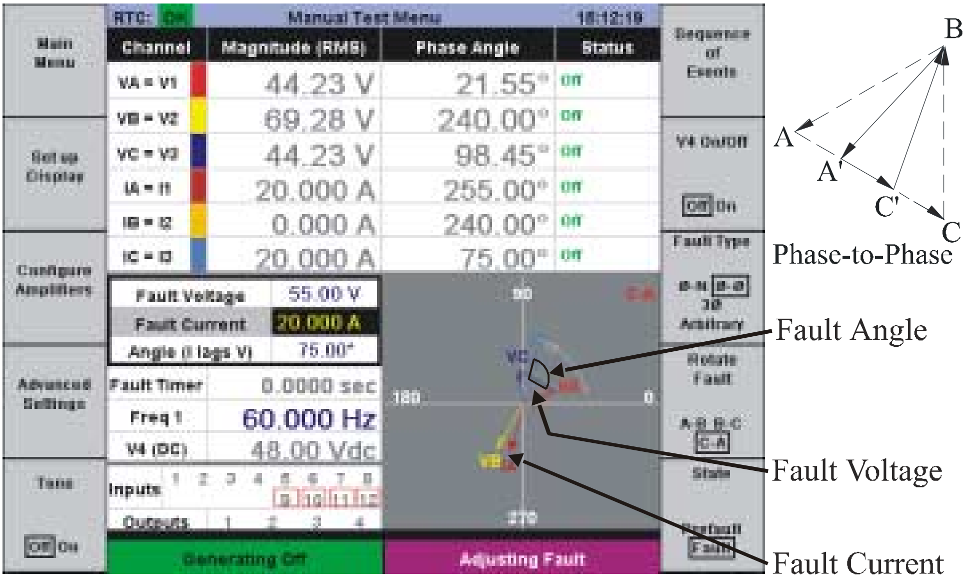


FIGURE 4.9 PHASE-TO-PHASE FAULT

The Φ-Φ Fault type allows direct control of the phase-to-phase voltage and current. The MODIFY knob or pushbuttons simultaneously change the amplitude and phase of two selected Φ-N voltages, resulting in the desired change of the Φ-Φ voltage, see the vector diagram in the upper right corner of Fig 4.9 above. The phase angle of the Φ-Φ vector does not change, but its amplitude does. Notice how the same 55 volt fault value as specified in the Φ-N fault of the previous section results in much different individual amplitude and phase settings for the faulted phases, see Fig 4.8. A single input specification has automatically calculated and applied four parameter changes.

A major advantage of this ease of adjustment is that when testing Φ-Φ elements of impedance relays, the current may be fixed at a safe level and only the voltage modified.

In a Φ-Φ fault the fault current flows out one phase and back the other, so current in the two faulted phases is equal in amplitude but opposite in direction. As above, a single input specification has automatically calculated and output four parameter changes.

The phase angle relationships between voltage and current in a Φ-Φ fault is not immediately obvious from looking at the individual voltage and current source phase angles, since the sources are configured Φ-N. In *Arbitrary* mode the necessary Φ-N settings must be calculated from the Φ-Φ values using geometrical formulae. By specifying the desired fault phase angle in the Three Phase Parameter box however, the necessary phase angles are automatically calculated and applied to the current output channels. Here, a single input specification has automatically calculated and applied two parameter changes.

Once the fault voltages, currents and phase angle are set, they can be applied to any pair of phases (A-B, B-C, C-A) by pressing the *Rotate Fault* [F9] button. The fault voltage and current, plus the specified angle between them, will rotate to the next phase. This is illustrated in Figures 4.6 and 4.7 on page 4-10.

The fault selected at any time is indicated by text in the upper right corner of the phasor display, as well as the highlighted selections on the *Fault Type* and *Rotate Fault* labels, in the above illustration *C-A*, Φ-Φ, and *C-A* respectively.

4.3.3 3Φ (Φ–Φ) Fault Type

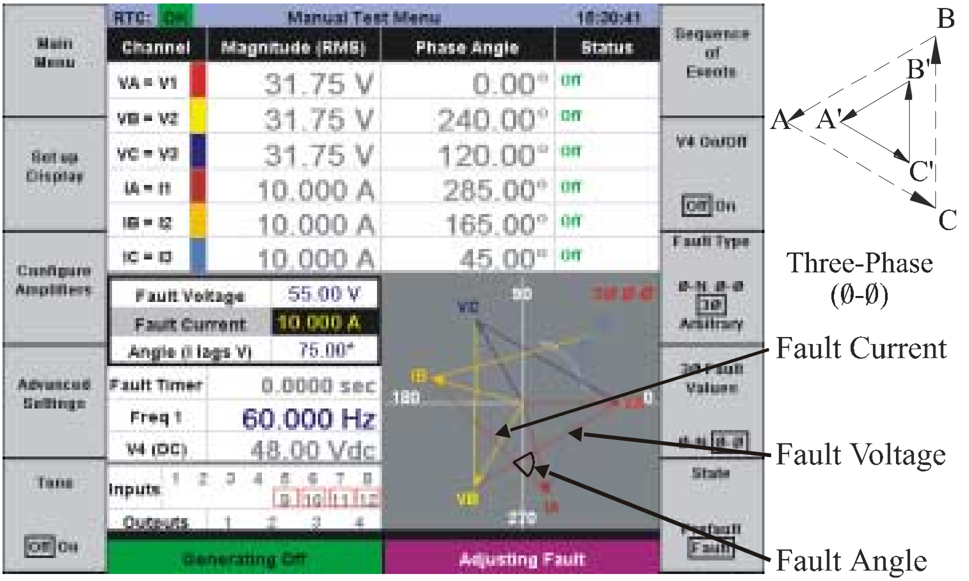


FIGURE 4.10 THREE PHASE FAULT **(Φ–Φ)**

The 3Φ (Φ-Φ) Fault type enables the symmetrical collapsing or expansion respectively of the entire 3Φ voltage and current triangles from the nominal values. When this fault type is selected, the MODIFY knob or keypad inputs simultaneously change the amplitude of all three phases of **(Φ–Φ)** voltage or current, see the vector diagram in the upper corner of the Figure above.

Note that when 3Φ is selected by the *Fault Type* [F8] button, a new selection button *3Φ Fault Values* [F9] appears. Select the desired fault type, Φ–Φ in this example, on the latter button. Because these fault levels are identical on all three phases, there is no need for the *Fault Rotate* button which is displaced by *3Φ Fault Values*.

When *Fault Voltage* within the Three Phase Parameters box is selected, the MODIFY knob or pushbuttons will simultaneously adjust the amplitude of all three voltage vectors but leave their phase angles unchanged. Notice how the same 55 volts fault value as specified in previous examples results in different individual amplitude and phase settings for all the voltage phases, see Fig 4.8 and 4.9. A single input specification has automatically calculated and output three parameter changes, modifying the Φ-N voltage outputs to obtain the specified Φ-Φ voltage.

The **Φ-Φ** *Fault Current* adjustments are identical in nature to the *Fault Voltage*. Again, a single input specification automatically calculates and outputs three parameter changes. Notice on the vector display, and in the specified **Φ**-N current settings, the difference between the symmetrical current flow in this 3**Φ** fault, and the **Φ-Φ** currents of the previous section.

The *Fault Angle* value specified will automatically calculate and apply the three current phase angle adjustments necessary to generate the desired phase angle between the **Φ-Φ** voltage and **Φ-Φ** current. Notice on the vector display that both the **Φ**-N vectors actually generated by the current and voltage sources, and the **Φ-Φ** vectors derived from them, are shown.

The fault selected at any time is indicated by text in the upper right corner of the phasor display, as well as the highlighted selections on the *Fault Type* and *3***Φ** *Fault Values* labels, in the above illustration *3***Φ** **Φ-Φ**, *3***Φ**, and **Φ-Φ** respectively.

4.3.4 3Φ (Φ-N) Fault Type

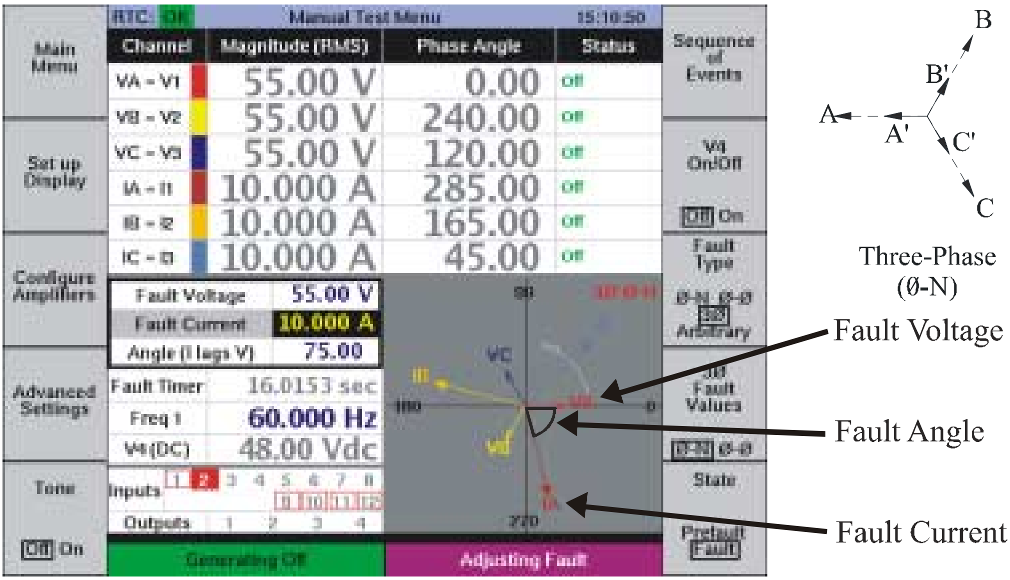


FIGURE 4.11 THREE PHASE FAULT (Φ-N)

The 3Φ (Φ-N) fault type is similar to the 3Φ (Φ-Φ) fault type, except that the voltage and current being controlled are Φ-N values. After selecting 3Φ on the *Fault Type* [F8] button, a new selection button 3Φ *Fault Values* [F9] appears below it. Select Φ-*N* on the latter button.

When *Fault Voltage* within the Three Phase Parameters box is selected, the MODIFY knob or pushbutton inputs will simultaneously adjust the amplitude of all three voltage vectors but leave their phase angles unchanged. Notice how the same 55 volts fault value specified in previous examples results in different individual amplitude and phase settings for all the voltage phases, see Fig 4.8 to 4.10. A single input specification has automatically calculated and output three parameter changes.

The Φ–N *Fault Current* adjustments are identical in nature to the *Fault Voltage*. Again, a single input specification automatically calculates and outputs three parameter changes. Notice on the vector display, and in the specified Φ-N current settings, the difference between the individual currents in this 3Φ fault, and the Φ-Φ currents of the previous section.

The *Fault Angle* value specified will automatically calculate and apply the three current phase angle adjustments necessary to generate the desired phase angle between the individual voltages and currents.

4.4 STATUS INPUTS CONFIGURATION

The 12 status inputs are used to sense operation of the device(s) under test, or to initiate specific functions of the MTS-5000.

- They may be configured to sense changes in status of dry contacts (Channels 1-8 only) or DC voltages (all Channels).
- An audible tone may be assigned to any input to indicate change of state.
- The voltage sensing threshold and debounce time (the time in milliseconds an input signal must remain at a changed level before recognition) are programmable.
- The inputs may be programmed to respond only during a specific fault state, and to force the system to another specific fault state.
- They may be used to control 4 independent timers.
- The input impedance of each input exceeds 25 kohms and each input pair is galvanically isolated from both the other inputs and all other circuitry of the MTS-5000.
- Inputs 1-8 can perform waveform capture

The most common application of the status inputs is to detect the operation of the trip output contact(s) of protective relays. The large number of inputs allow simultaneous monitoring of multiple outputs on complex microprocessor-based relays, the trip outputs of multiple relays installed in the three phases of a protective relay system, and/or key operating points in the trip output circuitry of a complete protection system. This allows rapid efficient manual or automated testing without the need to keep relocating the operation sensing leads.

This type of application effectively monitors digital status, i.e. on or off state, of dry contacts or DC voltage levels. The MTS-5000 incorporates a very useful Sequence of Events recorder function driven by the status inputs, which records status of all inputs in both tabular and graphical form. See Section 4.11 on page 4-39 for detailed information on this function.

The first 8 channels of status inputs are also capable of waveform capture, functioning as a multi-channel oscillograph. This can be very useful in applications such as verifying the accuracy of complex waveforms generated by the MTS-5000’s AC output channels. See Section 4.12 Oscilloscope Display on page 4-41 for detailed information on this function.

To check or modify configuration of the status inputs from the Manual Test Menu, press *Advanced Settings* [F4], then *Set up I/O and Timers* [F2] to bring up the I/O Setup Menu.

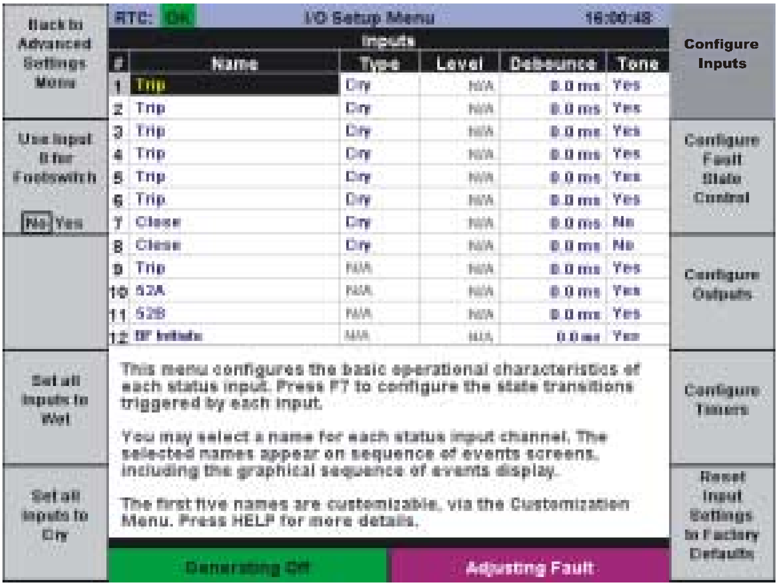


FIGURE 4.12 I/O SETUP MENU

By default most inputs 1-8 are configured for dry contact operation sensing, no debounce, enabled in any fault state, triggering forces the system to Postfault mode and stops the Fault Timer, and the audio tone is enabled. Separate setup screens are provided via F6 and F7 for basic input configuration and Fault State Control.

4.4.1 Basic Configuration

Press *Configure Inputs* [F6]. Move the cursor to the cell associated with the parameter to be modified, then rotate the MODIFY knob to view and select the desired option. Leaving the selection on the option for a couple of seconds, pressing ENTER, or pressing a cursor key to move to the next cell, locks in the selection.

4.4.1.1 Input Name

Making a selection under *Name* in the manner described above will generate the list shown at the right. The list contains the name of functions commonly encountered in protective relaying, as well as 5 customizable names. These labels will assist in identifying the function associated with each input as they are recorded in the text or graphic Sequence of Events Recorder displays. For information on creating custom names see section 3.8.1, page 3-43. For information on the Sequence of Events recorder see Section 7.6 on page 7-10.

4.4.1.2 Contact Type

The *Type* column identifies whether the input will sense a *Dry* or *Wet* contact operation. Dry mode senses the operation of an isolated relay output contact. Wet contact mode will sense the presence of voltage. Input number 8 may be selected for *Footswitch* mode via button F2. Footswitch mode, which senses operation of an external foot-operated switch, is similar to *Dry* mode except that it returns the system to the previous fault state, typically Prefault, when opened. Selection of *Wet* mode is indicated by a red square around that input's status indicator (Fig 4.14, page 4-22).

Most trigger signals are normally open, that is they change from no continuity or no voltage to closed contact or voltage presence. The inputs are triggered by a change of state during fault states however, so normally closed signals will also trigger an input when they go open. It is also possible to configure the inputs to only respond to a specific direction of state transition, see Section 4.4.2.3. on page 4-21.

4.4.1.3 Threshold Level

The *Level* column allows programming of a voltage threshold detection level. When Wet contact sensing is selected, the default threshold level is 10 VDC, i.e. the voltage must exceed that level to be considered as valid. Enter a new threshold value with the MODIFY controls if desired. Note the following:

- The inputs will sense presence of AC voltage, but because of the continuous fluctuation of level it is not suitable for precision timing applications
- If the input has been set for *Dry* contact sensing, the corresponding *Level* cell will be marked *N/A* (Not Applicable)
- The *Threshold* level may be adjusted to any value between 3-220 VDC
- To ensure reliable triggering set the level about 10% below the maximum level expected. Too low a setting may cause false triggering from noise pickup.

4.4.1.4 Debounce Time

The *Debounce* column allows programming of the time an input signal must be sustained before it is considered as valid. This is most likely to be a factor in testing electromechanical relays operating just over their minimum pickup level, where contact bounce may be a factor. Typically the debounce time in such a case would be set to roughly equal the pickup time of high-speed auxiliary relays driven by the device under test.

4.4.1.5 Tone

This selection determines if an audible tone will be produced whenever the input is triggered to On. Note that there is also a separate master enable button for the audio tone, located on the Manual Test Menu. Press *Tone* [F5] to enable or disable the tone on all channels without modifying the individual channel configurations.

4.4.2 Fault State Control

Press *Configure Fault State Control* [F7]. This menu permits customization of the fault state transitions controlled by the input channels.

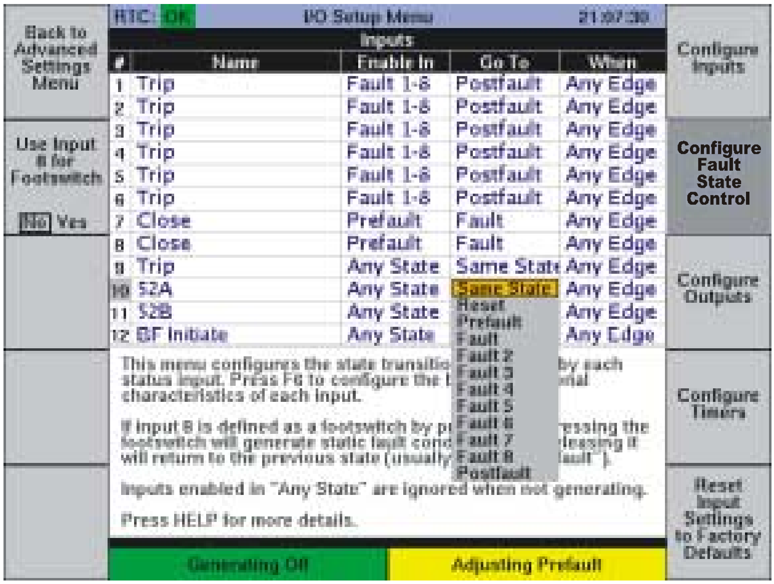


FIGURE 4.13 I/O FAULT STATE CONTROL

4.4.2.1 Enable In

This column defines in which fault state a trigger action on the input will be recognized. Rotating the MODIFY knob with the cursor over a cell in the *Enable In* column will scroll through the available options, which include:

Any State - The input will be enabled in any prefault, fault, or postfault state.

Prefault - A trigger action will only be recognized if Prefault state is active.

Fault - A trigger action will only be recognized if Fault state is active (no multiple faults programmed) or Fault 1 active (multiple faults programmed).

Fault 2 - A trigger action will only be recognized if Fault 2 state is active. Similar options are offered for Fault 3 through Fault 8.

Postfault - A trigger action will only be recognized if Postfault state is active.

Fault 1-8 - A trigger action will be recognized in any Fault state.

