LTC135

Load Tap Changer testing power supply

User's Manual

Megger

WWW.MEGGER.COM

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CE

Contents

Service and support

For technical assistance please contact your local Megger representative or direct your request to the office in Sweden.

Contact Information

Internet: www.megger.com

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Checklist before calling/e-mailing for support

- Read the manual
- Restart the instrument(-s), redo test connections and try again
- Try to repeat the failing operation if possible
- Identify the instrument model, serial number and revision of software.

Shipping

If you are going to send the instrument with parcel service use the original transport box or one with equivalent strength. Megger can not take responsibility for transport damages.

1 Safety

1.1 General

For your own safety and to get the maximum benefit from your instrument, please ensure that you read and understand the following safety instructions and warnings before using the instruments.

Important
Read and comply with the following instructions.
Always comply with local safety regulations.

Symbols on the instrument

	Caution, refer to accompanying documents.
	Protective conductor terminal.
	WEEE, Waste Electrical and Electronic Equipment. Please utilize your local WEEE collection facilities in the disposal of this product and otherwise observe all applicable requirements. The unit can also be returned to Megger at any time at no charge for the disposal.
CE	Equipment complies with current EU directives.

1.2 Safety instructions

Warning

1. **Grounding (Earthing)**
   Single ground system. This equipment can be used only in electrical systems with single ground.
   Before connecting this unit to power you must verify that High Voltage Ground and Low Voltage Protective Ground create a single protective ground with no measurable voltage potential existing between these ground systems. If a voltage potential is found between the ground systems please consult local safety regulations.
   Mains cord protective conductor. The instrument is equipped with a power cord with integral safety ground pin. Do not defeat the safety ground in any manner. The equipment must be connected to a grounded mains outlet.
   Separate ground wire. The instrument case must also be grounded by the separate protective ground wire with connection to the Protective Conductor Terminal on top of the instrument. Check the continuity of the protective ground wire before each use. Make sure the connector is fastened properly to the instrument Protective Conductor Terminal and to the connection point at the ground system.
   Note: The protective ground wire must not be loosened while any input connector is attached to the contacts of a high voltage test object or other device being subject to inductive or capacitive coupled interference from surrounding high voltage wires.
2. **Use an easily accessible power outlet**. This will ensure that you can disconnect the power quickly in case of a problem.
   The instrument should be operated only from the type of power source indicated on its nameplate.

3. **Connecting.** It is very important not to connect any leads on top of or too close to one another. Take the necessary precautions to assure one lead falling off will not take a second lead with it.
   Never connect the test equipment to energized equipment.
   Never make any connection or disconnections while the test equipment is generating or discharging.
4. **Testing.** When applying current to a transformer with very high inductance, additional care should be taken not to remove current leads while current is still flowing. This causes an extremely high voltage to develop across the point where current is broken. Under certain conditions, this voltage could prove to be lethal.

   Ensure that the transformer to be tested is completely de-energized. Check every winding. Ensure that all terminals of the transformer are disconnected from line or load at the transformer. Connections to ground may be left in place.
5. **Water and moisture.** Do not use the instrument near water. To prevent fire or shock hazard, do not expose the instrument to rain or moisture.
   Do not touch the plug with wet hands
6. **Ventilation.** Slots and openings in the instrument are provided for ventilation. They ensure reliable operations of the instrument, keeping it from overheating. These openings must not be blocked nor covered during operation.
7. **Service.** Do not attempt to service the instrument yourself. If you attempt to service the instrument yourself the warranty is no longer valid.
8. **Accessories**. Do not use any accessories that are not intended for use together with the instrument.
9. **Cleaning.** Use a damp cloth for cleaning. Do not use liquid cleaners or aerosol cleaners.

Important

1. Never leave the LTC135 unattended while it is turned on.
2. Refer all servicing to Megger authorized personnel.
3. If you need to return the instrument, please use either the original crate or one of equivalent strength.

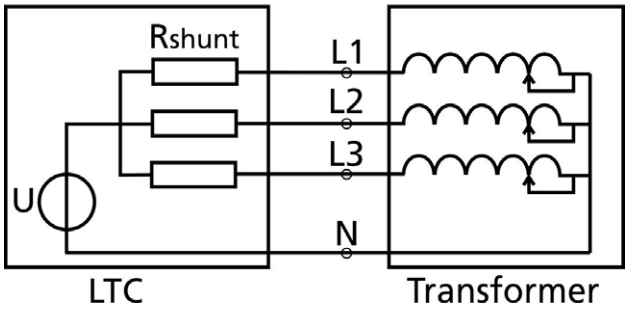
2 Introduction

2.1 General

This manual is valid for the LTC135 and it is designed for use together with the Megger instruments; TM1800, TM1700-series, TM1600 and EGIL.

LTC135 is a power supply designed for DC current testing of inductive loads. It is designed to perform as a current source with fixed source impedance.

LTC135 is used to perform static dynamic voltage and resistance measurements on load tap-changers. The unit can also be used for winding resistance measurements and other applications where a constant DC current test signal is requested.



The unit has built-in safety protection for testing transformers and other components with high inductance. To ensure operator safety, LTC135 automatically discharges the stored energy in the transformer at the end of each test. This is performed as an alternate current route through either of the potential leads. If a current lead is disconnected while current is flowing through the transformer, the current will flow through the alternate path of the potential lead without damage to instrument or electrical shock to operator.

2.2 Transformers tap changers

Many transformers used today have built-in taps. These taps allow ratio to be increased or decreased by a few percent. Any of the ratio changes involve a mechanical movement of a contact from one position to another. It is this contact that needs to be checked by way of its contact resistance and mechanical integrity. The contacts may go bad for a number of reasons. The contact may go bad for a number of reasons.

