PDHonline Course E120 (2 PDH)

Plant Electrical Troubleshooting

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Plant Electrical Troubleshooting

Thomas Mason, P.E.

Course Content

Formal troubleshooting consists of five steps, as follows:

1) listening carefully to a description of the perceived problem;

2) first hand observation of the situation and measurements, when possible;

3) talking with the person who observed the problem;

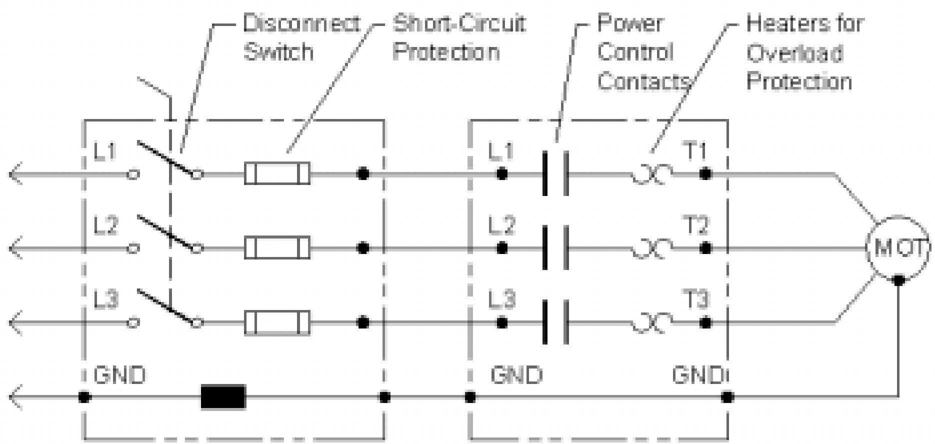
4) postulating a solution or course of action, based upon knowledge and experience;

5) testing and implementing the course of action.

Any proximity with open equipment requires attention to safety principles. These will be discussed throughout the course and summarized at the end.

Listen carefully to a description of the perceived problem: Try to solve the right problem. Most problems have a chain of interactions. It is critical to identify the desired end condition after the troubleshooting. A call-back is wasteful and damaging in many ways.

EXAMPLE: Motor won't start.



Simplified Three-Wire Diagram

similar to NEC Handbook Exhibit 430.2

Testing: Voltmeter following power circuit identifies power available at disconnect switch, but not on load side of fuse.

Solution: Replace fuse with larger fuse.

Discussion: Fuses do fail for no reason. More often, however, they fail from long-term overload or massive short-time fault. Replacing a fuse doesn't fix the overload or intermittent fault. (This graphic is from the PDHonline.org course on Motor Control.)

Similar examples: 1) Motor won't start; overload keeps tripping; replace with larger overload heater.

2) Motor won't start; starter contacts badly burned; replace contacts or install larger contactor.

Observe the situation and take measurements, when possible: Solving the problem is usually much easier than identifying the problem. Personal experience is that the phone call and first visit are usually followed by a second data gathering visit. One extremely helpful tool is the digital camera. Take photos of the nameplates of the equipment in question. Take panoramic photos of the room containing the equipment, including ceiling and floor. (These help answer later questions without a long drive and are meaningful in a report.) Take high resolution photos of the controls, also with the covers removed.

PERSONAL PROTECTION WARNING: The National Electric Code restricts electrical access to trained persons. OSHA is very leery of working on energized equipment.

SOLUTION: You want a local electrician to open cabinets and make measurements. (He is also helpful in keeping you from backing into energized busses while taking photos - consider a wide angle adapter lens.) Engineers are not electricians, even if you teach the safety course.

WARNING: Don't mess with high voltage. Insist on a local electrical high voltage technician or hire in a high voltage technician from one of the national service companies. The local technician who works on electrical utility can be contracted for several hundred dollars. The national service technician will cost $500-2,500. (Two 800-numbers for GE I&SD quoted $500 and $2500 to set the solid state trips on the molded case main cb of a 480V switchboard.)

EXAMPLE: The plant engineer for a large refinery was guiding a tour of visiting engineers. He pointed out the new medium voltage switchgear which fed the new process unit. He operated the door interlock defeat and opened the door. The breaker tripped. The unit shutdown. It is better to NOT be the visiting expert who opens the door.

EXAMPLE: Reported problem when plugging the floor buffer into particular hall receptacles.