4.4.2.2 Go To

This column defines the fault state transition that will be initiated by a trigger action on the input. Rotating the MODIFY knob with the cursor over a cell in the *Go To* column will scroll through the available options, which include:

Same State - A trigger action will not force a new fault state, the existing one will be maintained.

Reset - A trigger sensed in this mode clears any frozen readings if in Postfault mode, and interrupts the outputs if in Fault mode. It has the same action in other words as pressing the RESET pushbutton.

Prefault - A trigger action will force the AC outputs to the Prefault state.

Fault - A trigger action will force the AC outputs to the Fault state. This can be used to initiate a fault sequence from an external contact operation rather than from pressing the FAULT button.

Fault 2 - A trigger action will force the AC outputs to the Fault 2 state. This can be used to initiate a multiple fault sequence from an external signal such as a reclosure relay. Similar options are offered for Fault 3 through Fault 8.

Postfault - This is the default option for most inputs. A trigger action will freeze the timer and AC output readings, and force the AC outputs to Postfault state. Note that the AC outputs will only be energized in Postfault state if it has been enabled, otherwise the outputs will turn off.

4.4.2.3 When

Cells in this column permit the programming of an input to respond only to a specific transition direction. The default *Any Edge* setting means that the first status transition detected in the state in which the input is enabled (see 4.2.2.1 above) will trigger the input. Depending on the system being monitored by the input however, there may be cases where it is desired to generate a trigger response by detecting a specific direction of transition, which in turn requires ignoring the initial transition.

The available *Rising* and *Falling* settings allow the trigger response to be precisely programmed. Note that this is directly analogous to the rising edge/falling edge capability found on the trigger controls of most oscilloscopes.

4.4.3 Status Inputs Active Indication

A visual indicator of the status of the input channels, to verify each channel is responding correctly to the signal for which it is configured, is provided in the lower part of the Dynamic Display Area.

FIGURE 4.14 STATUS INPUTS ACTIVE INDICATION

As illustrated, it shows the trip sensing status of each input by highlighting active channels in red, in this case channel 2. Note that in this example channels 1 and 9 through 12 are configured for Wet operation, i.e. voltage presence sensing, as indicated by the square red outlines.

4.5 PROGRAMMABLE TIMERS

A primary application of the status inputs of the MTS-5000 is to determine the timing of events driven by the AC outputs of the system. By default the Fault timer is configured to start running as the AC outputs of a Fault state appear, and to stop when any status input programmed to initiate Postfault state is triggered.

In many applications however, especially on-panel system tests or multi-output relay tests, it is desirable to be able to record multiple timing events simultaneously. The MTS-5000 is provided with four additional timers, which may be configured independently to start and stop from any status input trigger or fault state initiation.

To select and program these timers, from the Manual Test Menu press *Advanced Settings* [F4], *Set up I/O and Timers* [F2], then *Configure Timers* [F9]. By default all the timers will be disabled.

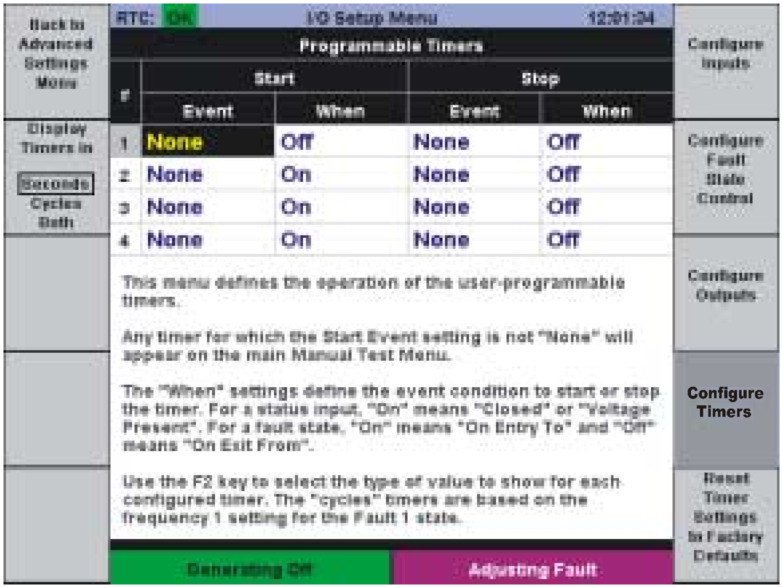


FIGURE 4.15 PROGRAMMABLE TIMER SETUP MENU

4.5.1 Timer Start: Event

Settings in this column determine what event will start the timer running. The options for this selection include:

None - The default selection, which disables the timer

Prefault - entry into or exit from this fault state, depending on the setting of the *When* column being *On* or *Off* respectively

Fault - entry into or exit from the default Fault state, depending on the setting of the *When* column being *On* or *Off* respectively

Fault 2 - 8 - entry into or exit from the Fault state 2, 3,.8, depending on the setting of the *When* column being *On* or *Off* respectively

Postfault - same as Fault, above

Input 1-12 - Transition of the specified input to an ‘On’ state (i.e. appearance of a closed contact or voltage presence) or to an ‘Off’ state (i.e. contact opening or voltage disappearing), depending on the setting of the *When* column being *On* or *Off* respectively

4.5.2 Timer Start: When

Settings in this column determine what type of transition of the event defined in the *Event* column above will start the timer running. The options for this selection include:

> **On -** Entry into the fault state specified under *Event*, or sensing of a contact closure or voltage appearance at any status input channel
>
> **Off -** The exit from a specified state, or the sensing of a contact opening or voltage disappearance at any status input channel

4.5.3 Timer Stop: Event and When

The options for programming a stop event and timing are identical to those described above for starting the timers. Notice that the timer readouts can be configured for *Seconds, Cycles*, or *Both* via pushbutton F2.

Once any programmable timer has been configured in this matter, its data readout will automatically be included in the information in the Dynamic Display Area of the Manual Test Menu.

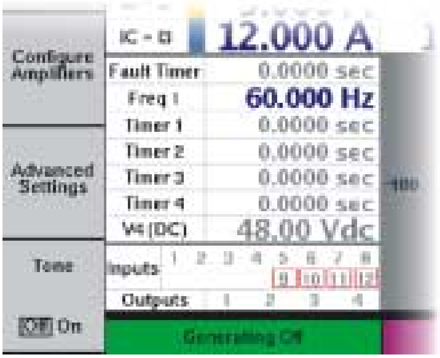


FIGURE 4.16 PROGRAMMABLE TIMERS DATA READOUT

The timer data readouts may be selected for seconds, cycles, or both, via pushbutton *Display Timers in* [F2], see figure 4.15 on the preceding page.

4.6 DIGITAL OUTPUTS CONFIGURATION

The digital outputs are isolated relay contacts which can be configured normally open (NO) or normally closed (NC), and programmed to operate at specific times in the Prefault/Fault/Postfault sequence. They can be used directly to simulate contacts of devices like circuit breakers, or indirectly to switch DC voltage for logic elements of a protective relay system. This permits complete testing of complex relays or relay systems which monitor the status of external equipment as part of their operational logic. Be careful not to exceed the maximum contact ratings of 0.4A resistive at 250VDC, or 5 Arms at 240 VAC.

By default, output #1 is a NO contact whose status is controlled by the Fault state. To configure the outputs, press *Advanced Settings* [F4] in the Manual Test Menu, *Set up I/O and Timers* [F2] in the Advanced Settings Menu, then *Configure Outputs* [F8] in the I/O Setup Menu.

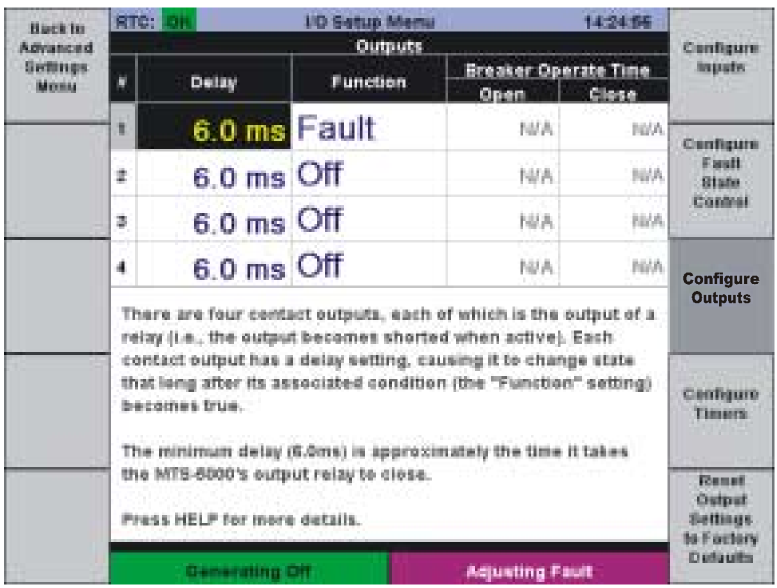


FIGURE 4.17 DIGITAL OUTPUTS SETUP MENU

4.6.1 Delay

The *Delay* column specifies the time delay before the contact operates, following initiation of a fault state. Move the cursor to a Delay cell and enter the desired time delay with the MODIFY knob or keypad. The minimum delay of 6ms is the approximate pickup time of the relay, and may vary ±1ms.

4.6.2 Function

The *Function* column cells determine the contact operating characteristic. Move the cursor to the desired channel cell and rotate the MODIFY knob to view and select the desired option. The following options are available:

Off - The output channel does nothing

Fault - The contact is closed during Fault state, and open at all other times (Prefault and Postfault). To simulate a remote permissive trip signal, a delay proportional to the actual permissive signal delays would be programmed in the *Delay* cell.

Fault 2 - The contact is closed during Fault 2 state, and open at all other times (Prefault and Postfault). Similar options are offered for Fault 3 through Fault 8.

52A -The contact simulates operation of a circuit breaker NO auxiliary contact, i.e. the contact is closed during Prefault and Fault, but opens on the tripping of Fault to Postfault state. If a Breaker Operate Time is specified in the *Open* column, the opening of the contact following sensing of a trip trigger will be delayed by that time. A time delay specified in the *Close* column will apply in the event the system is configured to simulate a reclosure operation. In this case, the contact would remain open until the specified time after a reclosure signal causes the system to transition from Postfault to Fault state.

52B - The contact simulates operation of a circuit breaker NC auxiliary contact, i.e. the contact is open during Prefault and Fault, but closes on the tripping of Fault into Postfault state. Operation is the inverse of the 52A described above.

Unblock - The contact is normally closed, but opens during Fault state. A delay proportional to the actual unblock signal delays should be programmed for this state.

Mimic 1 - This allows an output contact to be controlled by a status input, so that it follows the opening and closing of the latter. The *Mimic 1* selection will cause the output to follow input 1. Similar options are available for mimicing inputs 2 through 4.

4.6.3 Digital Outputs Status Indicator

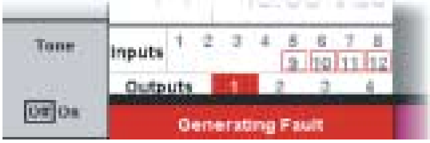


FIGURE 4.18 DIGITAL OUTPUTS STATUS INDICATION

The status indicator is located in the Dynamic Display Area of the Manual Test Menu. Any channels which are currently active are highlighted in red, for example the default Fault-configured output 1 as shown above.

4.7 AMPLIFIER CONFIGURATION

Many applications will not require the full complement of current and voltage sources. Disabling sources not currently in use will simplify the Manual Test Menu display, since only enabled sources are listed there. The text size will be increased when fewer sources are listed in the display, enhancing readability. Press *Configure Amplifiers* [F3] from the Manual Test Menu to bring up the Amplifier Configuration Menu.

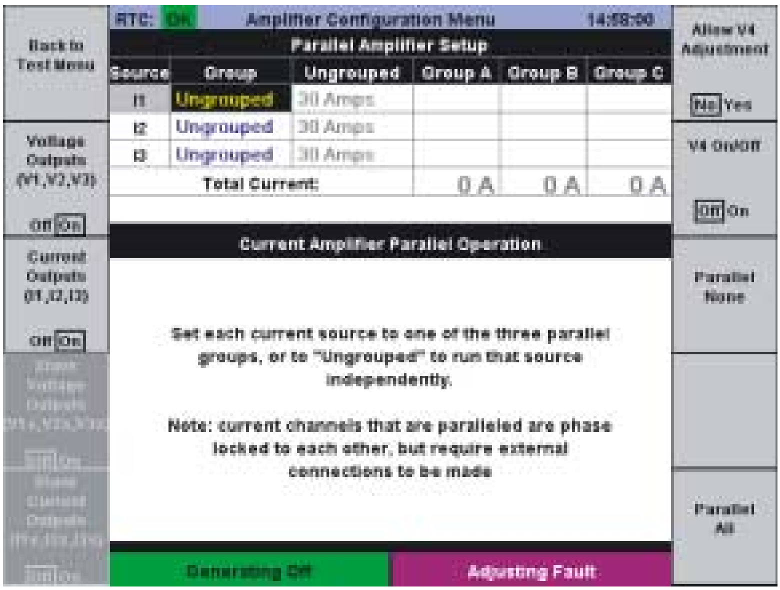


FIGURE 4.19 AMPLIFIER CONFIGURATION MENU

As shown, there are dedicated buttons to enable/disable three voltage sources [F2] and 3 currents [F3].

As described in Section 3.4.1 page 3-15, the V4 voltage output adjustment may be unlocked from the default value in this menu, by pressing *Allow V4 Adjustment* [F6].

Parallel operation of the current sources may also be configured here, as described in Section 3.5.1 page 3-17.

If two MTS-5000 systems are configured to run in master-slave mode, the slave unit voltages and currents may be enabled/disabled by the F4 and F5 buttons respectively, which will in turn be enabled as shown by their light grey background. See Section 8 MASTER-SLAVE OPERATION for further details.

4.8 ADVANCED SETTINGS

A number of less commonly used configurations can be set up from the Advanced Settings Menu. To access these in the Manual Test Menu, press *Advanced Settings* [F4].

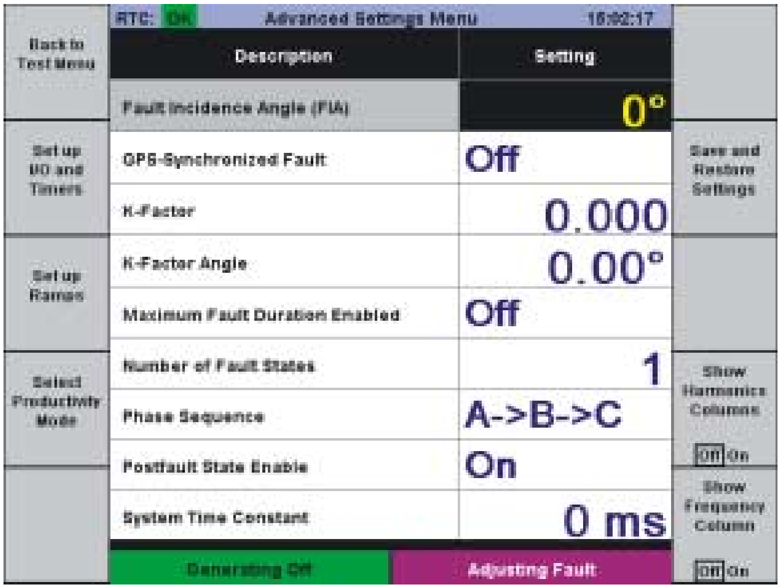
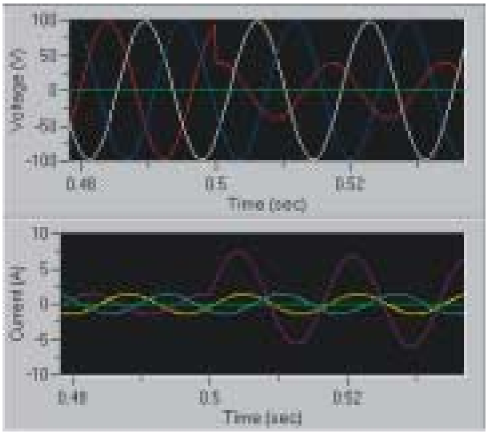


FIGURE 4.20 ADVANCED SETTINGS MENU

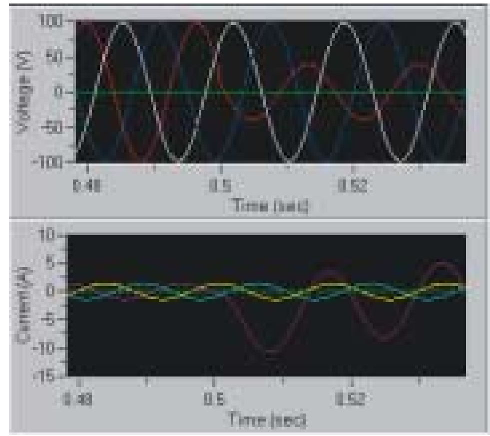
4.8.1 Fault Incidence Angle (FIA)

This selection allows precise setting of the point-on-wave at which the system outputs switch into the fault state. Electromechanical and digital relays behave differently in response to variations in fault incidence angle. Modern high-speed digital relays in particular will vary in operate time for varying fault incidence angle. For more information, see Manta Test Systems' application note "Effect of DC Offset on Instantaneous Element Performance".

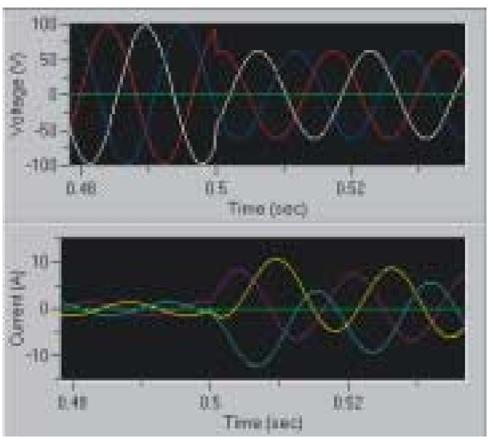
This feature allows any angle from 0-360° to be specified, as well as a random angle. Fault incidence or inception angle is defined as: The instantaneous electrical waveform angle of the current flowing in the shunt fault path (in the case of a shunt fault), immediately following inception of the fault. The 4 figures on the following page illustrate some examples.



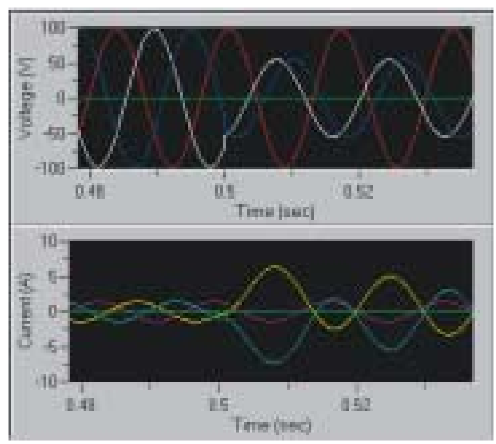
A-G Fault @ 0 Deg.



A-G Fault @ 90 Deg.



3 Phase Fault @ 0 Deg.



B-C Fault @ 90 Deg.

FIGURE 4.21 FAULT INCIDENCE ANGLE EXAMPLES

Note that when the fault type is set to 3-phase, the fault incidence angle is referred to the IA fault current. Note also that for proper realistic current waveforms, the system time constant (see item 4.8.7 below) must be set to a realistic non-zero value (e.g. 15 - 50ms), otherwise instantaneous phase/amplitude changes not representative of real world currents may cause unpredictable relay response yielding invalid test results.

The graphical sequence of events display feature (see Section 4.11 page 4-39) can be used to view the actual test waveforms.