- Misaligned when manufactured causing insufficient surface contact. Full load current overheats contact surface causing it to burn
- Current passing through contact exceeds full load rating.
- Tap changing operation failing to have the required "Make Before Break" sequence will create internal arcing of contact surface.
- An off-load tap changer is switched while on load. Contact surface becomes pitted and uneven.

Tap changers are divided into two different types; "on-load" and "off-load/de-energized". The "on-load" tap changer (LTC or OLTC) allows a ratio change while the transformer is in service. This means the ratio of a transformer can be changed while power (current) is still passing through it.

The "off-load/de-energized" tap changer (DETC) may only change connections when the transformer is taken out of service or at least disconnected from the load.

Load tap-changers can be divided into two groups; Resistive and reactive. Resistive LTC's are normally connected to the high voltage winding and can be of various design. Common for all is that they contain resistors and the switching time is fast, typically around 30-70 ms.

Reactance type LTCs uses a preventive auto transformer instead of the two resistors in the standard diverter switch which means that the additional resistance in the diverter device is very low.

Switching times in reactive tap-changers are significantly longer than in resistive types, typically several seconds.

2.3 Tap changer testing

Winding resistance measurements (static)

Winding resistance measurements (WRM) are normally performed for every tap the same way as measurements on individual windings. The test instrument is continuously injecting test current and the resistances for each tap setting are measured sequentially as the tap changer is stepped through its positions. Results are typically presented as a graph or table with resistance values for each tap.

Resistance changes between taps should be consistent with only small deviations between different

tap positions.

Dynamic measurements

There are several methods developed for testing tap changers but common for all are that a DC current is injected in the tap changer, either in one phase or all phases. During the operation of the tap changer, the current and/or the voltage is measured as a function of time. Test current vary from about 0.1 A to 1% of rated current for the transformer winding. Standard methods are;

- Discontinuity detection
- Dynamic current measurement (”ripple”)
- Dynamic voltage measurement
- Dynamic resistance measurement (DRM)

LTC135 can be used for continuity verification (any dynamic method works), dynamic current, dynamic voltage measurements (timing) and dynamic resistance measurements (timing and resistance).

2.4 Supported measurements

LTC135 together with the different Megger circuit breaker analyzers/recorders support the dynamic measurements shown in table below.

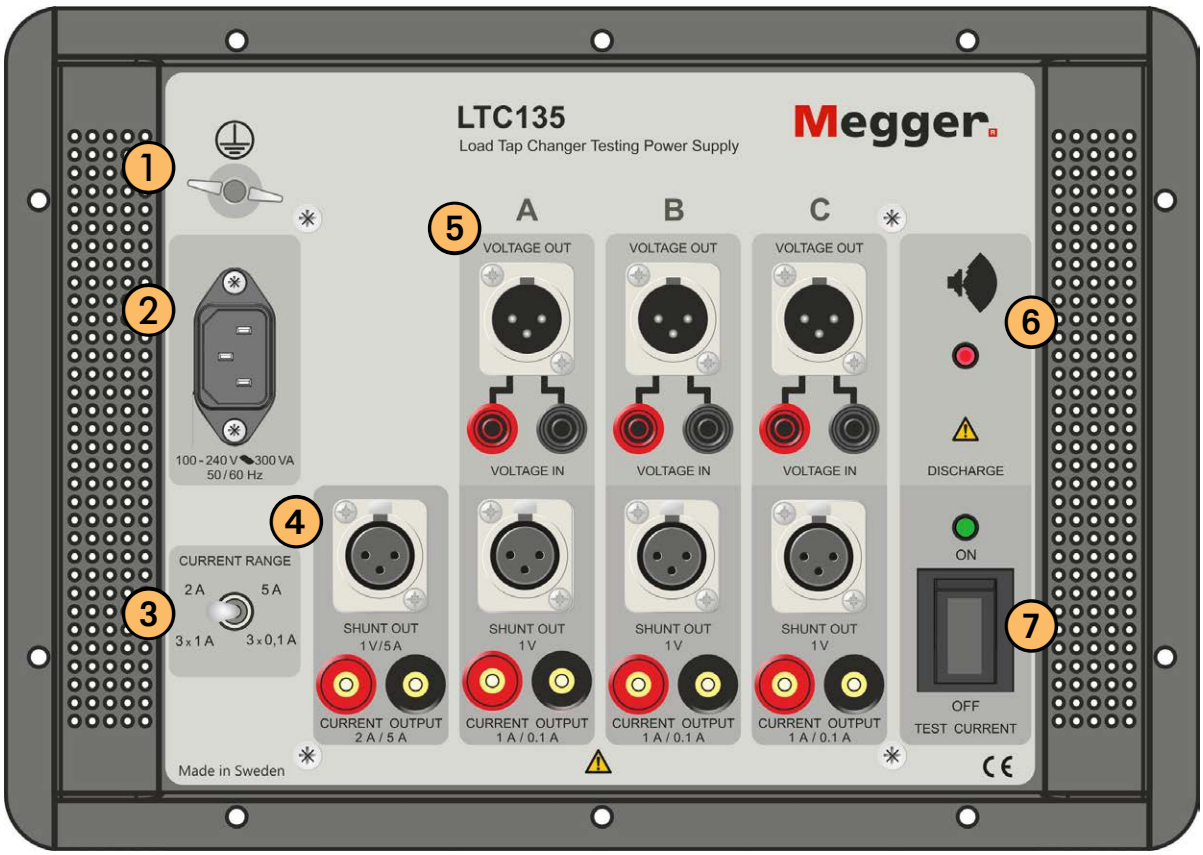
Supported measurements	**EGIL (with analog meas)**	**TM1600/ MA61**	**TM1700**	**TM1800**
Single-phase				
Continuity test	**x**	**x**	**x**	**x**
Dynamic current/timing	**x**	**x**	**x**	**x**
Dynamic voltage/timing	**x**	**x**	**x**	**x**
Dynamic resistance and timing	**x *)**	**x**	**x**	**x**
Motor current (external clamp-on)		**x**	**x**	**x**
Three-phase				
Continuity test		**x**	**x**	**x**
Dynamic voltage/timing		**x**	**x**	**x**
Dynamic resistance and timing		**x**	**x**	**x**
Motor current (external clamp-on)			**x**	**x**
LTC control	**x**	**x**	**x**	**x**