TESTING: Receptacle tester produced erratic readings. Appeared subject to handling of the plug in the receptacle.

SOLUTION: Receptacles installed with poke-in connectors, making poor contact. Replace receptacle devices; noted charring of insulation, indicating overheating.

Talking with the person who observed the problem: When you walk out in the plant with the electrician, talk to him. Ask about the overall electrical system. Ask about other electrical problems. Ask who reported the problem. Try to talk to that person.

EXAMPLE: The author drove 3-1/2 hr to observe a variable frequency drive which consistently tripped off at 6:30AM.

OBSERVATION: The VFD did not trip off at 6:30AM. The operator said that it tripped the previous day at 1:30PM. He further said that he observed no pattern in times of failure.

OBSERVATION: The voltage logger showed no perturbations over a two-week period, even though the VFD diagnostic reported tripping on low line voltage.

OBSERVATION: The adjacent machine, on the same power source, of identical design, installed at the same time, ran flawlessly through the test period.

SOLUTION: The drive was defective. When the service technician could be convinced to replace the regulator card, the machine worked well. The VFD diagnostic was in error. (Diagnostics should be considered indicators only.)

Postulating a solution or course of action, based upon knowledge and experience: Most startup problems are caused by poor wire terminations. More and more, factories are shipping machines without testing and quality assurance is performed by the Owner at start-up. (This may be more economic than paying for witnessed testing at the factory.)

EXAMPLE: A section of control cable was noted to be lacking jacket on a 4-ft section while being pulled into conduit.

SOLUTION: Remove the bad cable and re-pull. (Would this have been corrected if the Engineer were not on site at the time?)

PERSONAL PROTECTION WARNING: The electrician should be instructed to gently tug at the wires terminated into the terminal strip of the machine experiencing problems (both field and machine-side). With the statistically bad record of terminations, a pull-out is likely. This may NOT be the cause of the immediate problem.

EXAMPLE: Motor won't start. Bigger fuse blows. Larger overload trips.

TESTING: Break the coupling to the machine. Motor starts without problem. Measured line current has high inrush but very low running value.

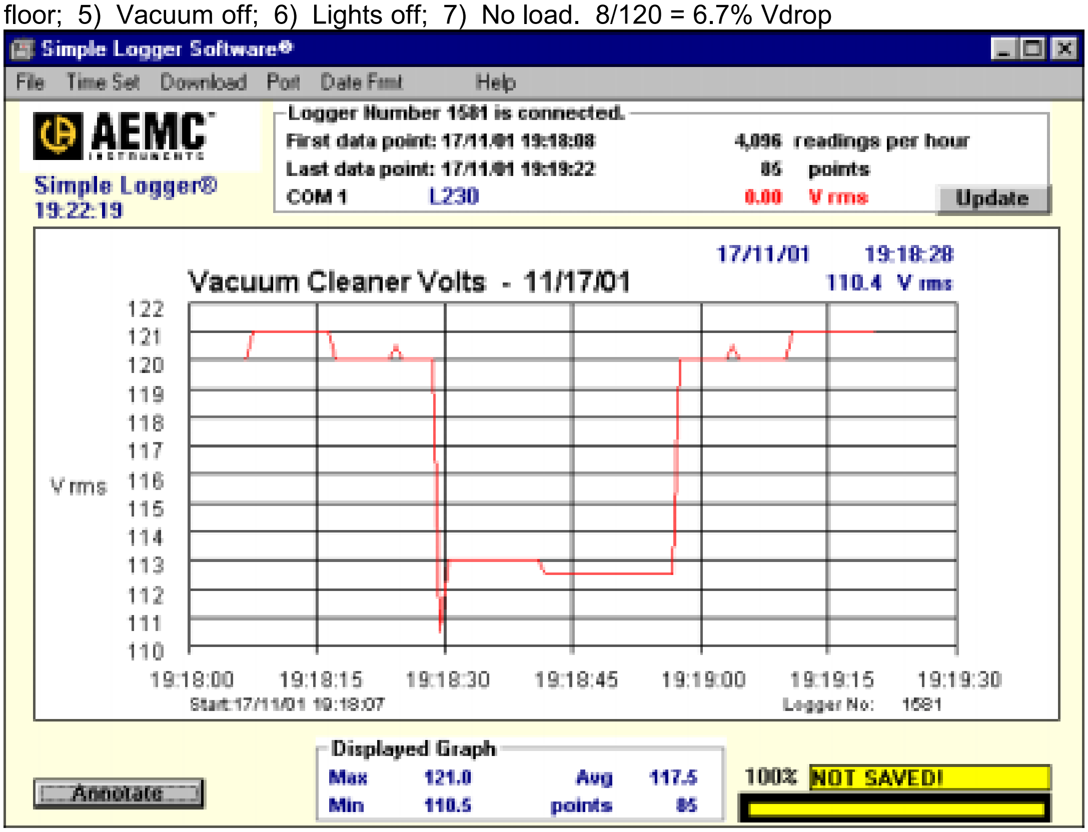
SOLUTION: There is a mechanical problem. Mechanical designers insist on undersized motors so that a mechanical problem does not destroy the linkages in the machine.