For “Arbitrary” fault type, the internal reference phasor (always set to 0 degrees) is the reference for the fault incidence angle setting. Note that when GPS time synchronization is enabled, the fault incidence angle setting is not available (as indicated by the text *N/A* that appears in the FIA cell), since in that mode the fault transition point is determined by GPS time rather than FIA. The FIA may still be controlled in a GPS-initiated test however by starting in Prefault state and varying the Prefault duration. A spreadsheet is available from Manta Test Systems’ technical support to assist with setting the prefault duration correctly for these situations.

If it is desired to display the FIA on the Manual Test Menu, to observe the timing and other results affected by its modification, it can be selected via the Display Setup Menu, see Section 4.9.4 page 4-34.

4.8.2 GPS-Synchronized Fault

This selection arms the system for multi-site synchronized fault initiations. Available selections are *Off*, *10 Seconds,* and *1 Minute.* For detailed explanations of this feature see Section 6 GPS OPERATION, and Section 7.5 INITIATING WAVEFORM PLAYBACK page 7-8.

4.8.3 K-Factor, K-Factor Angle

K-Factor is zero sequence compensation factor, the proportion of residual current supplied to ground fault impedance relays along with the Φ-N voltage and phase current to ensure the relays respond correctly to the positive sequence impedance of line to ground faults. Specifying values corresponding to those of a device under test will ensure a correct calculated value for Φ-N impedance. This value may be displayed in the Dynamic Display section of the Manual Test Menu, see Section 4.9.11 on page 4-35.

4.8.4 Maximum Fault Duration Enabled, Number of Fault States

For detailed explanations of these features, see Section 4.1.3 on page 4-3.

4.8.5 Phase Sequence

The default phase sequence of the system at power-up is determined by the setting in the Setup Menu, accessible by pressing *Setup* [F10] in the Main Menu which appears at power-up. To reverse this temporarily, when testing a phase sequence relay for example, use this selection on the Advanced Settings Menu. Options are *A->B->C* and *A->C->B.*

4.8.6 Postfault State Enable

For a detailed explanation of this feature, see Section 4.1.4 Postfault State on page 4-5.

4.8.7 System Time Constant

This setting enables the generation of an exponentially decaying DC offset to the AC current outputs at each state transition. For accurate results the number input via the MODIFY controls should correspond to the actual power system value at the location of the test. This feature is essential for testing many modern high-speed (subcycle) relays.

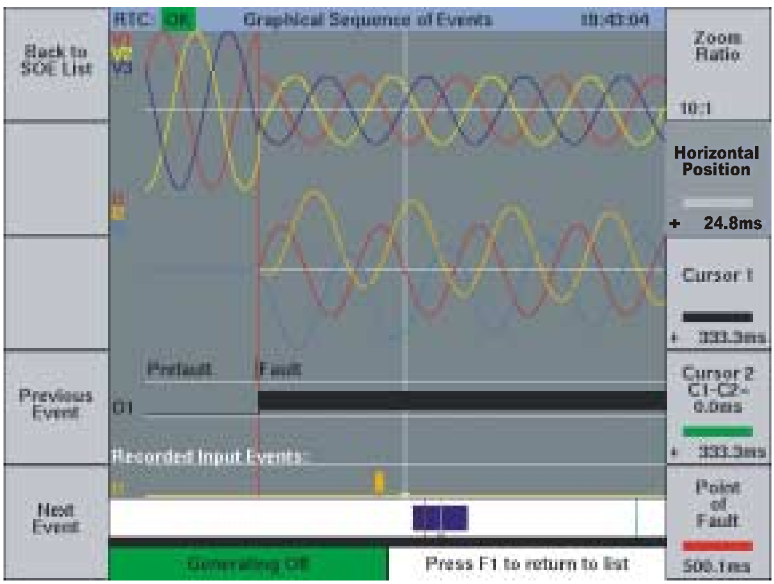


FIGURE 4.22 SYSTEM TIME CONSTANT EFFECT

Note in the figure above the effect of specifying a 50 ms system time constant for a symmetrical 3-phase fault with a 0° fault incidence angle (FIA), applied to a high-speed distance relay. Observe the offset in the B and C phase currents, while the A phase shows no offset, having been initiated at the specified °0. The short pulse on input 1 (I1) at the bottom of the display is the negative sequence overcurrent element of the relay, which in this case no longer operated inappropriately once the time constant was adjusted slightly higher.

The time constant value may be displayed in the Dynamic Display area of the Manual Test Menu, see section 4.9.5 System Time Constant on page 4-34.

4.8.8 Save and Restore Settings

An additional feature available within the Advanced Settings Menu is the ability to save and recall MTS-5000 settings. This can be useful for storing more complex test configurations to minimize the setup time in future use of that configuration. Detailed information on the procedure to follow after pressing *Save and Restore Settings* [F7] is available in Section 7.7.1 Save Settings File page 7-12. NOTE: special software is now available from Manta to directly generate multi-part settings files from customer generated MS Excel fault setting files.

4.9 ADDITIONAL DISPLAY INFORMATION

The Dynamic Display Area (see Fig 3.4 page 3-10) by default contains basic time and frequency data, and includes the Three Phase Parameters box when any of the three-phase Fault modes are selected. Up to 8 items of data may be displayed in this area at the same time, even if the Three Phase Parameters box is present. The text size is automatically scaled to give the largest display possible for the selected data. To alter the default display, or add additional data, press *Set Up Display* [F2] from the Manual Test Menu.

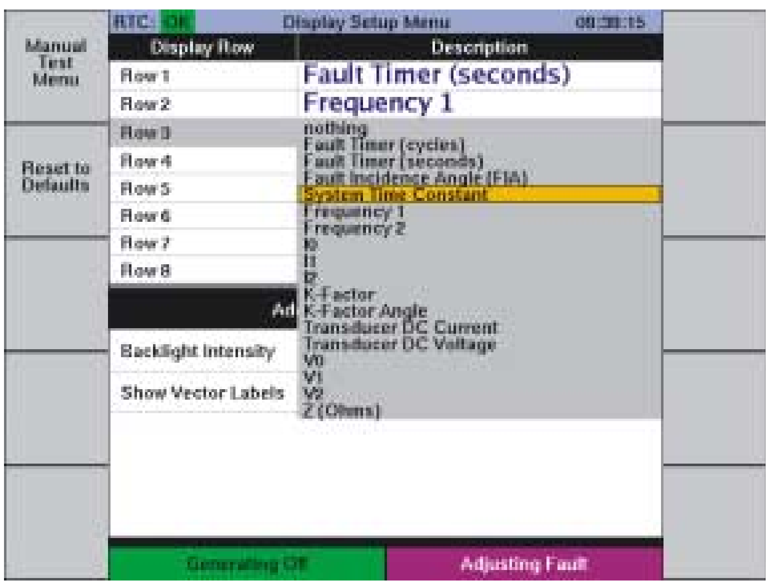


FIGURE 4.23 DISPLAY SETUP MENU

Move the cursor to the row to be modified, and rotate the MODIFY knob to display and select the options, which include:

4.9.1 Nothing

To maximize the display text size, choose this option for any rows whose information is not required for the present task.

4.9.2 Fault Timer (cycles)

This selection will cause the fault timer values to be displayed in cycles (of F1 frequency) rather than the default milliseconds.

4.9.3 Fault Timer (seconds)

This selection will cause the fault timer values to be displayed in seconds. It autoranges so the initial readings will be in milliseconds. It is the default selection for row 1. Note that the Fault Timer always measures only the time interval from fault initiation to tripping off of the initial fault. Timers 1-4 can be independently programmed for any timing interval, see sections 4.5.1 on page 4-23, and 4.5.3 on page 4-24.

4.9.4 FIA (Fault Incidence Angle)

This selection enables display of a specified fault incidence angle, as explained in section 4.8.1 on page 4-29.

4.9.5 System Time Constant

When a non-zero value is specified here, the value will be used to calculate the appropriate DC offset at the initiation of any fault, see 4.8.7 on page 4-32 for details.

4.9.6 Frequency 1

This is the default selection for row 2, identifying the default system frequency.

4.9.7 Frequency 2

This option allows a second frequency to be specified, which may then be assigned to selected AC outputs at the same time as the others output Frequency 1.

4.9.8 I0

This option enables display of the zero sequence component of the AC output current.

4.9.9 I1

This option enables display of the positive sequence component of the AC output current.

4.9.10 I2

This option enables display of the negative sequence component of the AC output current.

4.9.11 k-Factor (Zero Sequence Compensation Factor)

This option displays the magnitude of the zero sequence compensation factor, which is the proportion of residual current added to the Φ-N current of a ground fault impedance relay. The k-factor is used to compensate the measured phase current to be able to calculate the positive sequence impedance for ground impedance elements. This is also called the zero sequence compensation factor or ground compensation factor. The k-factor magnitude is the magnitude of this complex quantity. The number specified should be correct for the device being tested, so the impedance calculation (see 4.9.18 below) will be accurate.

4.9.12 k-Factor Angle

This option enables display of the angle of the zero compensation factor in degrees, as explained in the previous item.

4.9.13 Transducer DC Current

This option enables display of the DC output current from an external transducer driven by the AC outputs of the MTS-5000, via the Transducer 20 mA inputs in the Auxiliary I/O panel on the right side of the case. This enables accuracy checks to be performed on external AC driven transducers, by comparing the AC output value of the MTS-5000 to the DC current produced by the transducer driven by the AC current and/or voltage. The maximum accuracy possible is determined by the sum of the errors of the voltage and/or current sources used plus the error of the DC input. See Section 2 Specifications for the relevant accuracy figures.

4.9.14 Transducer DC Voltage

This option enables display of the DC output voltage from an external transducer driven by the AC outputs of the MTS-5000, via the Transducer 10V inputs in the Auxiliary I/O panel on the right side of the case.

4.9.15 V0

This option enables display of the zero sequence component of the AC output voltage.

4.9.16 V1

This option enables display of the positive sequence component of the AC output voltage.

4.9.17 V2

This option enables display of the negative sequence component of the AC output voltage.

4.9.18 Z(Ohms)

This option will compute and display impedance based on the fault voltage, the fault current, and if appropriate the k-factor specified above (see 4.9.11). It automatically chooses the appropriate formula based on fault type selection. It can be very useful for testing impedance relays, as it eliminates the need to perform a complex calculation to verify the impedance value at which the relay operates.

4.9.19 Additional Display Settings

These two additional settings affect other areas of the display.

> *Backlight Intensity* increases or decreases the brightness of the display. This can override the default setting in the Setup Menu accessible from the Main Menu screen, see Figure 5.2 page 5-2.
>
> *Show Vector Labels* will turn off or on the text labels on the vector display. By default the labels are on.

4.10 RAMPING OUTPUTS

Comprehensive ramping programmability is available for all AC outputs. This can be very useful during tests where it is desired to continuously vary a parameter at a specific rate, for example in testing a frequency rate-of-change relay. Voltages, currents, phase angles and frequencies may be ramped simultaneously, both up and down, in both Prefault and Fault state. To access ramping from the Manual Test Menu, press *Advanced Settings* [F4], then in the Advanced Settings Menu (see Fig 4.13) press *Set up Ramps* [F3] to open the Ramps Setup Menu.

FIGURE 4.24 RAMPS SETUP MENU

As noted in the menu, the frequency ramps will function in all modes, but the voltage, current and phase angle ramps will only function in Arbitrary mode. With the cursor and MODIFY controls, select those parameters you wish to ramp, and go through the following steps:

- Enter the initial or *Start* value
- Enter the final or *Stop* value
- Enter the *Ramp Rate*
- Select *Enable* to *On*

If the final value is smaller than the initial value, the parameter will ramp downwards, if it is larger the parameter will ramp upwards. All ramps begin when the first fault state is initiated. An individual ramp stops when its final or *Stop* value is reached. Multiple parameters may be ramped simultaneously. Different ramps may be programmed for different fault states, so ensure the desired fault state is selected via the *State* [F10] button.

The figure above is an example of multiple ramps, programmed for Fault state. Frequency 1 will ramp downwards at 1 Hz/ second (for 2 seconds), the VA channel will ramp downwards at 10 V/s, and the IA channel will ramp upwards at 1 A/s.

Ramping will begin at the entry into the state for which it is programmed.

4.11 SEQUENCE OF EVENTS (SOE) RECORDER

The MTS-5000 is capable of capturing and displaying in text format all state changes of the status inputs, output contacts, and output state changes, to a resolution of 0.1 milliseconds. This can be very useful in documenting test results, particularly when on-panel testing of complete protective relay systems is being conducted. To access the display, press *Sequence of Events* [F6] from the Manual Test Menu.

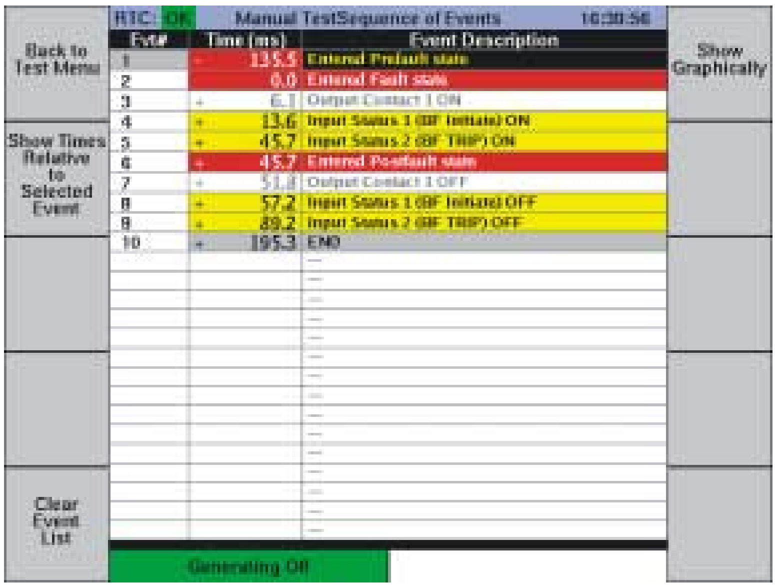


FIGURE 4.25 SEQUENCE OF EVENTS RECORDER

Because of the high timing resolution, contact bounce will sometimes result in multiple events being recorded for a single status input, unless the debounce delay has been adjusted appropriately. If more events are captured than may be displayed on a single screen, use the cursor controls or MODIFY knob to scroll down or up through the list.

Normally the timing of all events is relative to the point at which the system entered Fault mode, as shown in the figure above. It is possible however to re-initialize the timing reference point to any event in the list, by scrolling to the event with the cursor controls, and pressing *Show Times Relative to Selected Event* [F2]

It is also possible to show the sequence of events list in graphical form by pressing *Show Graphically* [F6]. The event depicted in text above is shown graphically below.

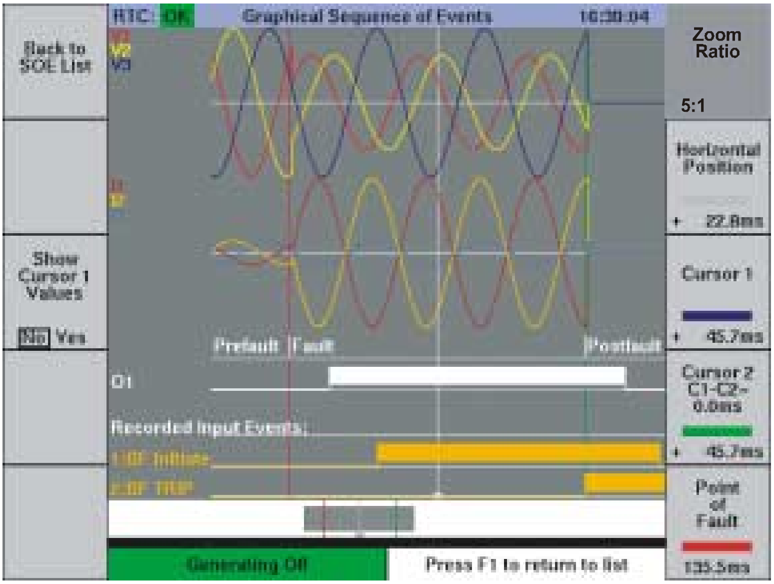


FIGURE 4.26 GRAPHICAL SEQUENCE OF EVENTS

Notice how the digital status of Inputs 1 and 2, and Output 1, correlate to the analog AC waveforms associated with the Prefault, Fault, and Postfault states listed in the SOE text of the preceding figure. Although only two inputs and one output are depicted in the graphical SOE above, all inputs and outputs that change state during the captured event will automatically be added and the display rescaled as necessary to show all the information. Note that input 2 has been assigned a custom name, see Section 3.8.1 on page 3-43 for details on this procedure.

The more events that are captured, for example excessive contact bounce, or the longer a test sequence runs, for example a postfault state that is not terminated manually or automatically following a trip, the longer it could take to process the data required to generate the graphical display. Keep this in mind when capturing events for display, and remember to clear any captured event by pressing *Clear Event List* [F5] in the SOE display before recording a new event.

The graphical SOE recorder is very similar in appearance and function to the graphical Waveform Playback display used to show the waveform data contained in Comtrade format waveform files which can be downloaded to the system, see Section 7.3 Viewing Waveform Files, page 7-4. Screens from either display may be saved to a PC via the Screen Capture feature in the Web Server, see Section 5.3.6 on page 5-12.

Controls for the display are explained in more detail in the following section.

4.12 OSCILLOSCOPE DISPLAY

The MTS-5000 status inputs are capable of capturing waveform data when connected to AC voltage signals from the MTS-5000 outputs, or other sources. The response time is 100 microseconds. Accuracy is 1.0V for <±28V, or 4.0V for >±28V. To access this function from the Manual Test Menu, press *Main Menu* [F1], then *Oscilloscope Display* [F4].

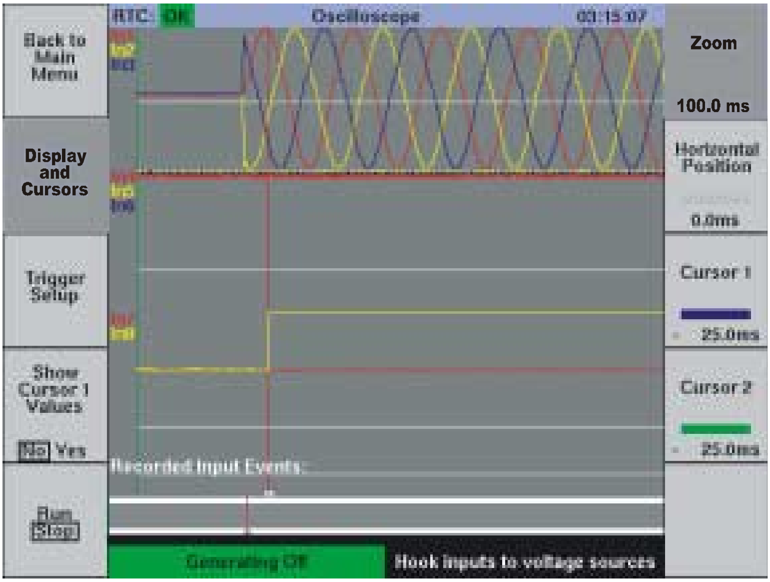


FIGURE 4.27 OSCILLOSCOPE DISPLAY

The figure above shows the default screen with a balanced three-phase 60Hz voltage applied to inputs 1-3. Use voltage-output clamp-on c.t.s for current waveforms. In this example, a DC signal on input 8 was used to trigger a single-shot capture, with 25% pre-trigger data.

The oscilloscope display looks very similar to the graphical sequence of events display shown on the previous page. An important distinction between the two however is that the SOE display waveform is automatically generated directly from the digital data used to control the output amplifiers, whereas the oscilloscope display is generated by digitizing analog voltage waveforms applied to the status inputs, and requires a trigger signal, like an oscilloscope, to capture the waveform data.

Another way of stating this is that the SOE display shows the theoretical waveforms, while the oscilloscope shows measured waveforms.