**) Resistance can be indicated/estimated by combining measured dynamic voltage and assumed/set test current.*

3 The instrument

3.1 The top panel

On top is the panel that includes all connectors for in and outputs.



1	**Protective conductor terminal** Connection to earth (ground), see "1.1 Safety instructions".
2	**Mains input** Always use the power cord supplied with the unit. The unit is "on" when the power chord is connected to mains.
3	**CURRENT RANGE** Toggle switch for selecting output currents
4	**SHUNT OUT** One shunt out (1 V / 5 A) and a group of three similar outputs (1 V) A,B and C suited for 3-phase operation **CURRENT OUPUT** One current output (2 A / 5 A) and a group of three similar outputs (1 A / 0.1 A) A,B and C suited for 3-phase operation
5	**VOLTAGE OUT** **VOLTAGE IN** The terminals are grouped in three similar sections A,B and C suited for 3-phase operation.
6	**DISCHARGE** Built-in discharge circuit safely discharges the test object when test is completed. LED and audio indicate the charging status.
7	**TEST CURRENT** ON/OFF Switch for generation of test current

4 Operation

4.1 Prepare for test

IMPORTANT
Always follow the safety regulations in chapter 1 of this manual.
Always comply with local safety regulations.

This example describes the principal connections and steps for single-phase DRM on a single-phase transformer with a resistive type LTC on HV winding. Recording device is Megger TM1760 circuit-breaker analyzer (CBA).

1] Use the supplied safety ground cable to connect the LTC135 ground terminal directly to local station earth (Ground). Ensure that the transformer chassis also has a low impedance connection to local station earth ground potential.

2] Input power source ground terminal should be less than 100 mΩ of impedance to local station earth (Ground).

3] Make sure that the test current switch is set to "off".

4] Connect all test leads that are to be used to the LTC135 and the CBA.

5] Put the motor current clamp-on on one of the motor current leads if the motor current is to be recorded.

6] Connect control leads from CBA trip/close circuitry to LTC control circuitry (up/down contacts/buttons).

7] Connect VOLTAGE OUT on LTC135 to CBA Voltage sensing channel (TM1760 Timing M/R).

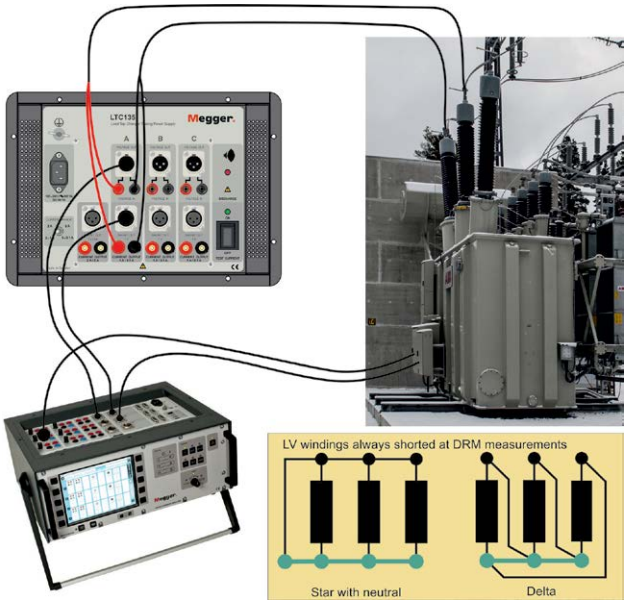
8] Connect SHUNT OUT on LTC135 to CBA Current sensing channel (TM1760 Analog).

9] Connect CURRENT OUTPUT/VOLTAGE IN to transformer winding where LTC is to be tested e.g. A-N.

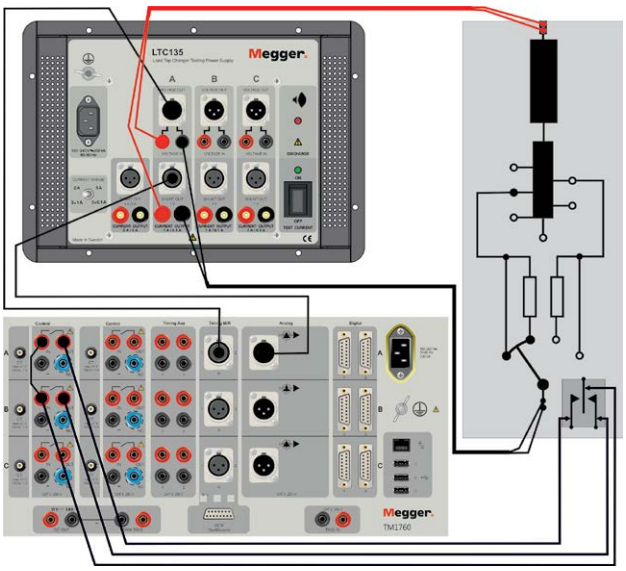
10] Short circuit the corresponding/adjacent LV winding of the transformer e.g. a-n.

11] Connect the input power cable to the LTC135 and then to the power source.