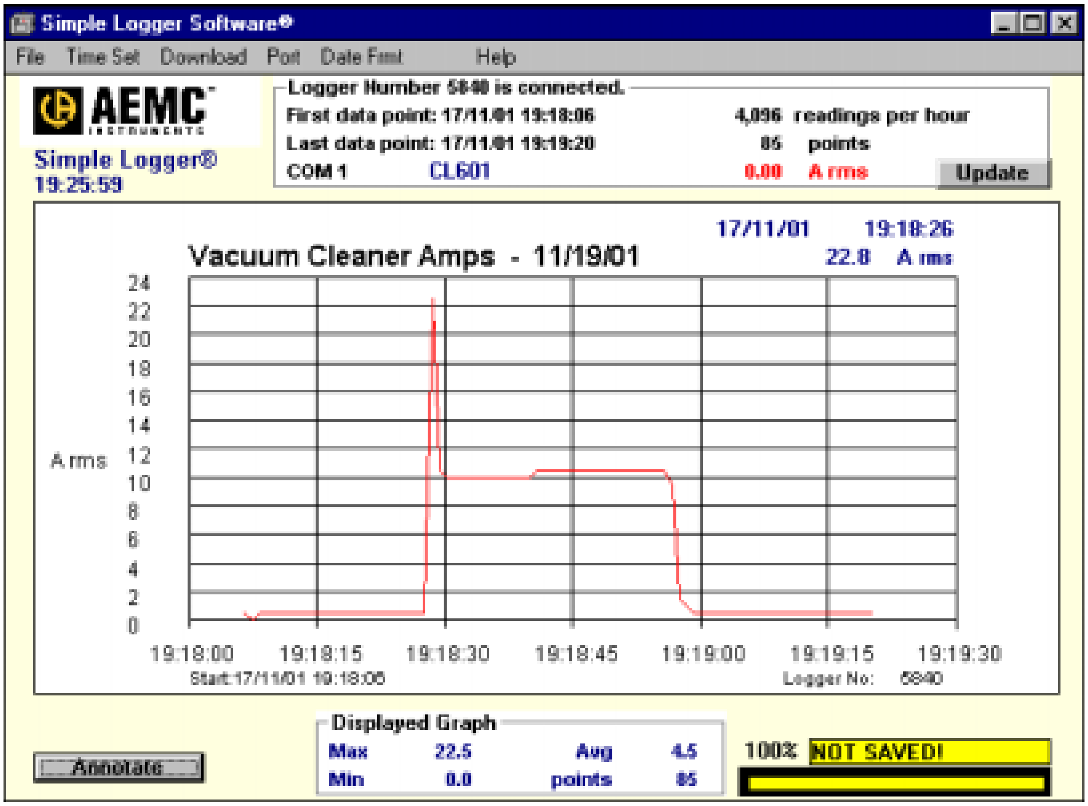
There is a very interesting conversation available if you suggest rewinding the motor for more torque. The mechanical maintenance person doesn't want to find the "fuse" in the mechanical system.

Motor inrush is largely misunderstood. There are two components - magnetizing current and load accelerating current. Magnetizing current is independent of load and lasts a fraction of a second. It is observed with an oscilloscope and a "bump" of the ammeter needle. Load accelerating current starts high and diminishes until the motor reaches full speed in less than 10 seconds. (Motor damage occurs if full speed is not attained within 10 seconds.)

The following test was performed to verify "lights dimming" when the vacuum cleaner started. (The manually entered date on one chart is in error; they are simultaneous.)