4.12.1 Horizontal Zoom and Position

The current release of this function has automatic amplitude scaling for each group of inputs (1-3, 4-6, and 7-8) and a fixed data capture length of 100 msec, as shown on the figure on the previous page. To see any portion of the waveform in greater horizontal (i.e. time) detail, such as the 20 msec window shown below, press *Zoom* [F6] and rotate the MODIFY knob to zoom in or out on the captured data, in a 1,2,5 sequence.

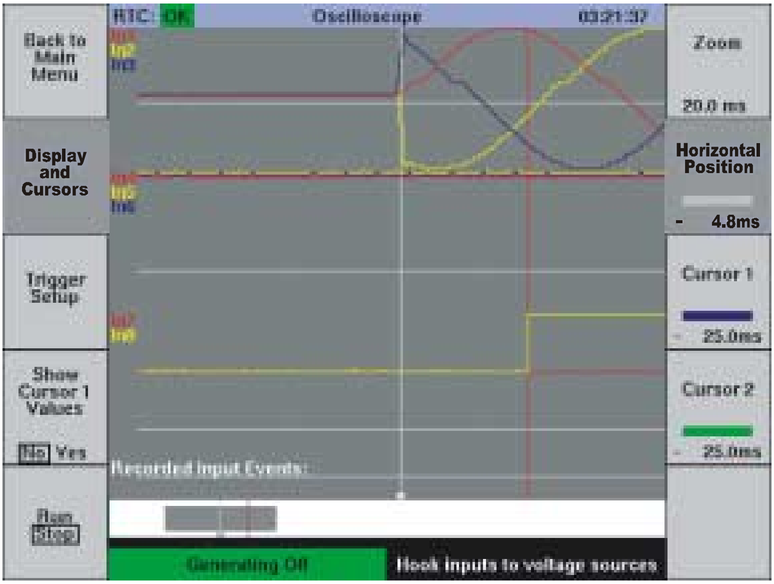


FIGURE 4.28 OSCILLOSCOPE ZOOM FUNCTION

The white bar at the bottom of the display represents the full 100 msec data buffer, and the grey rectangle within it the size of the data block chosen for display via the *Zoom* button. Compare the 20 msec block above to the 100 msec block on the previous page.

The *Horizontal Position* button [F7] enables selection, via the MODIFY knob, of the 'zoomed' block of data from anywhere within the 100 msec data buffer. The grey rectangle will move right or left with clockwise or counterclockwise rotation of the MODIFY knob to show where you are at any time within the 100msec of data.

The vertical red line in both the main display and the data window above is the trigger point. By default, the Zoom function is centered on the trigger time line. If the *Horizontal Position* control is used to move the 'zoomed' data block, subsequent Zoom operations will be centered on the mid-point of the data block, indicated by the vertical white line in both display windows. The time indication (ex.4.8 msec) in the *Horizontal Position* control is the time from this mid-point to the trigger point.

4.12.2 Oscilloscope Trigger

Trigger functions for the oscilloscope are similar to those found on conventional digital storage oscilloscopes, permitting capture of 1-shot events, pretrigger waveform viewing, and continuous-update viewing of live waveforms. Waveform capture is not automatic based on any input channel state change or fault state change as it is for the graphic SOE display, so a trigger signal must be correctly configured to capture events controlled from the Manual Test Menu. Press *Trigger Setup* [F3].

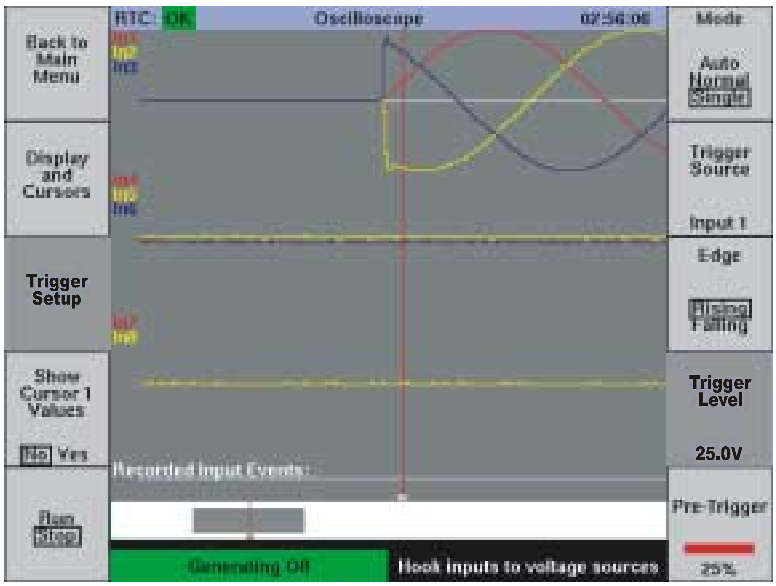


FIGURE 4.29 OSCLLOSCOPE TRIGGER SETUP

Trigger Source [F7] allows the signal on any status input from 1-8 to be selected as the trigger source. Rotate the MODIFY knob to select any input channel connected to a signal suitable for triggering.

Mode [F6] configures the system for *Auto* (default), *Normal*, or *Single* trigger operation. The first two selections are for viewing continuous live waveforms. *Auto* is the easiest to use, since it automatically generates a trigger from the internal clock signal. This produces a continuous update of the display even in the absence of an external trigger. *Normal* mode uses a trigger from an external source, as determined by the *Trigger Source* [F7], *Edge* [F8], and *Trigger Level* [F9] settings.

To freeze a display at any time during *Auto* or *Normal* mode, press *Run/Stop* [F5]. To release the frozen display and renew updating, press *Run/Stop* again. If at any time the display does not seem to be updating, check that *Run* is selected.

Single mode is used to capture one-shot events such as a COMTRADE file based fault sequence, or a short manual-controlled fault sequence terminated by a relay trip. NOTE: This is the mode that must be used if it is desired to capture waveforms on the output of the MTS-5000 itself rather than external waveforms. In *Auto* mode, and *Normal* mode (except when a valid trigger sequence appears once only) the repeated triggering causes the waveform data to be continuously updated, and since exiting from the Manual Control Menu turns off the AC outputs, no waveforms will remain on the oscilloscope display when it is reselected.

If monitoring the MTS-5000 AC outputs with its own input channels, select all input channels to *Type: Wet*, see section 4.4.1.2 page 4-19 for details. The default *Dry* setting produces a small DC voltage on the input terminals, necessary for measuring the open/closed status of isolated (dry) contacts. Although the *Dry* configuration will not be damaged by external voltage, the internally generated DC voltage can cause errors in measuring the external voltage.

Notice in Figure 4-29 on the previous page how input 1 has been programmed to generate a trigger on a rising edge at a level of 25 volts, via the *Edge* [F8] and *Trigger Level* [F9] controls. The red vertical trigger cursor intersecting the input 1 (69VRMS) voltage waveform at +25V verifies that this is where the trigger occurred. In this manner the presence of output voltage alone can be used to trigger capture of the output waveforms.

The output contact of a relay under test can also be used to trigger the capture of a fault event. Any input programmed to sense relay operation can be selected via *Trigger Source* [F7] to initiate the waveform capture. Ensure for this method of capture that the *Pre-Trigger* [F10] setting, the percentage of the 100 msec data buffer allocated to pre-trigger data, is large enough to ensure capture of the complete event resulting in operation of the trip contact.

A third method of triggering, useful in long multi-fault sequences which can exceed the available 100 msec data capture buffer, is to enable a trigger signal only in a specified fault state. Any input can be programmed to trigger this way, see Section 4.4.2.1 on page 4-20. Select the programmed input via *Trigger Source* [F7].

Once the trigger has been set by any of the above methods, enable the trigger action by selecting *Run* [F5], and exit to the Manual Test Menu ([F1] + [F1]) to initiate the test. After running the test, return to the oscilloscope display. F5 will now display *Stop* and the captured waveform will be visible. Remember to re-enable the trigger via F5 before each new event.

4.12.3 Oscilloscope Cursors

There are two cursors available to enable accurate time and/or amplitude measurements to be made on captured waveforms. Press *Display and Cursors* [F2].

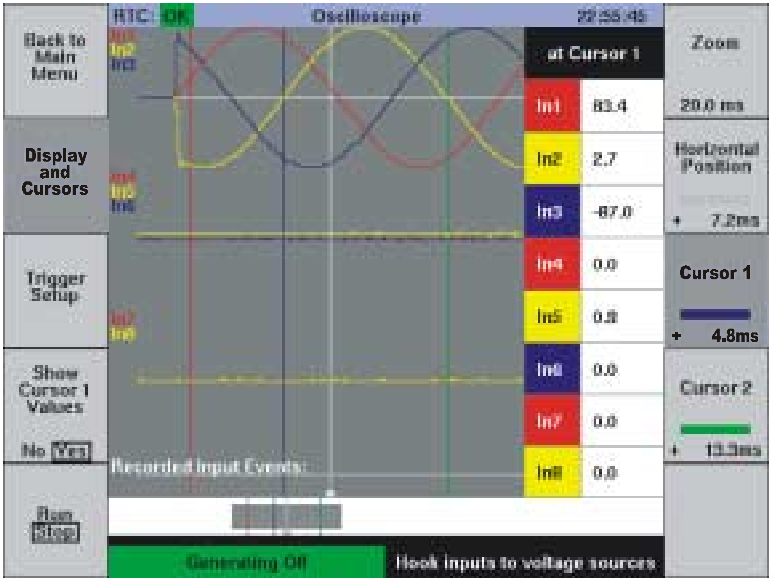


FIGURE 4.30 OSCILLOSCOPE CURSORS

Cursor 1 [F8] and *Cursor 2* [F9] buttons enable control via the MODIFY knob of the blue and green vertical cursor lines respectively. The time readouts that appear in the control labels (4.8 and 13.3 ms) indicate the difference in time between the cursor positions and the trigger point.

To access information about the signal amplitude at the cursor, press *Show Cursor 1 Values* [F4] to select *Yes*. The column of data labelled *at Cursor 1* will appear on the right side of the display as shown above. It will remain in place when the *Cursor 1* [F8] control is again selected to enable movement of the blue Cursor 1 line.

Note that when first selected the cursors may not be visible in the main display, especially if it has been expanded with the *Zoom* control. By default they are located at the extreme left edge of the white 100ms bar at the bottom of the display. By rotating the MODIFY knob clockwise initially when a cursor is selected, the cursor line will appear in the white bar, and if moved into the grey rectangle will be visible in the main display, as shown above.

DATA INTERFACES

As may be seen in previous sections the MTS-5000 is capable of very complex tasks through the use of its manual interface and graphical display. There are additional capabilities added when it is interfaced to an external computer. These include remote control of the system, the ability to replay complex waveforms generated by waveform capture devices (including some protective relays) or specialized simulation software, and fully automated test sequences under the control of external computer programs such as Manta's MPower. The three types of data interface described below allow convenient interfacing to virtually any type of notebook or desktop computer. The connectors for all three are located in the Auxiliary I/O Panel located beneath the hinged cover on the right side of the instrument.

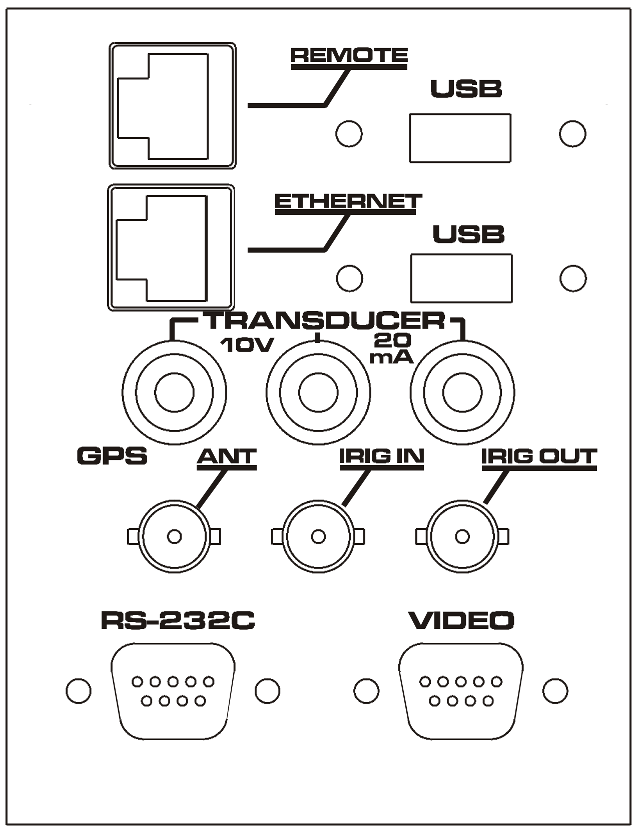


FIGURE 5.1 AUXILIARY I/O PANEL

5.1 RS-232 SERIAL

The serial port is suitable for applications requiring relatively low rates of data transmission. These include remote control via Manta’s MTS-2150 control software and MTS-2800 MPower testing automation software. For applications requiring transfer of large amounts of data, such as downloading complex waveform data, the higher-speed Ethernet or USB ports are a better choice.

The standard DB-9 male connector is wired as a DTE (Data Terminal Equipment) interface. It provides a communication facility for older computers which may not have an Ethernet interface. The data format is 8 bits, no parity, and no handshaking protocol. A standard DB-9 Null Modem cable is used to make the connection, see your Information Technology (IT) support person for assistance if necessary. It will be necessary to set the baud rate of the interface to the same as that in the software program on the computer with which it will be communicating, as described below.

If it is necessary to change the baud rate from the Manual Test Menu, press *Main Menu* [F1] to return to the menu which is always shown when the instrument is first turned on, then press *Setup* [F10] to reach the Setup Menu.

FIGURE 5.2 SETUP MENU

Move the cursor to the *Serial Port Baud Rate* cell and select a baud rate appropriate to the application. The available rates are 4800, 9600, 19.2k, 38.4k, 57.6k, and 115.2k baud. Press *Save* [F10], and this new selection will also become the default value each time the instrument is powered up.

The Hyper-Terminal program supplied with most Windows-based computers can be used as a quick test to verify RS-232C connections and settings. When baud rates have been matched as above, type HELP and press ENTER on the computer keyboard. If communications are correctly setup a message similar to that below will be returned from the MTS-5000.

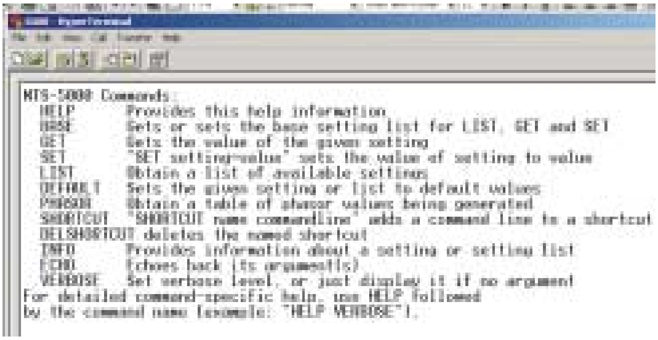


FIGURE 5.3 RS-232C COMMUNICATIONS

5.2 USB

The USB interface is capable of relatively high-speed rates of data transmission. Unlike Ethernet, it is an easy-to-use ‘Plug and Play’ interface which requires no preset configuration to work properly. The availability of compact inexpensive large-capacity ‘USB Drives’ makes it the interface of choice to field download large waveform files as well as for uploading individual test configurations and results. To download waveform files, simply insert a USB drive containing COMTRADE formatted files (ASCII or binary format) into either of the USB ports in the I/O Panel. After a brief delay the following screen will appear on the display:

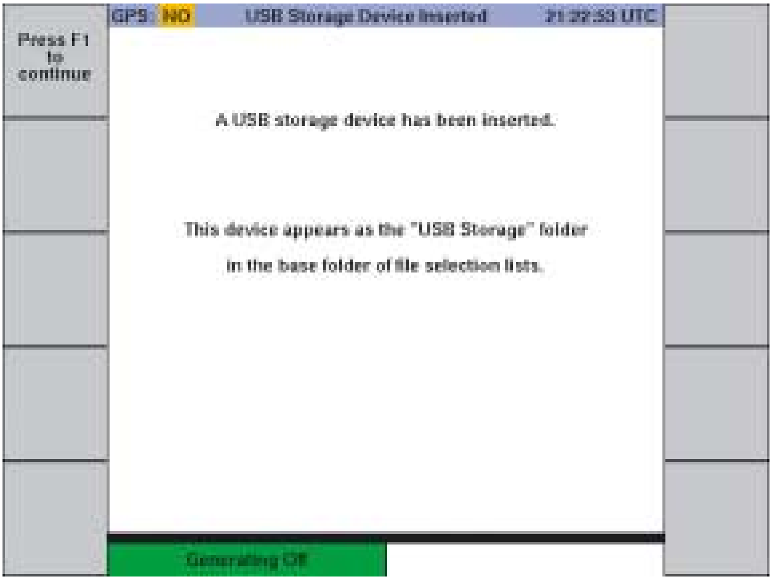


FIGURE 5.4 USB STORAGE DEVICE INSERTED

Once recognized, the files on the USB drive will appear in the file selection lists of the MTS-5000. The two file lists most likely to be used are the Save/Restore Manual Test Settings list and the Waveform Playback Files Selection list, illustrated below.

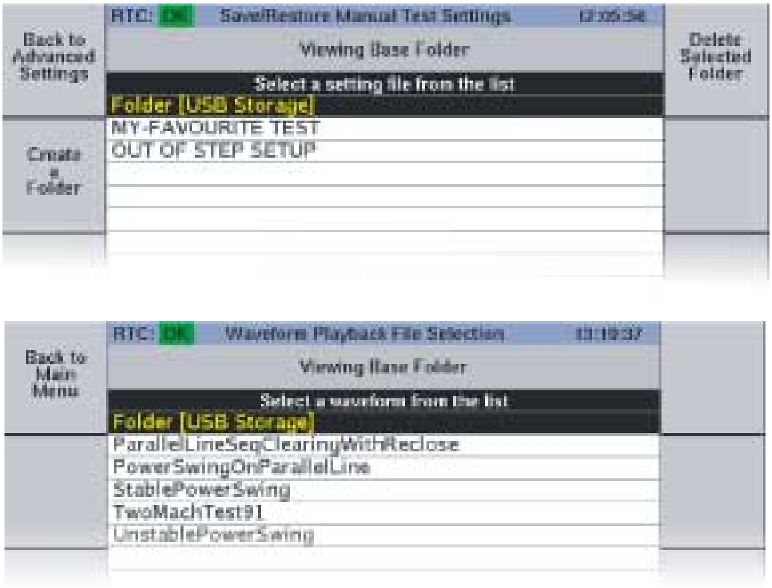


FIGURE 5.5 FILE SELECTION LISTS

The upper file list for Test Settings is accessed from the Manual Test Menu by pressing *Advanced Settings* [F4], then *Save and Restore Settings* [F7] in the Advanced Settings Menu.

The lower file list for Waveform Playback is accessed from the Manual Test Menu by pressing *Main Menu* [F1], then *Waveform Playback* [F3] in the Main Menu.

To select files from the USB drive, use the cursor controls to select the USB drive on the list, press *Enter Selected Folder* [F5] to open it, and rotate the MODIFY knob to select from the files list. For further information on Manual Test Settings see Sec 4.8.8 page 4-33, and for Waveform playback see Sec 7.2 ACCESSING WAVEFORM DATA FILES on page 7-3.