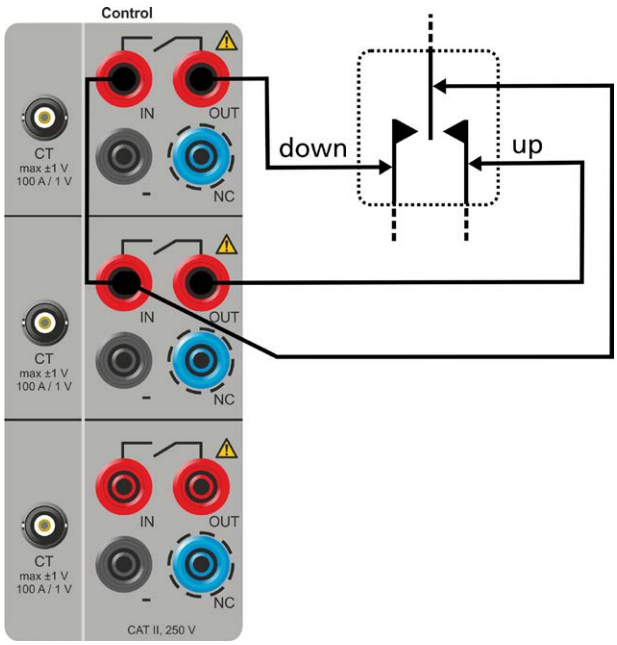
Note *If using separate voltage and current leads instead of the standard Kelvin-type leads, do not clip potential leads on to the current leads, since this will add contact resistance to the measurement. Potential leads should always be placed inside (between) current leads.*



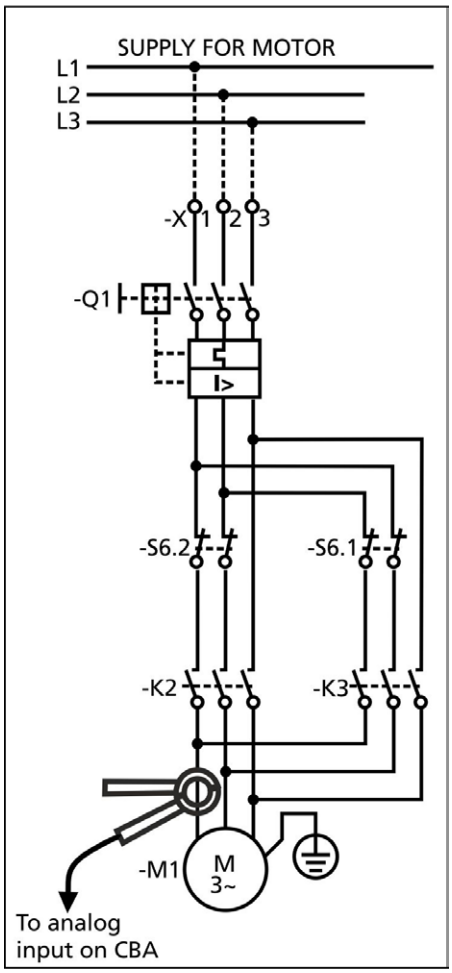
General hook-up overview, in this case together with TM1760.



Typical measurement/analysis setup for DRM measurement of a LTC.



CBA control connections to the LTC button for control circuitry (up/down).



Motor current clamp for recording of the motor current.

4.2 Running the test

Note *The discharge of a transformer after testing is critical to prevent excessive voltage build-up across the transformer bushings upon removal of current. When the current source is disconnected, the energy in a transformer will continue to flow. If there is high impedance (air), the voltage across the inductor will increase until there is a current path found for the energy. This can be either an internal or external current path. It is possible to attach a shorting cable across the transformer bushings before the current source is turned off. Since the short has very little resistance, the circulating current through the transformer and the short may continue for a very long period of time. The LTC135 discharge circuitry is built-in and will automatically initiate when the current source is disconnected from the transformer. It will also provide visual and audible indication of discharging. .*

1] Once all the precautions and steps of sections 1 “Safety” and 4.1 “Prepare for test” are complete, then the mains power cord is connected to the power outlet.

2] Select TEST CURRENT 0.1 or 1A (for DRM using constant current, 0.1 A is preferred (source impedance >> measured resistance) but 1 A may be used if necessary. 5 A is not recommended). For dynamic voltage measurement 1 or 5 A should be used.

3] Set switch TEST CURRENT to (1) ON, to initiate current.

4] Select appropriate test plan for DRM on CBA (if applicable) and select which transition to be measured.

5] Operate LTC from CBA (or manual + start recording) and record data.

6] Continue on next tap.

7] When measurement is finished set the TEST CURRENT switch to (0). The DISCHARGE lamp and sound will indicate that the discharging is in progress.

WARNING
Do not disconnect any test leads until the DISCHARGE light goes out and the sound stops.

4.3 Dynamic resistance measurements (DRM)

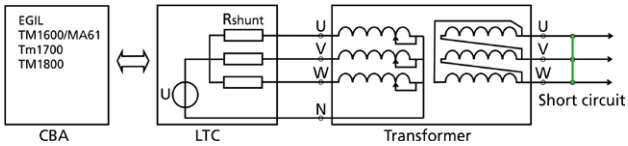
Dynamic resistance measurement (DRM) technique has been used extensively on high voltage circuit breakers to determine the condition and deterioration of arcing contacts inside the breaker. DRM is also an advanced diagnostic tool for LTCs to detect problems like deviation in switching times, damaged transition resistors, bouncing contacts, current discontinuity etc.