Test Procedure: 1) No load; 2) Lights only; 3) Vacuum on, tipped back; 4) Vacuum on, sweeping floor; 5) Vacuum off; 6) Lights off; 7) No load. 8/120 = 6.7% Vdrop





SOLUTION: The contractor tightened the screws on the receptacle and on the new circuit breaker, and voltage drop reduced to 4%.

MOTOR DISCUSSION: A vacuum cleaner motor is a specialized, peculiar motor. The same test was performed on a 200 HP high service pump at a water plant. It is very difficult to coordinate high speed instruments and the starting sequence for a 200 HP pump in service.

EXAMPLE: Three identical 200 HP high service pumps were installed at a new city water pump station. The computerized motor protective relay sometimes refused to let a motor complete its start sequence. Sometimes it tripped a motor offline after 5-15 minutes. The relay diagnostic reported "current imbalance". The trip threshold was raised from 5% to 30% to get the motors to run. The motor starter technician refused to take liability for system operation. The motor manufacturer claimed utility problems.

TESTING: Laboratory precision meters showed voltage imbalance less than 1% with or without the motor running. Current imbalance of 5-10% was measured. Measurements were made at the motor lead connections at the starter for each of the motors. At 60% rated load, IR gun temperature measurements showed the bearings were running hotter than the stator windings - all well within an acceptable temperature range. [Note that rotor temperatures are not accessible - one of the benefits of the computerized relay that is advertised to simulate rotor temp.]

DISCUSSION: The Owner wanted assurances of 20-year useful life and capability to perform at 100% when needed.

SOLUTION: The electrical consultant recommended the Owner refuse the motors as being defective.

OUTCOME: The Owner decided that the utility was at fault and accepted the motors.

EXAMPLE: A switchboard was replaced at a large manufacturing plant. There were no process changes or utility changes. The new switchboard included a computerized protective relay. The relay kept tripping when process load was applied. The panel meter on the switchboard said current was within rating. Trip threshold was raised above the switchboard rating to permit process operation.

TESTING: A power analyzer revealed that the heating controls for the process generated substantial harmonic content on the line current from the switchboard.

DISCUSSION: A phone call to the switchgear technical support brought information that the new computerized relay did not handle harmonic currents correctly. The manufacturer shipped a replacement unit at no charge.

SOLUTION: Experienced engineers are suspicious of first generation computerized protective devices. There are no peculiar failure modes for fuses, even the new ones with lights and popup buttons and color changes. There are no peculiar failure modes on thermal replica overload relays, even if fitted with an auxiliary contact so that the PLC knows who tripped off the machine. Adding a $100 belt-and-suspenders protection to a $50,000 installation might be reasonable.

EXAMPLE: Computerized direct digital controls were installed to replace existing pneumatic controls on HVAC systems at a large state university. As part of the retrofit, new sheet metal fan enclosures were furnished without dial thermometers. During startup and warranty, the supplier controls technician verified operation and ran diagnostics with his laptop computer. After the warranty period each call for the laptop cost $400.

TESTING: Several in house technicians learned to use the handheld diagnostic terminal supplied with the system. The remaining crews did not.

SOLUTION: Fifty dial thermometers, at $2.50 each, were purchased from the maintenance budget. Experienced HVAC technicians were able to track normal operation and localize malfunctions. Calls for the laptop were sharply reduced.

COMMENT: Panel meters are expensive options of factory built controls and switchgear and motor control centers. A donut current transformer and a LED display cost $50 total, if installed by maintenance personnel. A digital power meter with extensive voltage, current, power, power factor and harmonic displays (and computer output, if needed), including current transformers, costs less than $1000.

NOTE: ASHRAE 90.1(01), now part of most State Building Codes, requires utility check metering. The $1000 digital power meter meets this mandate.

Testing and implementing the course of action: In order to gain valid experience, you must pursue the results of your recommendations. Someone cared enough to invest your time in studying the problem; they probably implemented or ignored your recommendations. Make a phone call some months later. The range of outcomes is surprising and not particularly logical, from a technical viewpoint.

RECOMMENDATION: Get and protect a personal set of good test instruments, an RMS clamp-on ammeter/voltmeter and an IR thermometer "gun". These cost $200-500, depending upon brand. If budget permits, an autoranging 1000A RMS clamp-on logger is valuable. An autoranging 600V RMS single-phase voltage logger doesn't contribute much but adds interest in the final report. A non-contact voltage sensor may be a valuable safety tool, but requires care in its use. Until last week, most technicians also wanted a quality analog multimeter. The slow response and relatively low impedance reduce spurious data from transients.