5.3 ETHERNET

Most modern laptop computers are now equipped with Ethernet interfaces. Although configuration can initially be somewhat complex, once successfully established it is a robust high-speed method for data exchange. It is the preferred method for using Manta's software programs to communicate with or control the MTS-5000. These programs include the following:

- MTS-2150 Monitoring and Control software
- MTS-2170 Power System Model software
- MTS-2800 MPower Protection test management, execution, reporting, and analysis software.
- MTS-5050 Remote Console

Direct connection to a computer requires the use of an Ethernet crossover cable, formally called a CAT 5e Male-Male patch cable. A suitable cable is provided with each new system when shipped from the factory. Note that the straight-through patch cable commonly used to connect computers to Ethernet networks will not work. Connect the crossover cable between the computer's Ethernet port and the MTS-5000 Ethernet port in the I/O panel.

For successful Ethernet communication, in general the computer and the MTS-5000 should have the same subnet mask setting, and an IP address identical but for the last digit. The computer should also be configured for a static IP address, not to obtain one automatically.

The first action therefore is to obtain the current configuration of the computer. A quick check that can be done from most Windows environments is to type the DOS command "ipconfig" from within a DOS window, which is accessible via the Command Prompt program usually listed in Programs>Accessories.

For a more detailed explanation of how to access the required information within specific Windows versions, see the following sections.

5.3.1 Windows 98 Configuration

Click *Start, Settings, Control Panel, Network,* then the *Configuration* tab of the *Network* window. Double click on the *TCP/IP* icon (see Fig 5.6), and click the *IP Address* tab of the *TCP/IP Properties* window.

If the *Specify an IP address* button is already selected, record the IP Address and Subnet mask data.

If the *Obtain an IP address automatically* button is selected, click on the *Specify an IP address* button, and enter the data shown in Fig 5.6.

Click the OK button to return to the main screen. If you have changed the settings, you will be asked if you want to restart the computer to make the settings take effect, so click *Yes*.

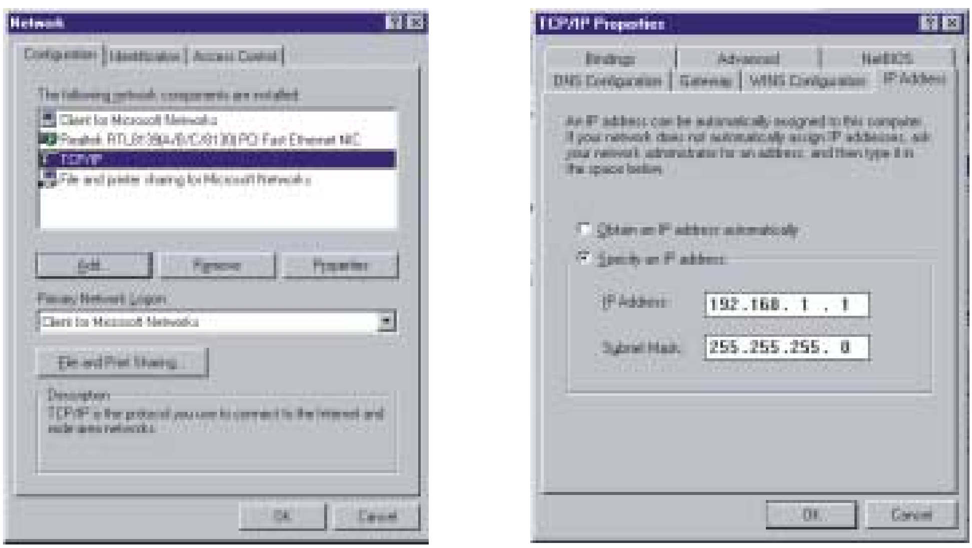


FIGURE 5.6 WINDOWS 98 NETWORK CONFIGURATION DATA

5.3.2 Windows 2000 Configuration

Click *Start*, *Settings*, *Network & Dial-Up Connection*, *Local Area Connection*, then the *Properties* button of the *Local Area Connection Status* window. Double click on the *Internet Protocol (TCP/IP)* icon (see Fig 5.7) on the *Local Area Connection Properties* window to bring up the *General* tab of the *Internet Protocol (TCP/IP) Properties* window.

If the *Use the following IP address* button is already selected, record the IP Address and Subnet mask data.

If the *Obtain an IP address automatically* button is selected, click on the *Use the following IP address* button, and enter the data shown in Fig 5.7 in the *Use the following IP address* fields.

Click the OK button to return to the main screen.

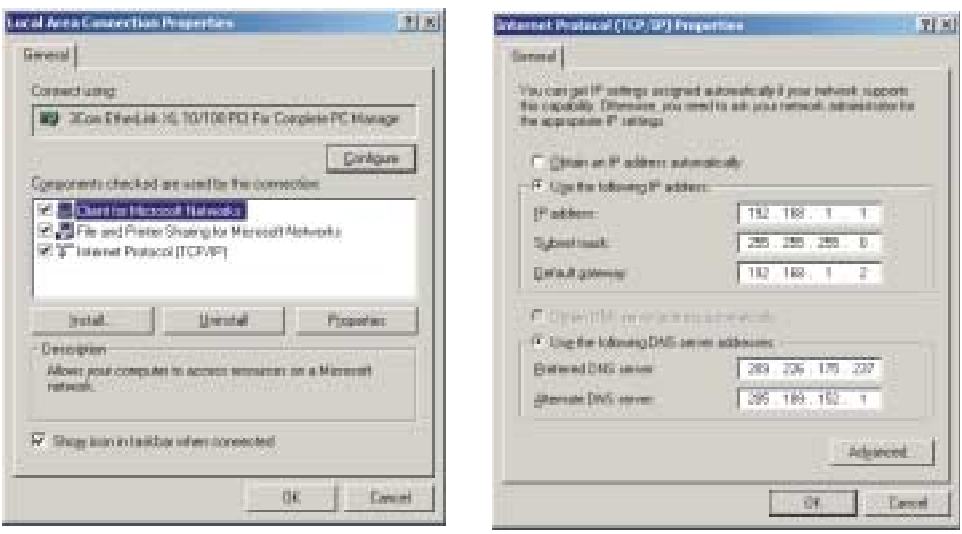


FIGURE 5.7 WINDOWS 2000 NETWORK CONFIGURATION DATA

5.3.3 Windows NT Workstation Configuration

Click *Start*, *Settings, Control Panel, Network*, then the *Protocols* tab of the *Network* window. Double click on the *TCP/IP Protocol* icon (see Fig 5.8) on the *Network* window to bring up the *IP Address* tab of the *Microsoft TCP/IP Properties* window.

If the *Specify an IP address* button is already selected, record the IP Address and Subnet mask data.

If the *Obtain an IP address from a DHCP server* button is selected, click on the *Specify an IP address* button, and enter the data shown in Fig 5.8 in the *Specify an IP address* fields.

Click the OK button to return to the main screen.

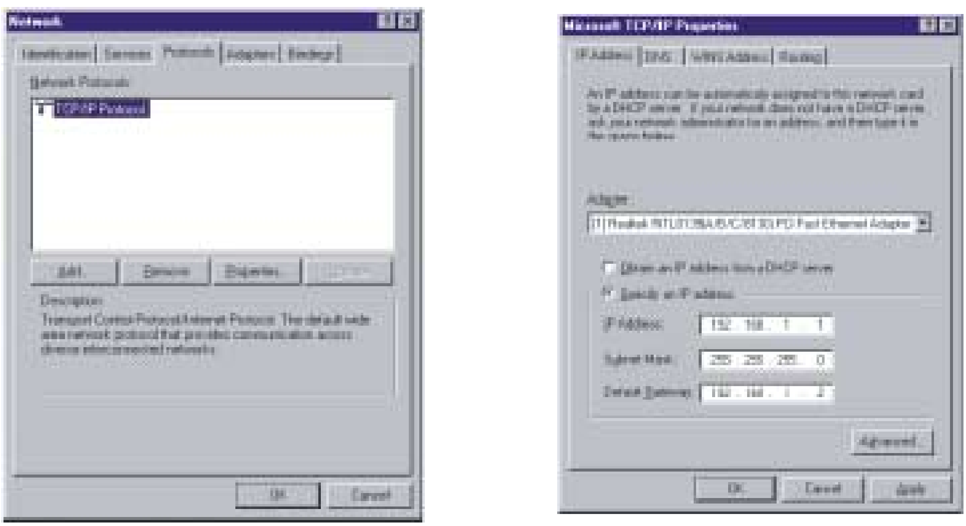


FIGURE 5.8 WINDOWS NT NETWORK CONFIGURATION DATA

5.3.4 Windows XP Configuration

Click *Start*, *Control Panel*, *Network Connections*, *Local Area Connection*, then the *Properties* button of the *Local Area Connection Status* window. Double click on the Internet Protocol TCP/IP icon (see Fig 5.9) on the *Local Area Connection Properties* window to bring up the *General* tab of the *Internet Protocol (TCP/IP) Properties* window.

If the *Use the Following IP address* button is already selected, record the IP Address and Subnet mask data.

If the *Obtain an IP address automatically* button is selected, click on the *Use the Following IP address* button, and enter the data shown in Fig 5.9 in the *Use the Following IP address* fields.

Click the OK button to return to the main screen.

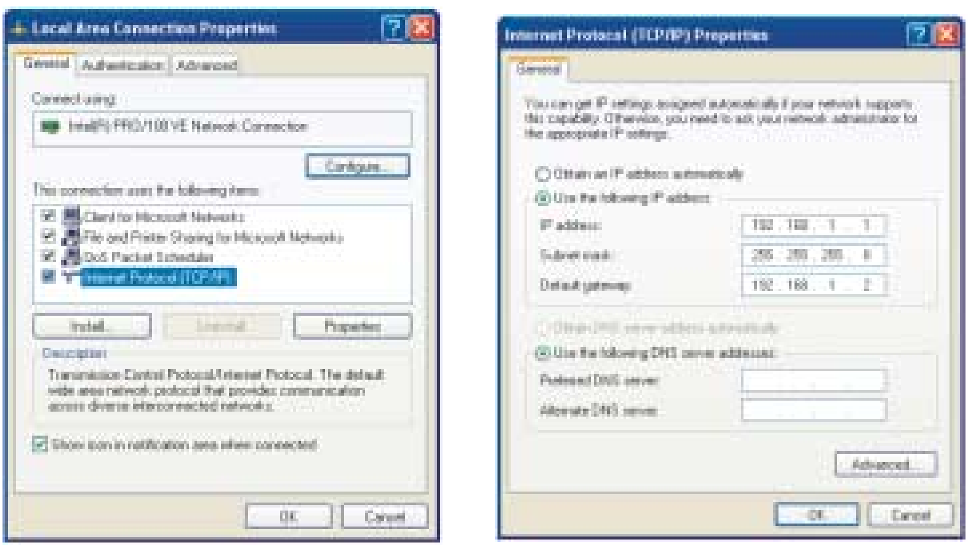


FIGURE 5.9 WINDOWS XP NETWORK CONFIGURATION DATA

5.3.5 MTS-5000 Configuration

Once the computer Ethernet configuration is known, it is necessary to check the MTS-5000 for compatible settings. From the Manual Test Menu press *Main Menu* [F1], then *Setup* [F10], then *Set up Network* [F5].

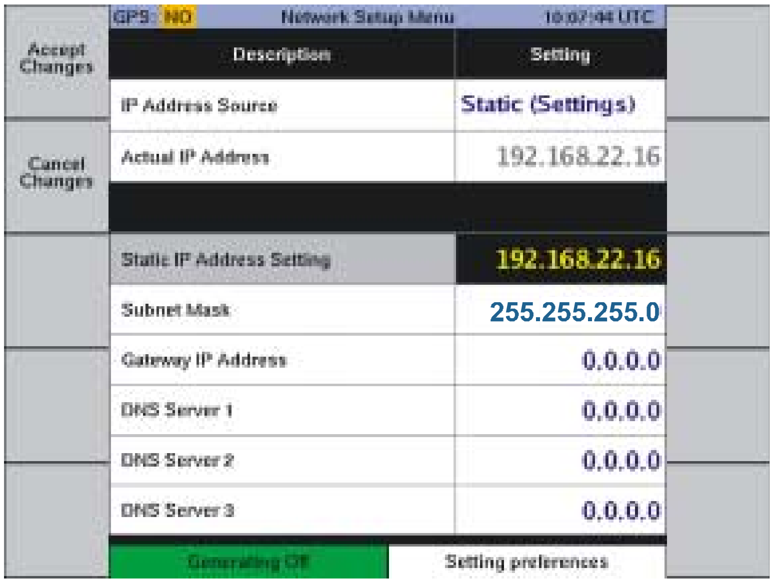


FIGURE 5.10 NETWORK SETUP MENU

Scroll to *Static IP Address Setting* and enter the IP address recorded during the appropriate Windows check in the preceding sections, identical except for the last digit. For example, in the figure above, the setting shown would be compatible with a computer having an IP address of 192.168.22.15. *Press Accept Changes* [F1], *Main Menu* [F1], and *Manual Test* [F1] to return to the Manual Test Menu.

To verify the connection is now functioning, enter the Command prompt or DOS screen on your computer. This is usually done by clicking Start, Programs, Accessories, Command Prompt. In the window that opens, type a command to ‘ping’ the MTS-5000 address; in the above example you would type “ping 192.168.22.16” followed by Enter. If the configuration is correct, some data will be returned from the MTS-5000, see Fig 5.11 on the following page.

If the ‘ping’ test fails, you may have to modify Ethernet settings on your computer. There are additional instructions available to set up this interface included in the Manta software programs that use an Ethernet interface. If necessary, see your IT technician for further assistance.

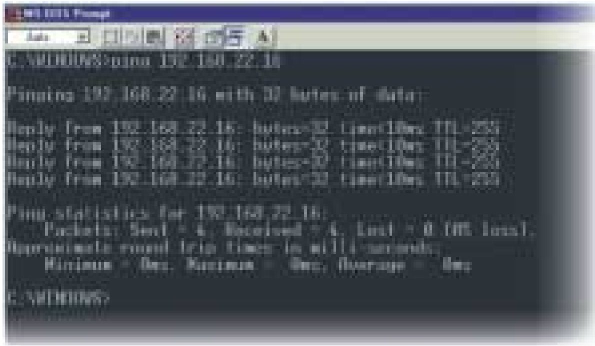


FIGURE 5.11 ETHERNET PING RESULTS

5.3.6 Web Server

The MTS-5000 incorporates a built-in web server, so it is possible to communicate with it via PC browser software such as Microsoft Internet Explorer. Entering the MTS-5000 IP address, as established in the preceding section, into the Address box of the browser, and pressing the Enter key, brings up a screen (see below) from which you may upgrade firmware, upload/download files, or do screen captures via Ethernet.

FIGURE 5.12 WEB SERVER SCREEN

Screen captures can be useful in developing training or support material, assisting in customer support troubleshooting, or saving test results such as graphic sequence of events displays. See Application Note AN5-1 for instructions on firmware upgrading via this screen. Refer to the following section for information on file management.

5.3.7 Ethernet File Management

Clicking on the link Manage Files Using FTP in the web server screen (see previous page) will open a Windows Explorer style page in the web browser, listing accessible files on the MTS-5000.

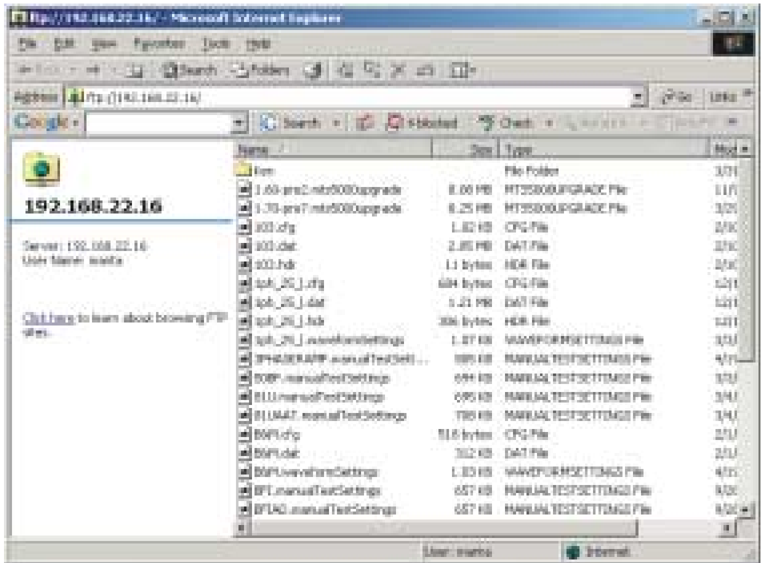


FIGURE 5.13 ETHERNET FILE TRANSFER

This offers a convenient way to download digital waveform files to the MTS-5000 directly from a desktop or laptop computer, or to remove older waveform files to make room for newer ones.

Note: if you have previously accessed the web server screen on your computer from an MTS-5000 running an earlier firmware release, the first time you run Version 1.7 or later firmware and click Manage Files Using FTP you may see a screen labelled Login As, requesting you to enter a password to login to the FTP server. In this event, press the Ctrl key on your computer and click the Refresh button on your web browser. This updates the web server screen cached on your computer. Click Manage Files Using FTP again, and you will now see the page which lists files on the MTS-5000.

The conventional method of ‘right clicking’ the computer mouse on files and selecting Copy, Paste or Delete as required from the pop-up option list can be used to move or delete waveform files. Only *.cfg or *.dat files should be erased, as other information such as earlier upgrade files are also kept in the same file folder. For information on accessing and viewing waveform data files once they are stored on the MTS-5000, see section 7.2 and 7.3, pages 7-3 and 7-4.

GPS OPERATION

A unique feature of the MTS-5000 is the on-board Global Positioning System (GPS) receiver, which allows ultra-precise time synchronization of 2 or more MTS-5000 systems. This means that it is possible for example to have 2 systems at physically separate locations, such as the two ends of a high voltage transmission line, accurately control their phase and/or frequency relationships with respect to each other. An obvious application is testing of transmission line differential protection systems which monitor phase relationships between the line terminals.

A second important capability this feature makes possible is synchronous end-to-end testing of transmission line protection systems, in which simulated faults are initiated at exactly the same time at the terminals of the line.

The GPS receiver decodes precise time data transmitted from a group of space-based satellites with on-board atomic clocks. This permits timing accuracy to ±1 microsecond at each receiver location. To receive this information, the receiver must be connected to an external antenna.

6.1 RECEPTION OF SATELLITE GPS SIGNALS

Before using the GPS receiver facility it may be necessary to select it as the time reference source. From Manual Test Menu press *Main Menu* [F1], then *Setup* [F10].

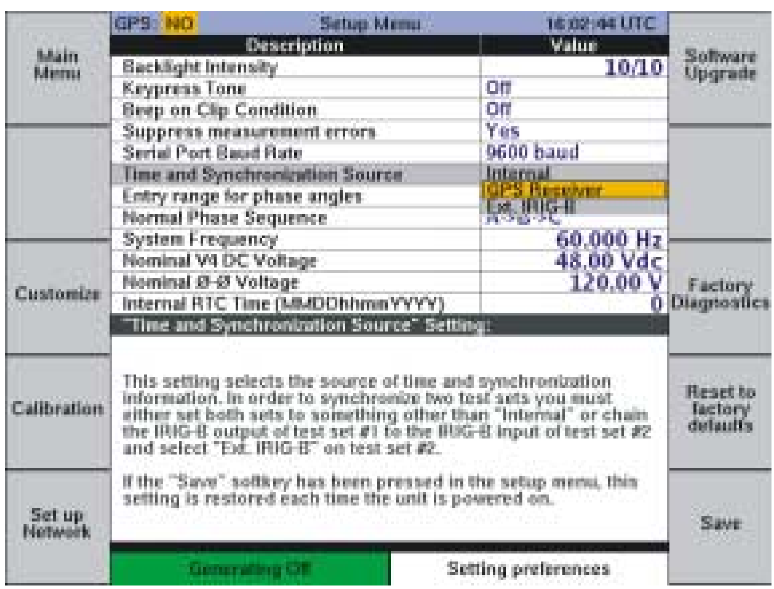


FIGURE 6.1 SETUP MENU

Move the cursor to *Time and Synchronization Source*, rotate the MODIFY knob, and select *GPS Receiver*. Note that the default selection *Internal* refers to the internal processor real-time clock. Return to the Manual Test Menu by pressing *Main Menu* [F1] and *Manual Test* [F1]. The text *GPS: NO* should now appear in the upper left corner of the Manual Test display.