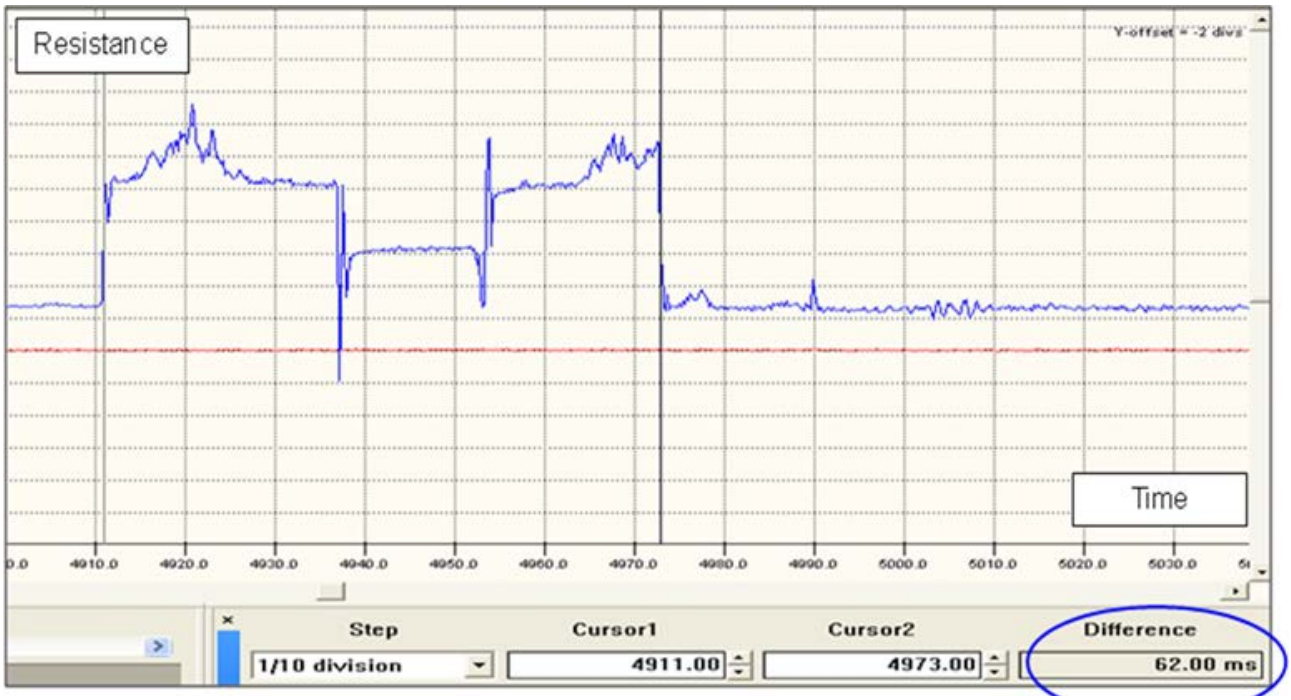
DRM on tap changers is measurement of resistance (or voltage from a constant current source) trace while the tap changer is switched from one extreme tap to the other and back. Since the resistance changes dynamically as the LTC taps are changed, it is recorded with a high sampling rate and plotted as a function of time. Dynamic change in resistance (or voltage) plot gives valuable information about the contact timing and condition which cannot be determined by traditional static winding resistance measurements (SRM).

The measurement is performed with a high impedance source and the corresponding (LV for resistive tap changers) winding is short-circuited to minimize the inductance. Test current and winding voltage is measured and resistance can be calculated as R=U/I when source impedance >> measured resistance. Highest source impedance is for 0.1 A test current and this range provides the least influence of the remaining inductance and accurate resistance readings can be achieved. In situations when higher current is necessary, 1A can be used. 5 A test current is not recommended for performing DRM with shorted secondary winding due to the low source impedance (9.6 Ω).

DRM measurements are used to confirm continuity, determine contact/transition times, detect contact bouncing and verify diverter resistor values.

DRM setup for a typical YNd transformer with LTC on HV side





DRM example with LV shorted, measurement current 0.1 A

4.4 Dynamic voltage measurements

Dynamic voltage measurements can be used for verification of continuity and contact/resistor switching times. Pending settings and test current it can also give an indication of diverter resistor values.

Dynamic voltage measurements are preferably done on the opposite side (LV if LTC on HV) of the transformer, recording the inductive/induced voltage. Main advantage with this method is its simplicity. Only connect a voltage measurement input to one or three windings, inject current and record LV voltage during the tap transition

4.5 Dynamic current measurements

Dynamic current measurements are performed by measuring the actual test current and the result is presented in a current-time diagram. The intention is to give a value that describes the conditions during operation and provide contact timing.

Dynamic current measurements are pending test current. If the test is performed at a current level below saturation level, the inductance in the transformer winding is high thus reducing the current change. If the test is performed at a current level at or above saturation level, the inductance is low and current level change will be higher.

The recommended method to reduce transformer inductance when performing dynamic current measurements is to short-circuit the corresponding LV windings. This action is principally "replacing" the inductance of the winding with the short-circuit impedance. Inductance is greatly reduced and changes in current can be measured more precisely.

4.6 Using with EGIL

Stand-alone mode

Dynamic voltage measurements

EGIL with analog measurement channel can be used in stand-alone mode with LTC135 to perform single-phase dynamic voltage measurement. One tap transition can be measured at a time.

1] Connect control cables from EGIL trip/close circuit to the LTC operating contacts.

2] Select test current, 1 or 5 A.

3] Connect LTC135 current output to the transformer winding to be measured.

4] Connect EGIL motion channel to the corresponding/adjacent winding to the LTC winding (LV if LTC on HV).

5] Set EGIL measurement time to 10 s.

6] Set Egil analog channel to voltage measurement. Voltage divider setting 1:1.