RECOMMENDATION: If you will have continuing responsibility for troubleshooting the equipment, have permanent instruments installed. An hour-meter costs about $25 and a starts-counter costs about $20. A current indicator CT/LED costs about $10. A low-end three-phase power meter and CT's costs about $1,000.

Safety Principles

- Identify hazards. Yes, we are testing Machine #1, but, be aware of unguarded pinch-points on adjacent Machine #1. In substations, be aware of adjacent controls or cabinets open for servicing.
- Work with someone. Many personal injuries can be minimized by timely removal of the electrical source, application of a pressure bandage and 911 on a cell phone. Also it may be very valuable to discuss a test plan before implementing it.
- Use quality instruments. A $10 bargain meter may be accurate, but may not have the best protective fuse or as much insulation as a $100 name brand. The name brand firm is protecting their reputation and has insurance.
- Use personal protective equipment.
- In many instances OSHA forbids working on energized equipment. Turn it off. Open the door. Apply test instruments. Close the door. Step back. Look the other way. Apply power.
- Falling and arc-flash are the most common injuries to electricians. Avoid precarious perches when testing. Look the other way when power is applied.
- The NEC limits electrical work to trained persons. This is more likely a plant electrician than an out-of-town troubleshooter. Talk about the test procedure. Watch him do it. Write down the results.

Attachments

Fluke Industrial Meter

Electrician's Combo Kit

Multimeter, Voltage Tester and Deluxe Accessories Designed to meet the demands of the Industrial Professional

Combo Kit includes:

- Fluke 179 True-rms Digital Multimeter with backlight
- Fluke 1AC Non-Contact Voltage Tester
- Fluke TL24 Silicone Test Leads
- Fluke TP20 Industrial Test Probes
- Fluke AC20 Heavy Duty Alligator Clips
- Fluke 80BK Integrated Temperature Probe
- Fluke C800 Durable Carrying Case

Rugged 1000 V CAT III multimeter with industrial strength test lead sets plus a noncontact voltage detector — all in a sleek, durable carrying case.

Ordering information

179/1AC CK	Fluke Electrician's Multimeter and Voltage Tester Combo Kit

AEMC Clamp-on with harmonics

Model 721 Clamp-on Meter

The Model 721 combines the simplicity and familiarity of digital clamp-ons with today's critical information on power quality and harmonics.

Operation is simple and direct, with no menus, calculations or complex analyzer procedures. Select Amps or Volts on the rotary dial, connect, and measure. The push of a button gives additional information. You can troubleshoot and measure power quality with the ease of using a digital clamp-on - simply, safely, and economically.

Features

- Designed for traditional and nonlinear loads
- Simple clamp-on operation with power quality features
- No menus, no calculations and no analyzing
- Accurate True RMS readings of amperes and volts
- Direct reading of %THD, %DF, CF and Peak
- Recording mode for Min, Max, Avg, Max Peak
- Works with oscilloscopes as a harmonic and current transducer
- Rugged Lexan® construction for professional daily use
- Built to UL®, CSA, VDE, GS and IEC1010 safety standards

Applications

- True RMS voltage and current values on any circuit
- Identify harmonic distortion patterns and sources of voltage harmonics
- Identify dominant load types in circuits
- Identify linear and nonlinear loads
- Locate sources of harmonic current
- Derating transformers
- Track down overloaded or unbalanced circuits
- Reduce system overloads
- Measure output frequency of adjustable speed drive controllers

Electromagnetic Compatibility

Electrostatic Discharge: IEC 801-2: No influence: 4kV class 2; Non-destructive: 15kV class 4

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RF:	IEC 801-3: No influence: 3V/m class 2; Minor influence: 10V/m class 3
Transients:	IEC 801-4: No influence: 2kV class 4
Electric Shocks:	IEC 801-5: No influence: 1kV class 3; CE MARK

Mechanical Specifications

Envelope Protection:	IEC 529: IP 40
Drop Test:	IEC 68-2-32: 1m
Vibration:	IEC 68-2-6
Shocks:	IEC 68-2-27