Connect the supplied antenna via the BNC connector marked GPS ANT in the Auxiliary I/O Panel located beneath the hinged cover on the right side of the instrument. Carry the antenna out of doors to any location that has a clear view of a large arc of open sky, and place it on any suitable object, with the rounded upper surface facing approximately straight up. It is important that this location is away from the side of any building or structures that may obscure it’s view of the open sky, as the very low-level satellite signals necessary for correct operation of the receiver are easily blocked. Correct operation can be verified by observing information on the Manual Test Menu.

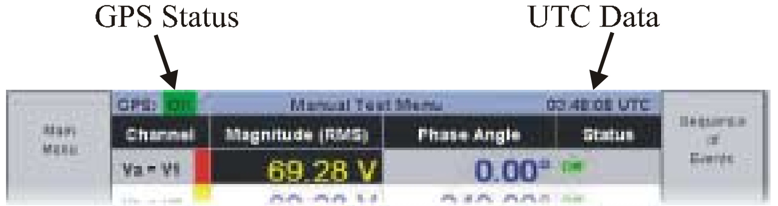


FIGURE 6.2 GPS STATUS DISPLAYS

If the receiver successfully locks on to GPS signals, approximately 1-2 minutes after the antenna is connected the GPS Status display at the top left of the display will change from *NO* in an amber box to *OK* (or *LS*) in a green box. On the top right of the display, a 6-digit number which updates once per second is visible. This number corresponds to the Coordinated Universal Time (also known as Greenwich Mean Time), in the figure above for example the time is 3 hours, 48 minutes, and eight seconds past midnight. Note that if the GPS signal is lost, this data will continue to update, but it is being maintained only by the GPS receiver’s internal clock signal, which will not be precise enough for synchronization with a second remote system. *LS* indicates the Leap Second information which is transmitted once each 12 minutes has not yet been received, so the absolute time may be out by several seconds (currently 13 sec). Therefore it may take up to 12 minutes for *LS* to change to *OK*.

If *OK* or *LS* status cannot be achieved within 5 minutes, try relocating the antenna for a better sky view. Note that it still takes up to 1 minute in a new location to lock on, so do not move the antenna continuously while monitoring the status display. The *OK* status may also appear for up to a minute after the antenna is disconnected or signal lock is lost.

6.2 USING AN EXISTING GPS SIGNAL

In some locations such as underground substations, or crowded urban areas with restricted sky view, it may not be possible to provide a usable signal for the internal GPS receiver. Since many substations now are provided with an IRIG-B signal derived from a permanently installed GPS receiver, it may be possible to make use of this data instead. The IRIG IN and IRIG OUT connectors in the Auxiliary I/O panel allow the user to tap into an existing signal with an appropriately terminated shielded coax cable.

If an existing output is available the data from it is routed to the IRIG IN connector. This port will accept either TTL or AM format data. If no output is available but the input to one of the installed devices in the data stream is accessible, the MTS-5000 may be inserted in series with the data stream. Note that the data output from the MTS-5000 IRIG OUT connector is TTL format only, so it is important to verify the downstream equipment will function correctly with TTL data. If it does, the IRIG-B signal source is routed to IRIG IN, and the IRIG OUT output is routed to the installed device input. In either application it will be necessary to purchase or construct BNC coax cables of adequate length with an appropriate connector at the installed device ends.

Once a successful connection has been made into the installed data stream, the new signal source must be manually selected. From the Manual Test Menu press *Main Menu* [F1], then in the Main Menu press *Setup* [F10]. In the Setup Menu, use the cursor keys to select *Time and Synchronization Source*, and with the MODIFY knob select *Ext IRIG-B* (see Fig 6.1 on page 6-1).

6.3 REMOTE SYCHRONIZATION

As soon as a GPS lock is achieved via either of the above procedures, and the status indicator shows *OK*, any other MTS-5000 system anywhere in the world which is also GPS locked in this manner will automatically be phase locked to your system. Frequency lock is also available just by applying the same frequency setting at both ends.

Differential line protection systems may easily be tested under these conditions by verbally co-ordinating tests at the terminals, via voice channel or telephone. An internal fault for example would require current phase reversal at one end, and an external fault would require identical current phasing at both ends.

6.4 END-TO-END TESTING

This advanced testing procedure requires simultaneous application of simulated faults at two or more terminals of a transmission line. Ideally, the fault values will be calculated independently for each terminal, based on their distance from the fault location. This means that different values would be generated at each location except for a fault equidistant from each location. By initiating these faults at precisely the same time, and using installed facilities such as fibre optic or power line carrier to transmit and receive co-ordination data, a very accurate simulation is performed, and important system performance data that is unavailable during static or single terminal testing may be captured.

To derive the most useful information from end-to-end testing, it is necessary to design a series of tests which will exercise as fully as possible all aspects of the protective relay system while minimizing the number of tests to be performed. This requires a thorough understanding of the protection scheme used, characteristics of the protection devices and communication equipment, and the ability to calculate expected fault values based on power system characteristics and fault type.

Manta’s MTS-2170 software is an efficient way specify the test characteristics and generate the settings information which the MTS-5000 requires. It will generate all data for a GPS synchronized test without the need to create COMTRADE files. It can also generate COMTRADE files for 1-terminal, 2-terminal, or 3-terminal protections in a single operation. A complete set of test scenarios will have to be generated for each terminal of a transmission line which will be participating in the test.

If the test scenarios are a series of manually-programmed faults, these will have to be programmed at the time of the test, as described in Section 4 Detailed Operation. For further information, refer to the following Application Notes, available from Manta:

- Time Synchronized End-to-End Testing of Line Protections with the MTS-5000
- Enhanced Time Synchronized End-to-End Testing of Line Protections with the MTS-5000

Except where only a very few test cases will be run, or where the intent is to modify test cases during the test sequence, a more efficient way to program multiple faults is to use the Ethernet or USB interfaces to download waveform data to the MTS-5000, see Section 5 DATA INTERFACES for more details.

A second essential aspect of end-to-end testing is reliable communication links between all terminals, preferably voice channels or telephone, since it will be necessary that each terminal initiate the appropriate test scenario at the same time.

Once each terminal has isolated the Equipment Under Test (EUT), made all necessary test wiring connections, powered up their test equipment, loaded the appropriate fault data, and has successfully established GPS synchronizing as described above, each user may arm their equipment for GPS-triggered fault initiation. In the Manual Test Menu, press *Advanced Settings* [F4], and in the Advanced Settings Menu move the cursor to *GPS-Synchronized Fault*.

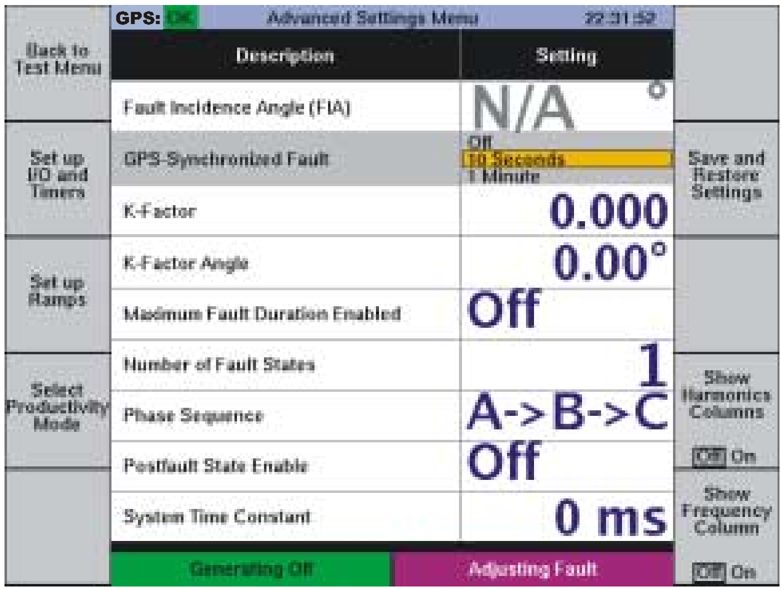


FIGURE 6.3 GPS-SYNCHRONISED FAULT

Rotate the MODIFY knob to select either *10 seconds* or *1 minute*. Press *Manual Test Menu* [F1] to return to the Manual Test Menu, and once all terminals participating in the test are ready, press the FAULT button. The AC Output warning LED will begin to flash, and a countdown indication of seconds remaining to fault initiation appears in the Fault Status box. This process may also be initiated by pressing PREFAULT, if it is desired to establish stable Prefault conditions as for example in testing a differential line protection system.

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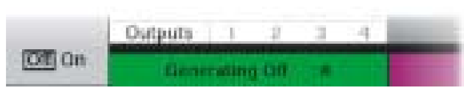


FIGURE 6.4 FAULT INITIATION COUNTDOWN

At either the next 10 second or 1 minute interval after pressing PREFAULT or FAULT, the MTS-5000 will automatically generate the programmed fault.

The actual time delay between pressing PREFAULT or FAULT and the fault initiation will vary depending on how long it will take to reach the above interval. By referring to the current UTC time displayed in the upper right corner, all participants can verbally agree to press the appropriate buttons at an appropriate time. If the FAULT button was pressed at UTC time 15:20:22 for example, and a delay of 10 seconds was specified, there would be a delay of 8 seconds until Fault state initiated, as shown in Figure 6.4.

If PREFAULT was pressed first to synchronously establish a stable Prefault state, it will then be necessary to press FAULT to initiate transition to the Fault state, and as before this will occur at the above time interval.

Once a successful synchronized fault event has been run, the results may be recorded, and the next test in the sequence initiated. The status inputs recording feature and multiple timer capabilities of the MTS-5000 are very useful in capturing results data, see Section 4.10 SEQUENCE OF EVENTS RECORDER, Section 4.11 WAVEFORM RECORDER, Section 7.6 SEQUENCE OF EVENTS and Section 4.4.6 Timer for details.

WAVEFORM PLAYBACK

The default AC output waveforms from the MTS-5000 are clean low-distortion sine waves, except when harmonic distortion is intentionally introduced to test the response to harmonics. It is also possible to introduce a DC offset to AC waveforms at the point of fault initiation by use of the System Time Constant setting, see Section 4.8.7 System Time Constant on page 4-32 for more information. In the real world however there are many cases where the waveforms seen by protective relays may contain significant distortion which can cause misoperation or delayed operation. Use of this real-world data can be of significant value in analyzing the response of protective relays to these less than perfect input waveforms. Sources of the data include digital fault recorders, EMTP or other software programs, and in some cases the digital memory of the relays themselves.

A second case where use of predetermined waveforms may be beneficial is in the use of a sequence of specific predetermined fault states, which if carefully chosen, may fully exercise all key aspects of the protective relay system in a relatively short time span. This can eliminate the need to do much more time-consuming conventional 'calibration' style testing.

In either type of application, a prerequisite is that the waveform data to be downloaded to the MTS-5000 is in COMTRADE format. This is the IEEE standard for digital waveform data exchange, and is widely used in digital waveform recorders and waveform generating software.

7.1 DOWNLOADING WAVEFORM DATA

In virtually all applications, the waveform data to be used will initially reside on an external PC which has either uploaded and/or processed stored data from a recorder or relay, or has run software to synthesize data. Two of the standard data interfaces on the MTS-5000 may be used to download the data:

- Ethernet port, requires precise configuration, but very high speed, and interfaces to office networks
- USB port, no configuration required, USB drives are inexpensive, high speed, highly portable, and easy to interface to a networked PC

For further information on these interfaces see Section 5 DATA INTERFACES.

The MTS-5000 has substantial on-board storage available for waveforms (currently 384 Mb), so it is feasible to download a large number of suitably-labelled files in an office environment for later use in the field. The Ethernet interface may be employed for this, but the current firmware for the instrument only supports FTP protocol for Ethernet data transfers; see Section 5.3.7 Ethernet File Management on page 5-13. For the purposes of this description, it will be assumed that a USB drive is used to store and download the waveform data, as it is easier and more convenient to use.

Before attempting waveform downloading, ensure that the data is IEEE C37.111 COMTRADE format, 1991 or 1999 standard. Not all COMTRADE files are in this format, especially older ones from the time period when the COMTRADE format first emerged. The software used to process and download the data should be able to identify the format, refer to the manufacturer of the software for assistance if necessary.

When using a USB drive to download the data, the MTS-5000 can read all the files available on the USB drive, and it is only necessary to download the file to be used for the current test. All the USB files may be stored in the MTS-5000 internal memory if desired however, see section 7.7 FILE STORAGE/RETREIVAL on page 7-11 for details.

Shortly after the USB drive is inserted in one of the USB connectors in the Auxiliary I/O Panel under the cover on the right hand side of the MTS-5000, a message screen appears on the display stating "*A USB storage device has been inserted. This device appears as the "USB Storage" folder in the base folder of the selection lists*." Press F1 to clear the message screen and return to the Manual Test Menu.

7.2 ACCESSING WAVEFORM DATA FILES

To access USB waveform files from the Manual Test Menu, press *Main Menu* [F1], then *Waveform Playback* [F3] to bring up the Waveform Playback File Selection screen. The USB files can be copied to the MTS-5000 file system via *Copy File From USB* [F10], or downloaded for immediate use as described below.

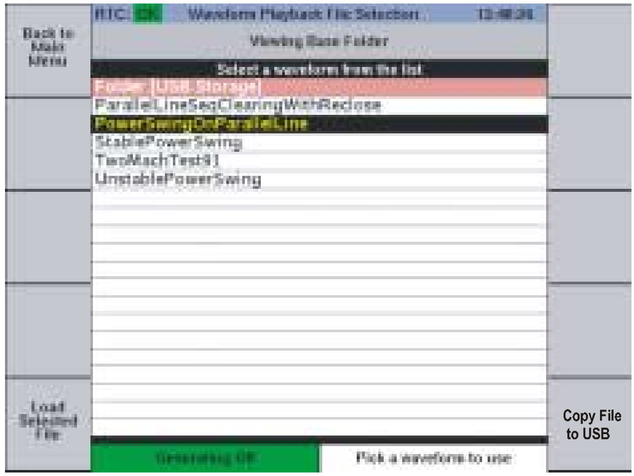


FIGURE 7.1 WAVEFORM PLAYBACK FILE SELECTION

Scroll the cursor through the list of folders and files to the USB device with the cursor controls or MODIFY knob, then press *Enter Selected Folder* [F5].

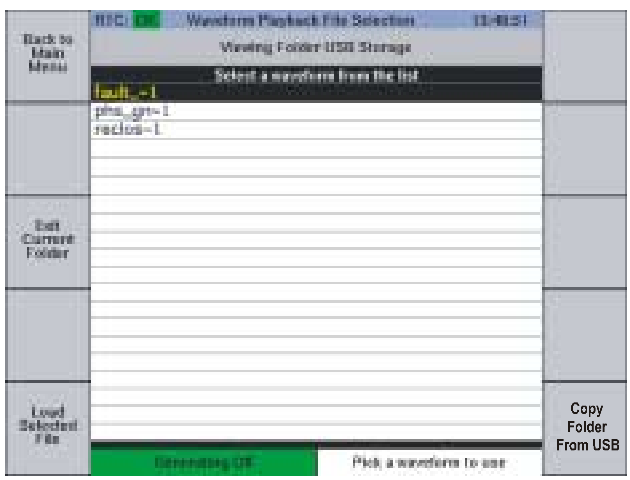


FIGURE 7.2 WAVEFORM FOLDER SELECTION

Scroll to the desired file within the folder, and press *Load Selected File* [F5]. As the file is being loaded and processed, status bargraphs show momentarily, then the waveform appears on a new screen *Waveform Playback File "filename"*, see Fig 7.3.

7.3 VIEWING WAVEFORM DATA FILES

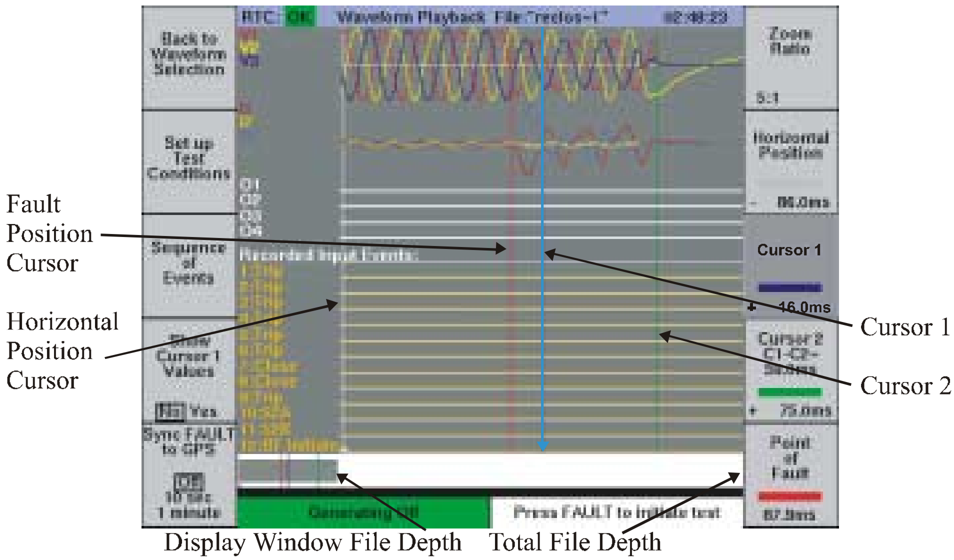


FIGURE 7.3 WAVEFORM PLAYBACK FILE DISPLAY

A number of zoom, scrolling and cursor features are provided to allow even very large files to viewed at desired zoom level and precise timing measurements to be taken.

The display window file depth bar at the lower left of the display conveys how much of the total file is currently shown in the main display window. The total file depth is indicated by the width of the entire file depth window, so in the figure above approximately 25% of the entire file is visible in the main display window.

It is possible to zoom in on any portion of the entire file. Zooming is centered about the Horizontal Position cursor. Press *Horizontal Position* [F7] and move the Horizontal cursor with the rotary knob to the place on the horizontal (time) axis you wish to zoom in on. Press *Zoom Ratio* [F6] and rotate the MODIFY knob clockwise or counterclockwise to zoom in or out respectively on that point.

Timing measurements are most often taken with respect to the point at which a fault is initiated. By default the red Point of Fault cursor will be located at the nominal initiation point, but it can be moved via *Point of Fault* [F10] and rotating the MODIFY knob. Cursor 1 readout is always with respect to the point of fault, and Cursor 2 readout displays the time between Cursor 1 and 2.

Show Cursor 1 Values [F4] will display V and I amplitudes at the Cursor 1 location.

Note that GPS synchronized fault initiation and Sequence of Events viewing are accessible from this screen via the *Synch FAULT to GPS* and *Sequence of Events* buttons F5 and F3 respectively. See Section 6 GPS OPERATION, Section 7.5 INITIATING WAVEFORM PLAYBACK, and Section 7.6 SEQUENCE OF EVENTS for more information.

7.4 CONFIGURING WAVEFORM DATA FILES

Before initiating a test using the waveform data it is necessary to ensure that the current and voltage channels have been assigned appropriately, and amplitudes specified by the data will not exceed the capabilities of the MTS-5000. Press *Set up Test Conditions* [F2] to bring up the Waveform Playback Setup screen.