7] Operate LTC/start measurement

8] Wait for results to be printed.

9] Continue to measure next tap transition.

10] When finished, turn off test current.

Note *Wait until discharge is finished before removing any cables.*

Dynamic current measurements

EGIL with analog measurement channel can be used in stand-alone mode with LTC135 to perform single-phase dynamic current measurement. One tap transition can be measured at a time.

1] Connect control cables from EGIL trip/close circuit to the LTC operating contacts.

2] Select and appropriate test current, typically 5 A.

3] Connect LTC135 current output to the transformer winding to be measured

4] Connect EGIL analog channel to the corresponding current shunt output on LTC.

5] Set EGIL measurement time to 10 s.

6] Set Egil analog channel to current shunt measurement. Settings as posted on LTC.

7] Operate LTC/start measurement.

8] Wait for results to be printed.

9] Continue to measure next tap transition

10] When finished, turn off test current.

WARNINGWait until discharge is finished before removing any cables.

With external computer and CABA

Dynamic voltage measurements

EGIL with analog measurement channel together with LTC135 can be controlled via CABA Win to perform single-phase dynamic voltage measurement. One tap transition can be measured at a time.

1] Connect control cables from EGIL trip/close circuit to the LTC operating contacts.

2] Select test current, 1 or 5 A

3] Connect LTC135 current output to the transformer winding to be measured

4] Connect EGIL motion channel to the corresponding/adjacent winding to the LTC winding (LV if LTC on HV)

5] In CABA Win select test plan for tap changer measurement with EGIL ("OLTC EGIL").

6] Make sure that there is a Voltage transducer with ratio 1:1 in transducer list in CABA Win and create one if needed

7] Create new test

8] Perform necessary steps to establish connection from CABA Win to EGIL

9] Select recording corresponding to tap transition to be measured

10] Press New recording in CABA Win

11] In dialog window select voltage transducer for EGIL (ratio 1:1) and press "OK"

12] In next dialog window press "Measure"

13] Operate LTC by turning MEASURE knob on EGIL to make measurement and wait until CABA Win collects data and displays results. Please observe if LTC is operated by means of external control one must make sure that LTC tap transition and EGIL measurement are synchronized correctly.

14] Close result window and continue with next tap (recording)

15] When finished, turn off test current.

Note *Wait until discharge is finished before removing any cables.*

4.7 Using with TM1600/ MA61

With external computer and CABA

Dynamic voltage measurements

1] Connect control cables from TM1600 trip/ close circuit to the LTC operating contacts.

2] Select test current, typically 1 or 5 A for single phase testing, 3 x 1A for three phase testing

3] Connect LTC135 current output to the transformer winding/windings to be measured

4] Connect TM1600 analog channels to all (3-phase) or one of the corresponding/adjacent winding to the LTC winding (LV if LTC on HV)

5] In CABA Win select test plan for tap changer measurement with TM1600 ("OLTC TM1600 Dynamic Voltage").

6] Make sure that there is a Voltage transducer with ratio 1:1 in transducer list in CABA Win and create one if needed

7] Create new test

8] Perform necessary steps to establish connection from CABA Win to TM1600

9] Select recording corresponding to tap transition to be measured

10] Press New recording in CABA Win

11] In dialog window select voltage transducer for TM1600 (ratio 1:1) and press "OK"

12] In next dialog window press "Measure"

13] Operate LTC by turning MEASURE knob on TM1600 to make measurement and wait until CABA Win collects data and displays results. Please observe if LTC is operated by means of external control one must make sure that LTC tap transition and TM1600 measurement are synchronized correctly.

14] Close result window and continue with next tap (recording)

15] When finished, turn off test current.

Note *Wait until discharge is finished before removing any cables.*

Dynamic resistance measurements

1] Connect control cables from TM1600 Coil control to the LTC operating contacts.

2] Close coil operates tap changes upwards, while trip coil tap changes downwards.

3] Select test current, 1 or 5 A.

4] Connect LTC135 current output to the transformer winding to be measured

5] Connect TM1600 analog channel A to voltage measurement output on LTC135.

6] Connect TM1600 analog channel B to the corresponding current measurement outputs on LTC135.

7] Connect TM1600 analog channel C to the current measuring clamp for tap changer motor current measurement

8] Connect TM1600 to computer with CABA Win and establish connection.

9] In CABA Win select test plan for tap changer measurement with TM1600 ("OLTC TM1600 DRM").

10] Make sure that there is a Current transducer with ratio corresponding to used current in transducer list in CABA Win and create one if needed.

11] Make sure that there is a Voltage transducer with ratio 1:1 in transducer list in CABA Win and create one if needed

12] Create new test.

13] Start New recording and in CABA Win dialog window select required current and voltage transducers

14] Depending on tap changes up or down select appropriate sequence of coil command

15] Turn knob Operate on TM1600 to make a measurement.

16] Close Results window and proceed with next tap.

17] When finished, turn off test current.

Note *Wait until discharge is finished before removing any cables.*

4.8 Using with TM1700/1800

Stand-alone mode

Dynamic voltage measurements

1] Connect control cables from TM1700/1800 trip/close circuit to the LTC operating contacts.

2] Select test current, typically 1 or 5 A for single phase testing, 3 x 1A for three phase testing.

3] Connect LTC135 current output to the transformer winding/windings equipped with OLTC.

4] Create new breaker using template for dynamic voltage measurement on OLTC.

5] Connect TM1800 analog channels to all (3-phase) or one of the corresponding/adjacent winding to the LTC winding (LV if LTC on HV).

6] Make sure that there is a Voltage transducer with ratio 1:1 in Transducers and create one if needed.

7] Create new test.