Environmental Specification

Operating Temperature:	+14° to 131°F (-10° to +55°C)
Storage Temperature:	-40° to 158°F (-40° to 70°C)
Operating Humidity:	0 to 80%RH to +40°C (50%RH @+55°C)
Storage Humidity:	0 to 95%RH
Operating Altitude:	2000m (6500ft)
Storage Altitude:	5000m (16,000ft)

Safety / Reference Specifications

Protection Level:	Double insulation; IEC 1010-1, 600V, Cat. III, Pollution degree 2
Working Voltage:	600VRMS
Dielectric Test:	5.5kV, 50/60Hz, I minute
Agency Approvals:	ULâ, CSA, GS, VDE

General Specifications

AC Current

Input Range	0.05 to 700.0Arms, ±9.99.9A Peak		
Range	0.3 to 99.99A	100.0 to 400.0A	400.0 to 700.0A
Basic Accuracy	2% Reading ±20cts	2% Reading	5% Reading
Crest Factor	>3.0 below 300A		

Crest Factor	>3.0 below 300A	
Frequency Range	15Hz to 10kHz	

Current Peak

Input Range	**0.05 to ±999.9A Peak**		
Range	0.05 to 99.99A	100 to 600A	600 to 999.9A
Basic Accuracy	3% Reading ±30cts		8% Reading

AC Volts

Input Range	**0.05 to 600VRMS, 0.05 to ±1200V Peak**	
Range	0.5 to 399.9V	400.0 to 999.9V
Basic Accuracy	1.5% Reading ±4cts	1.5% Reading
Crest Factor	>4.0 below 300V	
Input Impedance	1MΩ, 47pF	
Frequency Range	15Hz to 10kHz	

Voltage Peak

Input Range	**0.05 to 99.99V**	**100 to 999.9V**
Basic Accuracy	3% Reading ±30cts	

%THD

Range	**0.5% to 600.0%**
Resolution	0.001
Minimum Input	300mA, 300mV
Basic Accuracy	3% Reading ±2cts
Accuracy Hz	50/60Hz
Frequency Range	Fundamental 45 to 65Hz, 25th harmonic
Display	Digital: %THD, Bar graph: True RMS (A or V)

Crest Factor

Input Range	**1.00 to 10.00**
Resolution	0.0001
Minimum Input	300mA, 300mV
Accuracy (40 to 450Hz)	10% Reading ±3cts
Frequency Range	15Hz to 10kHz
Display	Digital: CF, Bar graph: True RMS (A or V)

Frequency

Range	**0.5 to 999.9Hz**	**1000 to 9999Hz**
Minimum Input	1A or 1V	
Accuracy	0.1% Reading ±1ct	0.2% Reading ±1ct
Display	Digital: Hz, Bar graph: True RMS (A or V)	

Overload Protection

Voltage	**1.5kV Peak permanent**
Current	3000A AC permanent

Analog Output	1.5kV Peak permanent

Display:	Quadriplexed LCD with 12.5mm digits; 4 digits, 9999 counts
Case:	Gray Lexanâ 920A, UL 94 V2
Jaws:	Red Lexanâ 500R, 10% fiberglass, UL 94 V0
LCD Lens:	Crystal Lexanâ 920A, UL 94 V1
Battery:	9V Alkaline (NEDA 1604, 6LF22, 6LR61)
Battery Life:	Approximately 50 hr continuous use
Dimensions:	10 x 3.8 x 1.7" (254 x 97 x 44mm)
Weight:	1.3lb (600g)

Model 721 • Basic Price $295.00 + S&H

CR Magnetics - Current Indicator

Specifications | Parts & Ordering | Applications | Catalog Pages | Press Release

The CR-45 series of Wire-Mounted Electrical Current Indicators provides an effective method of monitoring electrical current. The indicator is attached directly to a current-carrying wire. When the current exceeds the turn-on point, the LED will illuminate to indicate the presence of current.

Features

- Self powered
- Red or green indicator
- Easy to Install
- Supplied with plastic tie
- Bright yellow case for easy identification
- Panel mounting bracket available

Specifications

- Min. Turn-on Point: 2.0 for Red
- Min. Turn-on Point: 2.5 for Green
- Max. Continuous Current: 100 Amps
- Frequency: 50 to 60 Hz

Applications

- Monitor status of heater elements
- Observe remote loads
- Indicate phase loss
- Monitor motor operation

CR MAGNETICS, INC.
544 Axminister Drive, Fenton (St. Louis), MO 63026 USA
Phone: 636.343.8518 Fax: 636.343.5119
Email:sales@crmagnetics.com

Digital Power Meter, complete, materials only. Note ModBus communications for future energy management system.