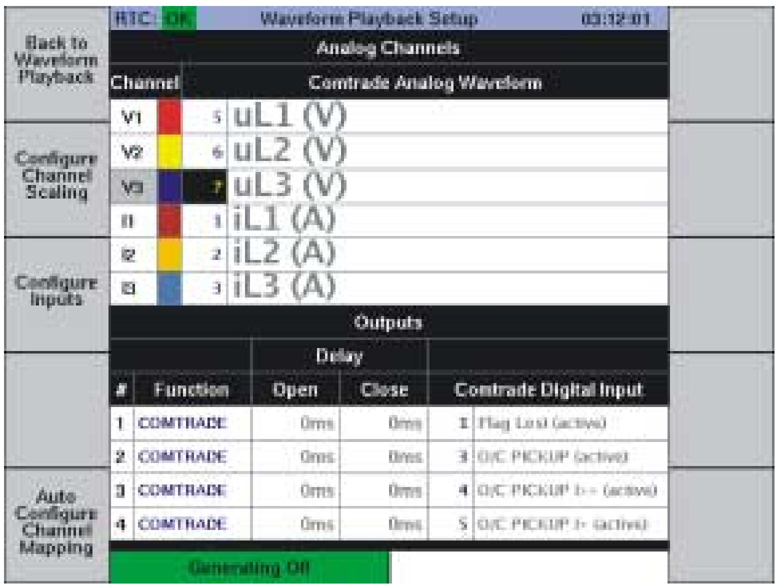


FIGURE 7.4 WAVEFORM PLAYBACK SETUP

COMTRADE files may contain more, or fewer than, the 3 voltages and 3 currents that the MTS-5000 provides. Any data channel can be assigned to any MTS-5000 output channel, so that current data for example might inadvertently be assigned to a voltage output channel. It is possible to manually select any data channel and assign it to any output channel by moving the cursor to a given output channel and selecting any data channel by rotating the MODIFY knob.

For many applications however the *Auto-Configure Channel Mapping* button [F5] will be the fastest and easiest way to map data to output channels. Pressing it will automatically assign the first three voltage data channels available to the three voltage output channels, the first three current data channels to the three current output channels, and the first four status data channels to the four digital output contacts.

It is also necessary to ensure that the AC output values specified by the data channels are within the capabilities of the MTS-5000. To access the appropriate setup screen press *Configure Channel Scaling* [F2].

FIGURE 7.5 WAVEFORM CHANNEL SCALING

The maximum values referred to in the display are peak values, which are equivalent to RMS values multiplied by the square root of 2 (i.e. 1.414). Since the MTS-5000 can generate maximum current and voltage of 30 ARMS and 150 VRMS respectively, the corresponding peak current and voltage amplitudes are 42.4A and 212.1V respectively, as noted in the display.

The *CT/PT Ratio* values may be revised if the raw file data would result in AC output values exceeding the capability of the MTS-5000. Ideally the raw data corresponds to the actual secondary current that would be seen by a relay, but since it may originate from a variety of sources, this may not always be the case. Data from a program emulating power system behavior for example might produce data representing primary current and voltage values only, and the end user would have to specify local current transformer and voltage transformer values to get correct secondary values. Even when the data does correspond to local secondary values, it may specify too high a value, particularly for current. Note that available current output levels may be doubled by using two MTS-5000 systems in master-slave configuration as described in Section 8 MASTER-SLAVE OPERATION.

When scaling of the data is necessary, there are several considerations to be kept in mind. First is that the same scaling factor should be applied to all phases of each parameter in use. Second is that the nature of the device being tested should be considered in modifying the scaling factor. Impedance relays for example monitor the ratio of current to voltage, so both parameters should be modified by the same amount even though one set of them (typically voltage) would produce acceptable output values. Third is that when doing synchronized testing with another location, which may have different c.t. and/or p.t. ratios, it is important to ensure that the end results of rescaling result in appropriate values at all locations participating in the test. It is possible for example that the local values, although all within equipment capabilities, would have to be rescaled to maintain the correct relationship to values at other terminals which would exceed equipment capabilities.

Once appropriate scaling has been verified or modified, return to the Waveform Setup display by pressing *Back to Waveform Setup* [F1]. If it is desired to change the labels on any input channels (See Fig. 7.3 page 7-4), press *Configure Inputs* [F3]. See Sec. 3.8.1 page 3-43 for a description of this process.

7.4.1 Configuring Digital Outputs

In some cases, especially actual fault files which have captured digital events like DC permissive trip signals as well as AC waveforms, it may be useful to program the MTS-5000 output channels to emulate one or more of these digital events. An example would be using an output channel to switch DC voltage to simulate the appearance of a permissive trip signal, which had been captured by a digital input channel on the recording device which generated the Comtrade file.

The lower portion of the Waveform Playback Setup screen (Figure 7.4 on page 7-5) provides a way to map selected Comtrade digital input channels to output channels on the MTS-5000. NOTE: do not confuse the COMTRADE input channels with the MTS-5000 input channels. As noted above, it is possible to provide text labels for the MTS-5000 input channels, to identify the function of the DC signal they are monitoring, which in turn is determined by the specific test connections. The COMTRADE input channels names are assigned within the device or program which generated the file, and may have no relationship to the MTS-5000 input functions.

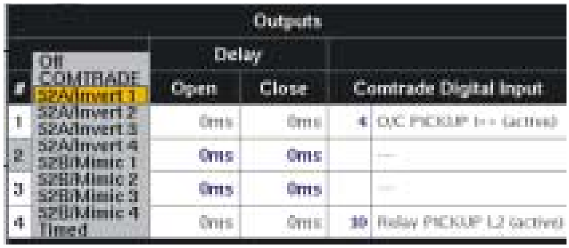


FIGURE 7.6 DIGITAL OUTPUT PROGRAMMING

The first column *Function* in the Outputs programming portion of the Waveform Playback Setup display is set by default to COMTRADE for all channels as shown in Fig. 7.3. As indicated above however, each channel may alternatively be set to simulate a breaker auxiliary switch (52A or 52B) controlled by trip sensing on inputs 1 through 4. In this event, the open and close time delays may be specified in the Open and Close columns respectively.

If COMTRADE is the chosen mode, the time delay cells will be greyed out, but the *Comtrade Digital Input* cell will be active. Cursor to this cell and rotate the MODIFY knob to select which of the available Comtrade input channels will be used to control that output channel.

7.5 INITIATING WAVEFORM PLAYBACK

With the waveform data downloaded, or accessed from on-board files, and properly configured as described in the previous sections, you may simply press the FAULT button, which will immediately initiate playback. This is the action to be followed when doing local tests. The output waveforms will be played continuously until either the outputs are tripped off by the sensing of a trip signal, the complete waveform event has been played back, or the operator presses the RESET button.

A second application is GPS synchronized fault playback, where at least two test locations need to initiate the sequences at exactly the same time. In this event, once all participating locations have confirmed they are ready, everyone selects their *Synch FAULT to GPS* [F5] setting to the same value (10 seconds or 1 minute, see Fig 7.3), then presses their FAULT button. The AC Output Warning LED will begin to flash, and at the moment the GPS time displayed in the upper right corner of the display reaches the next 10 seconds or 1 minute, all locations will begin waveform playback. See Section 6 GPS OPERATIONS for further details.

The Waveform Playback File display will update as shown on the following page to record any activity on the MTS-5000 digital inputs and/or outputs.

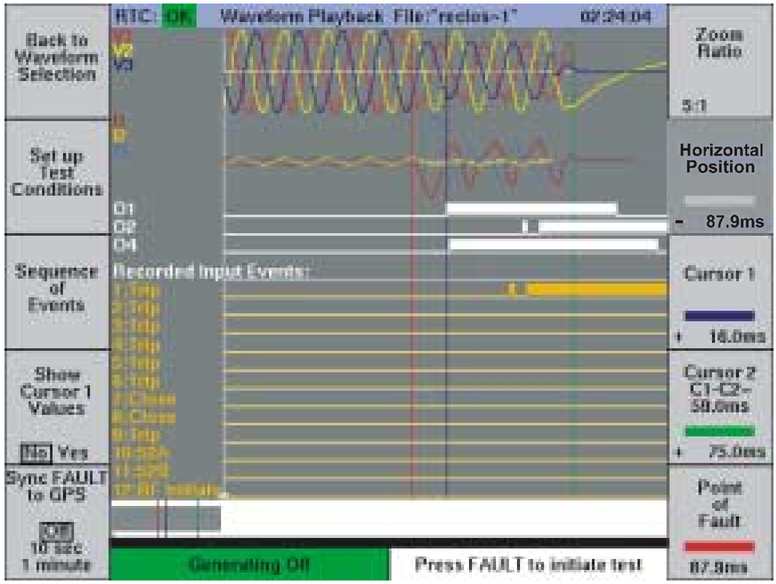


FIGURE 7.7 WAVEFORM PLAYBACK RESULTS

Compare the display above to that in Fig. 7.3 page 7-4. Note that the AC waveforms are identical, but the digital input and output traces show the response of the system under test. The programming applied to the digital output channels is identical to that illustrated in Fig.7.6 on the previous page, i.e. outputs 1 and 4 are mapped to Comtrade digital input channels, output 2 is set to *52B/Mimic 1*, and output 3 is set to *Off*. Channels set to Off will not appear on the display.

Each time the test is run again, the display will overwrite the existing one with the new test results. To save a copy of the results, or to view the events in text format, press *Sequence of Events* [F3].

7.6 SEQUENCE OF EVENTS

A tabular sequence of events record is accessible from the graphic Waveform Playback display by pressing *Sequence of Events* [F3] in that display. Shown below is the tabular version of the event shown graphically on the previous page.

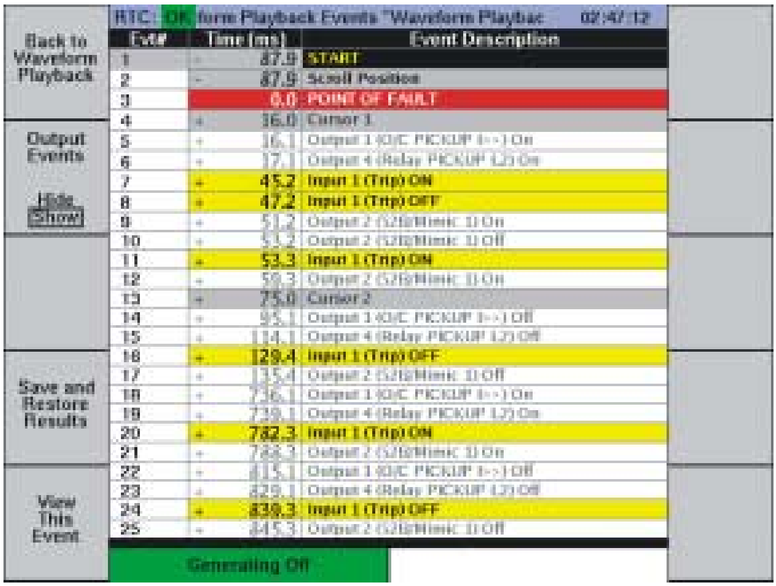


FIGURE 7.8 WAVEFORM PLAYBACK SEQUENCE OF EVENTS

As may be seen on the display, the timing events are reported with respect to the *Point of Fault*. Compare the text information in this display to the waveform traces and cursor positions on the previous page. To minimize the data appearing on the screen, there is an *Output Events Hide/Show* button [F2] which controls visibility of the digital outputs actions. The digital outputs are usually only of interest if they have been programmed to perform a specific function within the fault sequence.

To view the related waveform data at a specific point on the record, scroll the cursor to that point with the rotary knob, and press *View This Event* [F5]. This will return the screen to the waveform display, with the Horizontal Display cursor located at the exact data point.

To save the complete graphical and tabular data, press *Save and Restore Results* [F4]. The following section describes the process.

7.7 FILE STORAGE/RETRIEVAL

To store the sequence of events record for later recall, press *Save and Restore Results* [F4]. The resulting screen shown below will list all existing folders and individual files, and provides buttons for creating, editing and saving them.

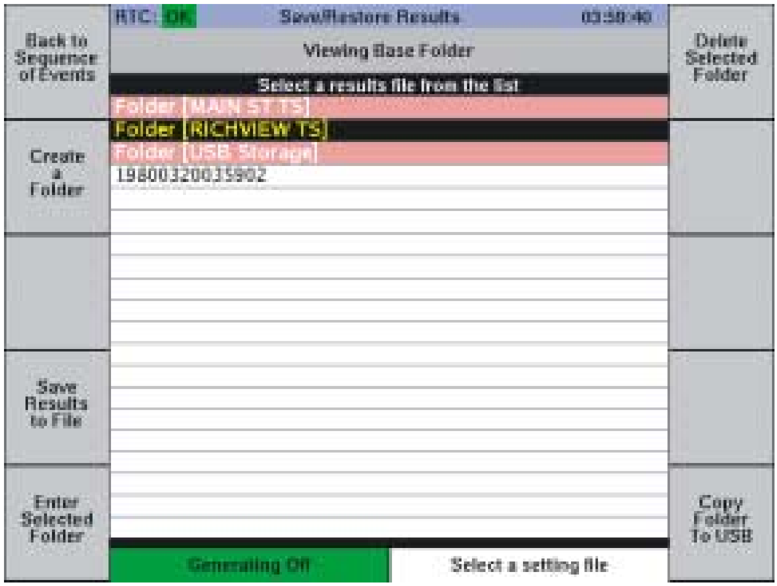


FIGURE 7.9 SAVE/RESTORE RESULTS FILES

The folders and files are similar in concept to what is found on a PC, i.e. a single data storage location is called a file, and a folder is a container for files. This means that multiple files associated with for example a particular substation can be kept within a single folder identified with the name of that station. This makes it easier to manage large numbers of files. The screen may list both files and folders. Folders are a different color to differentiate them from files.

To store the results in an existing folder, select the folder from the list by scrolling the cursor to it with the rotary knob. One may enter, delete, or exit from that folder with the *Enter Selected Folder*, *Delete Selected Folder*, or *Exit Current Folder* buttons F5, F6, or F3 respectively. Note that if a file is selected in this manner instead of a folder, the labels on buttons F5 and F6 change to *Enter Selected File* and *Delete Selected File* respectively.

During initial use of the MTS-5000 there will be no folders, and it will be necessary to create them as the categories for folders expand. To make a new folder press *Create a*

Folder [F2]. This will bring up the Folder Name Entry screen which allows alphanumeric text to be generated to label the folder.

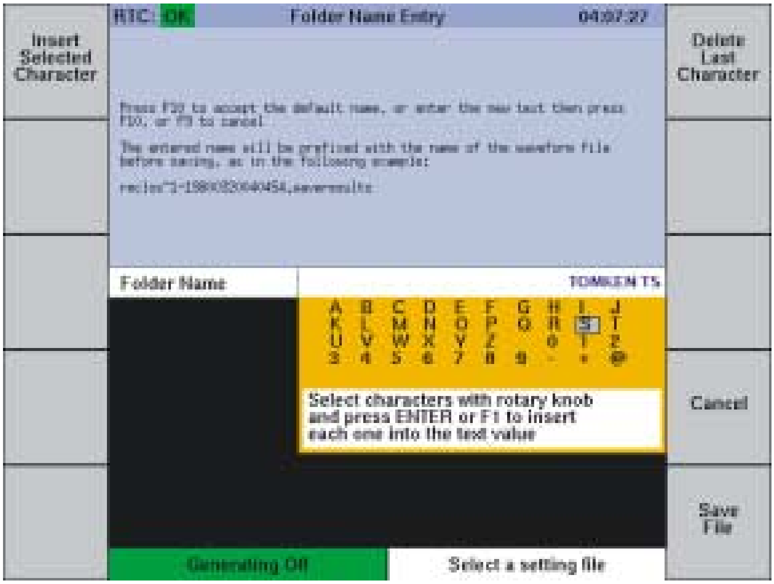


FIGURE 7.10 FOLDER NAME ENTRY

A unique name can quickly be generated for the folder using the rotary knob to select text or numbers and entering them with the *Insert Selected Character* button [F1]. The name appears immediately above the character grid. Edit as required with the *Delete Last Character* button [F6] and press *Save File* [F10] when completed. This will return you to the Save/Restore Results screen (Fig 7.9), still within the folder just created. To see the name of the new folder, press *Exit Current Folder* [F3].

To add a file to the new folder, instead of exiting from it, press *Save Settings to a File* [F4]. This will return you to the File Name Entry screen, identical to the Folder Name Screen of Fig 7.10 above except the text “Folder” is replaced by “File”. Follow the same procedure to generate a name for the file. The instructions regarding default naming in the upper part of the figure above refer to files not folders.

7.7.1 Save Settings File

It is also possible to save MTS-5000 test configurations in a file for subsequent rapid setup of complex tests. Pressing *Save and Restore* [F7] in the Advanced Settings Menu will bring the user to the Save/Store Results screen of Fig 7.9. Creation of folders and/or files for this application is identical to the process described in the preceding Section 7.7. See Section 4.7.8 on page 4-33 for further details.

MASTER-SLAVE OPERATION

A unique feature of the MTS-5000 is its ability to work in a master-slave configuration with a second MTS-5000. This permits up to 6 currents plus 6 voltages to be controlled from a single manual interface. Applications include 3-phase testing at up to 60 amps per phase, single phase testing at up to 180 amps, testing modern transformer differential relays with 6 simultaneous currents, synchrocheck relay checks with up to 6 voltages, and bench testing of line differential relay systems.

The only additional hardware required to configure 2 systems for master-slave operation is an Ethernet crossover cable, formally called a CAT 5e Male-Male patch cable. A suitable cable has been provided with your system at the time of purchase. Plug this cable into the RJ-45 Remote jack in the Auxiliary I/O bay located behind the panel on the right hand side of each system, see Figure 5.1 on page 5-1.

8.1 SLAVE SYSTEM CONFIGURATION

Power up both systems, and on the system which is to operate in slave mode, from the Main Menu press *Remote Control* [F18] to enter the Remote Menu. Press *Slave Mode* [F2] to enter the Slave Mode Menu.

FIGURE 8.1 SLAVE MODE MENU

With successful communication established between the 2 units the display will look like Fig. 8.1. The slave unit retains local control only for the V4 DC output via *V4 On/Off* [F6]. Do not press any other buttons on the slave unit until testing requiring master-slave configuration is complete.

8.2 MASTER SYSTEM CONFIGURATION

The other system automatically assumes master configuration, and its Manual Test Menu will by default display all 12 current and voltage channels, which may be manually controlled in the normal manner via the cursor and MODIFY controls.

FIGURE 8.2 DEFAULT MASTER CONTROL DISPLAY

Most testing applications will not require the full complement of individually controllable sources as shown above. Disabling voltage sources which are not required, and paralleling currents as needed, will simplify the control display, and will increase the text size on the display.

To optimize the control interface by selecting only the sources required for the application, enter the Amplifier Configuration Menu by pressing *Configure Amplifiers* [F3].

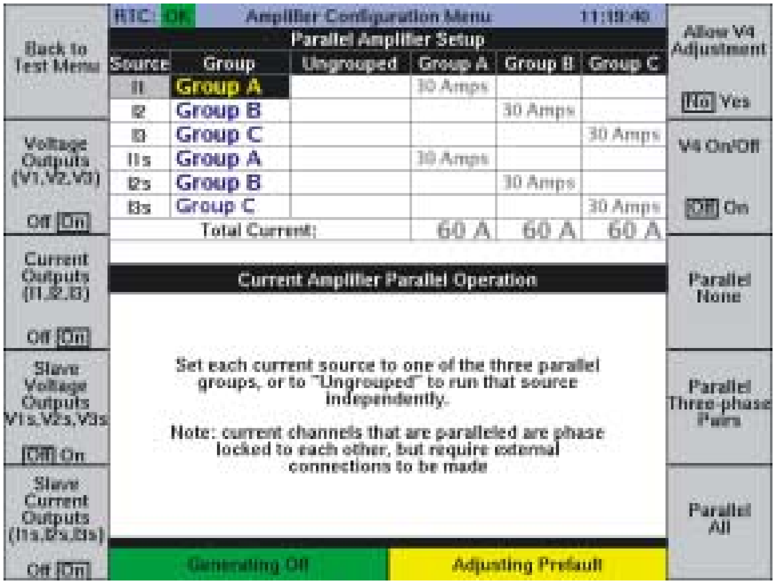


FIGURE 8.3 AMPLIFIER CONFIGURATION MENU

In the example above, the currents have been paralleled via *Parallel Three-phase Pairs* [F9], and the slave unit voltages disabled via *Slave Voltage Outputs*.[F4].