8] Select recording corresponding to tap transition to be measured.

9] Go to Analyzer view and select current transducers for blinking channel(s).

10] Turn knob Operate/Measure on TM1700/1800 to make a measurement.

11] Close Results window and proceed with next tap.

12] When finished, turn off test current.

Note *Wait until discharge is finished before removing any cables.*

Dynamic resistance measurements

TM1700/1800 can be used in stand-alone mode with LTC135 to perform single-phase or three-phase dynamic resistance measurement. One tap transition can be measured at a time. Motor current can be measured if the TM1700/1800 unit has sufficient number of analog channels.

1] Connect control cables from TM1700/1800 Control module to the LTC operating contacts.)

2] Channel A operates tap changes upwards, while channel B tap changes downwards.

3] Select test current, 1 or 5 A.

4] Connect LTC135 current output to the transformer winding to be measured.

5] Connect TM1700/1800 Timing M/R module channel(s) to voltage measurement output(s) on LTC135.

6] Connect TM1700/1800 analog channel(s) to the corresponding current measurement outputs on LTC135.

7] In CABA Local select test plan for tap changer measurement with TM1700/1800 ("OLTC TM1800 DRM").

8] Make sure that there is a Current transducer with ratio corresponding to used current in transducer list in CABA Local and create one if needed.

9] Create new test.

10] Select recording corresponding to tap transition to be measured. Go to Analyzer view and select current transducers for blinking channel(s).

11] Turn knob Operate/Measure on TM1700/1800 to make a measurement.

12] Close Results window and proceed with next tap.

13] When finished, turn off test current.

Note *Wait until discharge is finished before removing any cables.*

With external computer and CABA

Dynamic voltage measurements

1] Connect control cables from TM1700/1800 trip/close circuit to the LTC operating contacts.

2] Select test current, typically 1 or 5 A for single phase testing, 3 x 1A for three phase testing

3] Connect LTC135 current output to the transformer winding/windings equipped with OLTC

4] Create new breaker in CABA Win using test plan for dynamic voltage measurement on OLTC.

5] Connect TM1800 analog channels to all (3-phase) or one of the corresponding/adjacent winding to the LTC winding (LV if LTC on HV).

6] Connect TM1700/1800 to computer with CABA Win and establish connection.

7] In CABA Win select test plan for dynamic voltage measurement on OLTC with TM1700/1800 ("OLTC TM1800 DYNVOL").

8] Make sure that there is a Voltage transducer with ratio 1:1 in Transducers and create one if needed.

9] Create new test.

10] Select operation corresponding to tap transition to be measured.

11] Start New recording and in CABA Remote Interface select required transducer for voltage measurement.

12] Turn knob Operate/Measure on TM1700/1800 to make a measurement.

13] Close Results window and proceed with next tap.

14] When finished, turn off test current.

Note *Wait until discharge is finished before removing any cables.*

Dynamic resistance measurements

TM1700/1800 together with LTC135 can be controlled via CABA Win to perform dynamic resistance measurement. One tap transition can be measured at a time. Motor current can be measured if the TM1700/1800 unit has sufficient number of analog channels.

1] Connect control cables from TM1700/1800 Control module to the LTC operating contacts

2] Channel A operates tap changes upwards, while channel B tap changes downwards.

3] Select test current, 1 or 5 A.

4] Connect LTC135 current output to the transformer winding to be measured.

5] Connect TM1700/1800 Timing M/R module channel(s) to voltage measurement output(s) on LTC135.

6] Connect TM1700/1800 analog channel(s) to the corresponding current measurement outputs on LTC135.

7] Connect TM1700/1800 to computer with CABA Win and establish connection.

8] In CABA Win select test plan for tap changer measurement with TM1700/1800 (“OLTC TM1800 DRM”).

9] Make sure that there is a Current transducer with ratio corresponding to used current in transducer list in CABA Win and create one if needed.

10] Create new test.

11] Start New recording and in CABA Remote Interface select required current transducer.

12] Turn knob Operate/Measure on TM1700/1800 to make a measurement.

13] Close Results window and proceed with next tap.

14] When finished, turn off test current.

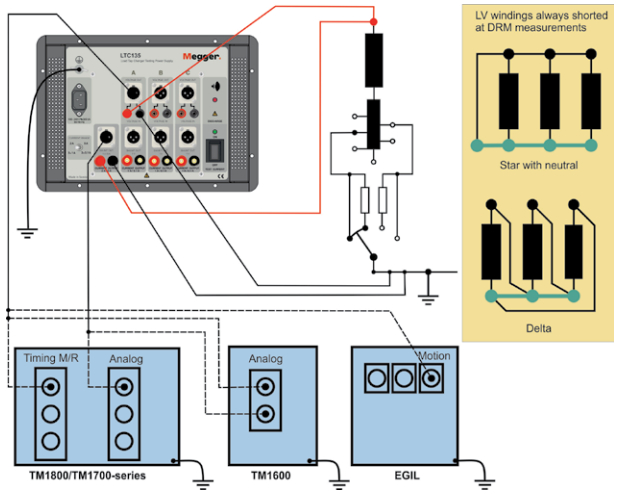
Note *Wait until discharge is finished before removing any cables.*