Quotation for Ralph Tyler Companies

Attention:
Mr. Tom Mason
Ralph Tyler Companies
1120 Chester Ave. Suite 200
Cleveland, OH 44114

Business: (216) 623-0808
Fax: (216) 623-0979

Sales Contact:
Sean Stapleton
Inside Sales Support - US East
2195 Keating Cross Road
Saanichton, B.C.
Canada V8M 2A5
Tel: 250-652-7100 ext.7530
Fax: 250-652-0411
Email: sean.stapleton@pwrm.com

Submit Order To:
Order Management Dept.
2195 Keating Cross Rd.
Saanichton, BC
Canada V8M 2A5
Telephone: (250) 652-7103
Fax: (250) 652-7107
E-mail: order.entry@pwrm.com
Please Reference: ON80671-5471

Total Investment	**$986.75**

Qty	Description	Part #	Unit Price (USD$)	Extended Price (USD$)
1	ION 6200 Compact Modular Power & Energy Meter, Integrated Display, Standard 5A, Autoranging (690VAC L-L), P240: 85-240VAC/110-330VDC, Autoranging (50Hz and 60Hz), Single RS485 port (with Modbus RTU), No pulse Outputs, Password Protected, Enhanced Package #1		$545.00	$545.00
	Sub Total	**P6200A0A0B0A0A0P**		**$545.00**
3	Split Core CT's		$147.25	$441.75
	Sub Total	**CT4FSH-1000**		**$441.75**

- This quote is valid for 60 days from date of quote.
- All prices are in US Dollars (USD).
- Typical product lead-time for small quantity orders is 3 – 5 weeks from receipt of PO.
- The following payment methods are accepted: VISA, MasterCard, wire transfers, cheques, letters of credit, and bank drafts.
- Installation and minor materials are not included.
- Refer to the attached *Terms and Conditions of Sale* for other important information.

ION 6200 information:

http://www.pwrm.com/Literature/Power_Library/English/Products/Datasheets/ION6200_short_datasheet.pdf
CT information:
http://www.pwrm.com/Literature/Power_Library/English/Products/CTPT_catalog2002/Section06/P1_revised.pdf

Ideal SureTest receptable analyzer, m/n 61-150, 151, 152

SureTest® Model ST 1D Instructions

Introduction
The SureTest® family of circuit analyzers identify problems common to electrical circuits quickly, easily and accurately. They have a patented voltage drop test, which applies a full 15 ampere load without causing interruption to equipment on the circuit.

Product Features
- Identifies and Locates
  Loose Wire Connections
  Bad Splices/Receptacles
  High Resistance Grounds
  False (Bootleg) Grounds
  Shared Neutrals
- Verifies
  Proper Wiring in 3-Wire Receptacles
  Proper GFCI Operation
  Dedicated Circuit Presence
  Isolated Ground Presence (with the 61-176 Isolated Ground Adapter)
- Measures
  Line Voltage
  Ground Impedance
  % Voltage Drop by Conducting an Actual Full 15 Amp Load Test
  % Voltage Drop by Simulating a 20 Amp Load Test
  GFCI Trip Time
  Neutral-to-Ground Voltage
  Estimated Load on Circuit

Specifications

Case Construction:	GE Cycolac molded plastic
Operating Range:	108 to 132 Volts (61-152)
	207 to 253 v. (61-153)
Power Consumption:	1 Watt contin; 1800 W peak
Wiring Indications:	Pass/Fail format.
Digital Display:	Seven segment L.E.D., .3"
Operating Temp.:	0 C to 50 C
Storage Temp.:	-20 C to +65 C
Dimensions:	17.78 x 7.62 x 3.81 cm
Weight:	200 grams (7 ounces)

Accuracy

Line Voltage:	±2.5% full scale ±1 digit
Voltage Drop:	±2.5% full scale ±1 digit
Ground-to-Neutral Voltage:	±2.5% full scale ±1 digit
Est. Load on Circuit:	±10% full scale ±1 digit
Ground Impedance:	±2.5% full scale ±1 digit (0-1 Ohm)
	±5.0% full scale ±1 digit (1-2 Ohm)
GFCI Trip Time:	±2.5" full scale ±1 digit

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