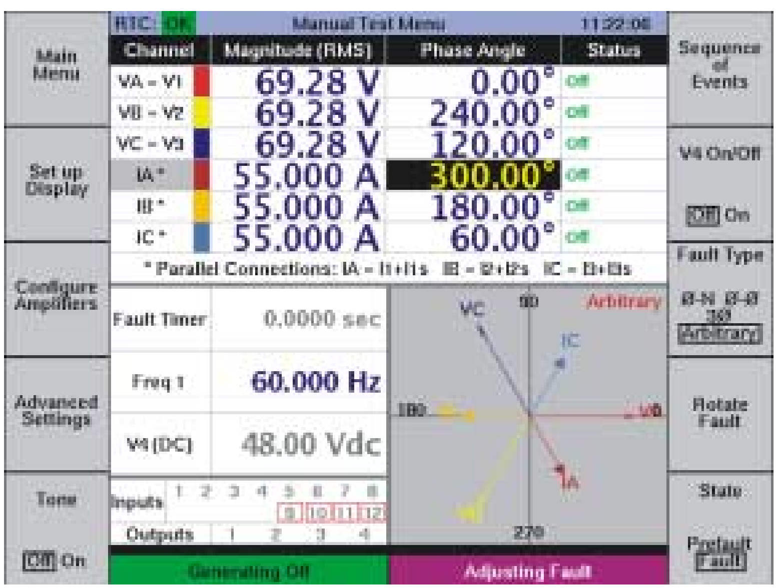


FIGURE 8.4 MODIFIED MASTER CONTROL DISPLAY

Note the cleaner appearance of the display after the above changes.

8.3 APPLICATIONS

Although the systems automatically make the individual amplitude, phase, and frequency adjustments to paralleled current channels, the outputs of all parallel channels must physically be paralleled externally, as shown below.

NOTE: ONCE A CURRENT SOURCE IS ASSIGNED TO A PARALLEL GROUP, IT MUST BE CONNECTED IN PARALLEL WITH THE OTHERS OF ITS GROUP OR SHORT CIRCUITED. ANY PARALLELED SOURCE NOT CONNECTED WILL OVERLOAD (CLIP).

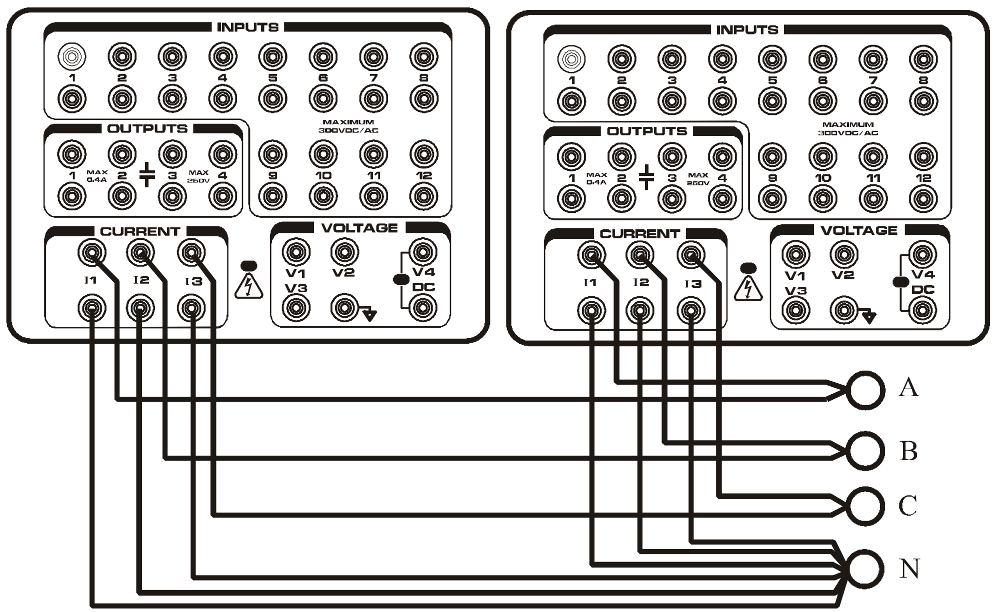


FIGURE 8.5 CURRENT CONNECTIONS FOR 3X2 PARALLEL OUTPUTS

Note that the maximum compliance voltage available is equal to that of a single current channel only, so if the V=IR voltage drop across the test load at the desired current level exceeds the compliance voltage, clipping will occur, and an alarm warning *Clip* will appear in the Status cell of the affected channel(s).

To maximize compliance voltage available at the relay terminals, i.e. to maximize the current available without clipping, use the largest gauge wiring possible and ensure all connections from the wiring to the relay inputs are firmly tightened. It is also important to supply individual leads from each channel's neutral terminal as shown, even though they are all internally connected, to avoid overloading the neutral lead.

The following figure shows the current connections required for a 6-current transformer differential relay test.

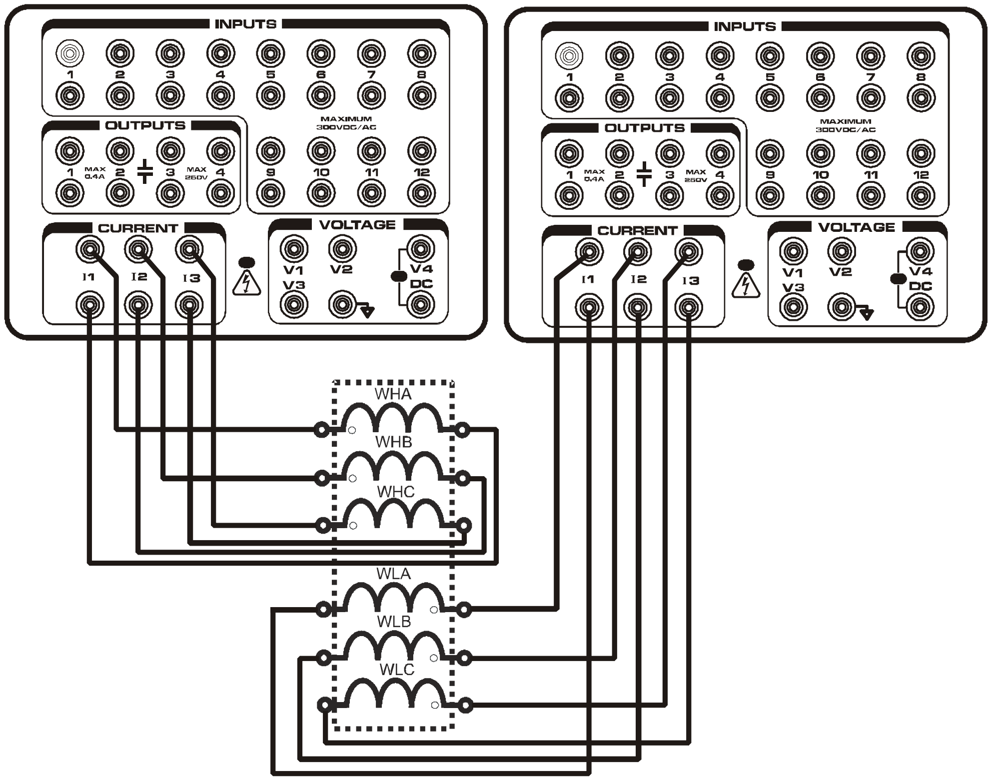


FIGURE 8.6 6-CURRENT TRANSFORMER DIFFERENTIAL TEST

The connections shown allow for the highest possible current levels. If the tests are performed at relatively low levels, where the total current of all three phases from one MTS-5000 system will not exceed 30 amps, the individual current leads from each current source neutral to the relay winding ‘non-spot’ terminals may be reduced to a single lead between any current source neutral and any non-spot terminal, which must in turn be connected to the other two non-spot terminals with jumper conductors. This will reduce the number of longer test leads running from each MTS-5000 by two each.

The following figure shows current connections required for bench testing a line differential relay protection system.

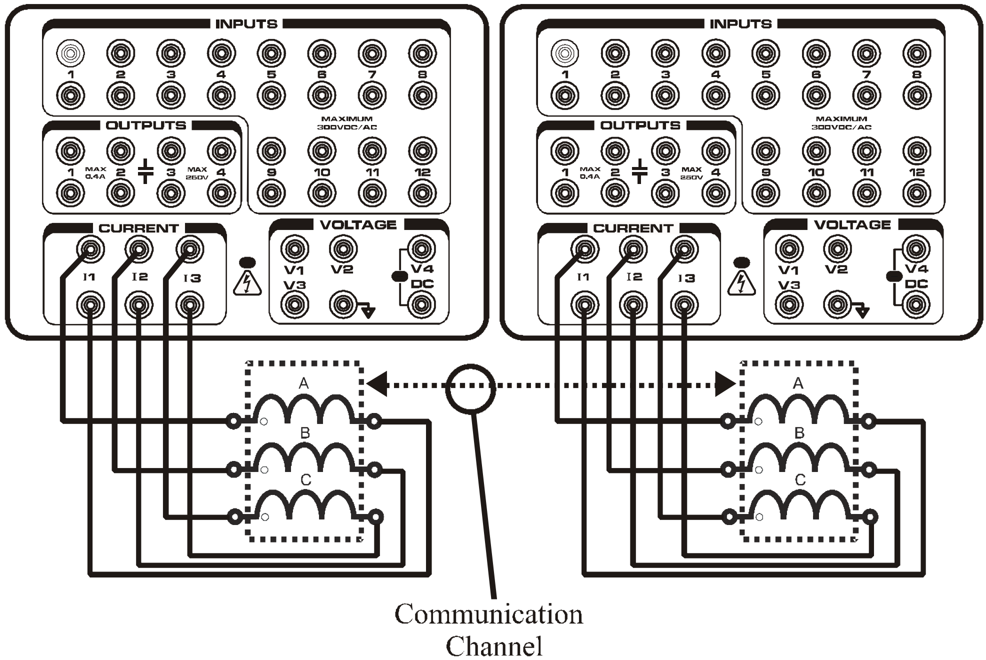


FIGURE 8.7 LINE DIFFERENTIAL RELAY TEST CONNECTIONS

These connections are identical to those used for in-service testing of a line differential protection system, except that appropriate communication link(s) between the two relays must be temporarily established for the duration of the test.

Bench testing in this manner allows the performance of the system to be verified at a single location, without the need for establishing a GPS lock to synchronize the MTS-5000 systems.

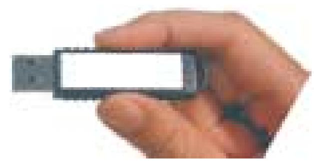
As in the previous example, connections shown are suitable for high-current testing. If the total current from an MTS-5000 system will not exceed 30 amps, a single conductor may be used between the jumpered-together 'non-spot' terminals of the relay and any 1 of the 3 current channel neutral terminals.

For in-service testing of line differential relays using master-slave configurations at each end to achieve higher phase currents, it is only necessary to connect a GPS antenna or IRIG-B signal to the master unit at each location.

SOFTWARE UPGRADE PROCEDURE

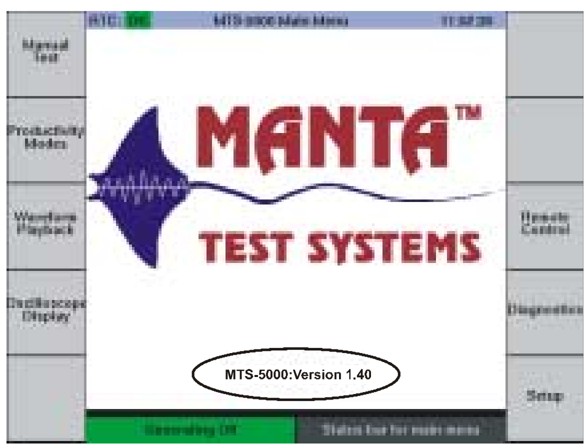
1 INTRODUCTION

The MTS-5000 uses FLASH memory for program storage. This makes software upgrades in the field a quick and simple process. Software upgrades take approximately two minutes. The only hardware required is a standard USB drive loaded with the appropriate upgrade software, which can be downloaded from Manta.



2 PROCEDURE

Power up the MTS-5000, and when the MTS-5000 Main Menu is displayed record the software version.



Press *Setup* [F10], then *Software Upgrade* [F6].

Insert the USB drive into either of the USB ports on the right side of the case. After approximately 10 seconds the message "*A USB Storage device has been Inserted*" should appear.

Press F1 to proceed to the next screen shown below. If necessary use the cursor keys to select *"Folder [USB Storage]"*.

Press *Enter Selected Folder* [F5]. If necessary use the cursor keys to select the desired upgrade file.

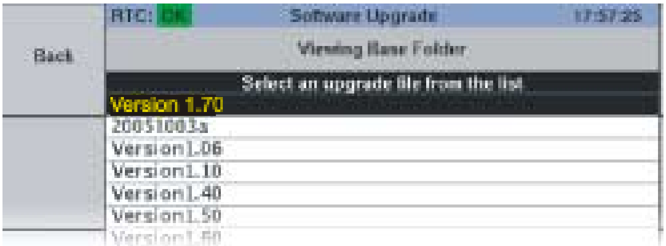
Press *Copy File From USB* [F10] and <u>WAIT</u> until the button turns from dark grey to light grey again. This loads the file into the MTS-5000's on-board files.

Press *Exit Current Folder* [F3] and remove the USB memory stick. Wait for the following screen, then press F1 *Press F1 to Continue*.

Turn off the mains power to the MTS-5000, wait several seconds, and power it on again.

From the Main Menu press *Setup* [F10], then *Software Upgrade* [F6].

If necessary use the cursor keys to select the upgrade file just uploaded.



Press *Load selected File* [F5], and wait for the following screen to appear.

Press *Install* [F1], and wait for the following screen to appear.

Turn off the mains power to the MTS-5000, wait several seconds, and power it on again.

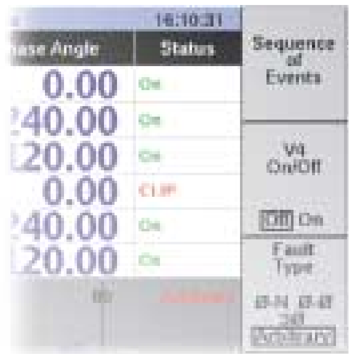
In most cases the screen on the following page will be displayed the first time the unit is powered up after a software upgrade.

This occurs only when the new software also requires new firmware to be loaded into each amplifier. After about 15 seconds the status message for all amplifiers will change to *Off*.

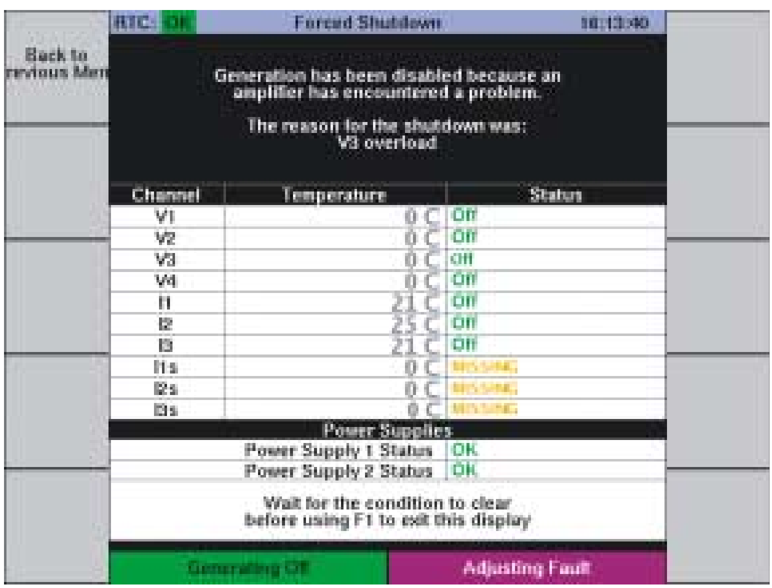
Verify that the unit powers up in a normal fashion, and that the desired software version has been loaded.

STATUS MESSAGES

The *Status* column of the MTS-5000 conveys information on equipment status as well as warning and error messages. By far the most common messages are *On* and *Off* as the AC outputs are turned on and off respectively. Occasionally an abnormal operating condition may bring in an alarm as shown below.



The message in this example is caused by clipping of the IA current channel, the most common alarm type. Some less common situations may shut down all outputs and generate the following display.



Note that different colors are used to differentiate message classes, and that the *Forced Shutdown* display offers some additional information on system conditions.

Listed below are the messages that may appear in the Status column, with explanation of their meanings, and actions if any to be taken.

On - The output channel associated with this status cell is turned on.

Off - The output channel associated with this status cell is turned off.

CONTROLLED BY MASTER - This message indicates that the output channels are being remotely controlled by a second MTS-5000 in a master-slave configuration, and will not respond to local manual control.

CLIP - The output channel associated with this status cell is clipping, i.e. the amplifier in that channel can not produce a sinusoidal output voltage high enough to supply the connected load with the programmed current or voltage.

In most cases this will be a current channel, and the cause will be an open current circuit or too high a load burden for the specified current. In either case the outputs should be turned off until the problem is rectified. The system may be programmed to produce a warning beep for this condition, see page 3-33.

An open circuit is usually due to a lead falling off a terminal, or an incorrect connection. Verify the connections integrity before re-energizing the output.

Excess current load clipping may be rectified by reducing burden by shorting out elements of the output circuit which are not currently being tested, or by running the test at reduced current level.

clip - This remains on for a few seconds after clipping has been detected. It can be useful to indicate a problem during short-duration current pulses.

SHORTED - The output of the voltage amplifier associated with this alarm may be shorted. Turn the outputs off and correct the output wiring.

HOT - The output amplifier associated with this status cell is overheating. This is most likely to occur with the current amplifiers, when they are delivering high power. High ambient temperatures can contribute to this condition.

To minimize the occurrence of this condition, ensure all cooling inlets and exhausts are free and unrestricted. Leave the equipment powered up with fans running but outputs off to cool it down. If necessary to do tests at high power levels, reduce the duty cycle of the tests.

TOO HOT **-** The power supply is overheating. This condition may affect all output channels. Same resolution as for *Hot* alarm.

OVERLOAD **-** The output amplifier associated with this status cell is overheating due to too high output power requirements. This is most likely to occur when testing complete racks of electromechanical relays, or when very high output power settings are being specified.

The output load must be decreased by shorting current elements or removing voltage elements not under test, or by specifying lower output levels.

Loading n...n **-** This is a transient message, normally only appearing while the equipment software is being upgraded. It clears when the update process is complete. Other messages that may also appear briefly during this process are: *MISSING, Loading, Loading n-F, READING CAL, SAVING CAL, CAL CHANGED,* and *NOT CALIBRATED*.

MISSING **-** This message may appear if an amplifier has been removed for service.

NOT CALIBRATED **-** If this message appears during normal operation, the calibration factors for that channel may have been lost. Contact Manta for assistance.

OFFLINE **-** This may indicate an internal problem with the channel. Other messages of this nature are *FAILED*, and *SHUT DOWN*. Contact Manta for assistance.

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