5 Measurement connections

5.1 Single-phase measurements

Single-phase transformer

Dynamic resistance measurements



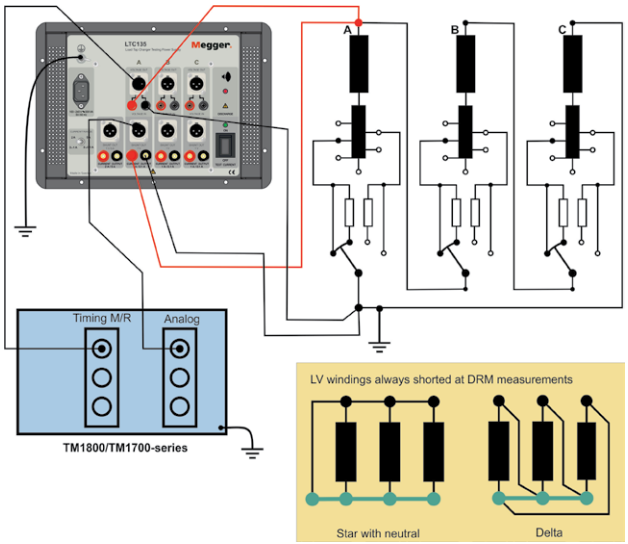
Connection diagram for dynamic resistance measurements on a single-phase transformer. Test current is the same as measured current from LTC135.

Dynamic voltage measurements

For dynamic voltage measurements; Connect voltage measurement to the corresponding/adjacent winding to the LTC winding (LV if LTC on HV)

Three-phase transformer

Dynamic resistance measurements



Connection diagram for single-phase dynamic resistance measurements on a three-phase Dy or Dd transformer.

Note *For HV delta configurations, the test current is 2/3 of measured current from LTC135. Assign a 3/2 current transducer in the CBA to get correct resistance calculation.*

For a YNy or YNd transformer connect A-N or B-N or C-N. Test current is the same as measured current from LTC135.

Dynamic voltage measurements

For dynamic voltage measurements; Remove LV short and connect voltage measurement to the corresponding/adjacent winding to the LTC winding (LV if LTC on HV) according to the following tables.

Configuration (IEC)	HV current injection	LV voltage measurement
YNyn0	A-N	a-n
	B-N	b-n
	C-N	c-n
YNyn6	A-N	n-a
	B-N	n-b
	C-N	n-c
YNy0	A-N	a-(b+c)
	B-N	b-(a+c)
	C-N	c-(a+b)
YNy6	A-N	(b+c)-a
	B-N	(c+a)-b
	C-N	(a+b)-c

YNd1	A-N	a-b
	B-N	b-c
	C-N	c-a
YNd5	A-N	c-a
	B-N	a-b
	C-N	b-c
YNd7	A-N	b-a
	B-N	c-b
	C-N	a-c
YNd11	A-N	a-c
	B-N	b-a
	C-N	c-b
Dy1	A-B	(a+c)-b
	B-C	(a+b)-c
	C-A	(b+c)-a
Dyn1	A-B	n-b
	B-C	n-c
	C-A	n-a
Dy5	A-B	(b+c)-a
	B-C	(a+c)-b
	C-A	(a+b)-c
Dyn5	A-B	n-a
	B-C	n-b
	C-A	n-c
Dy7	A-B	b-(a+c)
	B-C	c-(a+b)
	C-A	a-(b+c)
Dyn7	A-B	b-n
	B-C	c-n
	C-A	a-n
Dy11	A-B	a-(b+c)
	B-C	b-(a+c)
	C-A	c-(b+a)
Dyn11	A-B	a-n
	B-C	b-n
	C-A	c-n

Test connections (IEC) for dynamic voltage measurements.

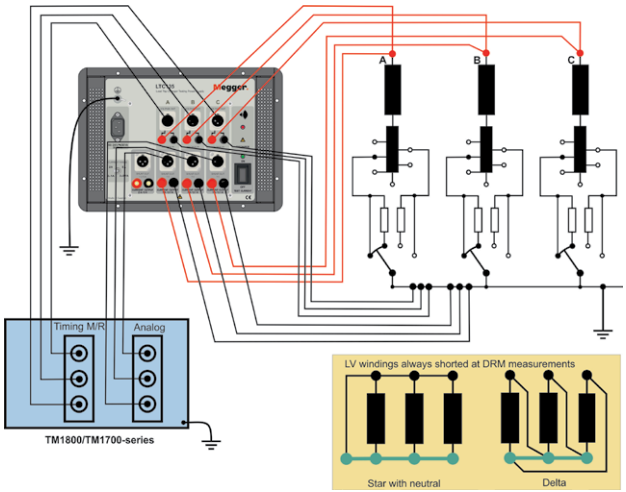
Configuration (ANSI)	**HV current injection**	**LV voltage measure-ment**
YNyn0	H1-H0	X1-X0
	H2-H0	X2-X0
	H3-H0	X3-X0
YNyn6	H1-H0	X0-X1
	H2-H0	X0-X2
	H3-H0	X0-X3
YNy0	H1-H0	X1-(X2+X3)
	H2-H0	X2-(X3+X1)
	H3-H0	X3-(X1+X2)
YNy6	H1-H0	(X2+X3)-X1
	H2-H0	(X3+X1)-X2
	H3-H0	(X1+X2)-X3
YNd1	H1-H0	X1-X2
	H2-H0	X2-X3
	H3-H0	X3-X1
YNd5	H1-H0	X3-X1
	H2-H0	X1-X2
	H3-H0	X2-X3
YNd7	H1-H0	X2-X1
	H2-H0	X3-X2
	H3-H0	X1-X3
YNd11	H1-H0	X1-X3
	H2-H0	X2-X1
	H3-H0	X3-X2
Dy1	H1-H3	X1-(X2+X3)
	H2-H1	X2-(X3+X1)
	H3-H2	X3-(X1+X2)
Dyn1	H1-H3	X1-X0
	H2-H1	X2-X0
	H3-H2	X3-X0
Dy3	H1-H3	X2-(X3+X1)
	H2-H1	X3-(X2+X3)
	H3-H2	X1-(X2+X3)
Dyn3	H1-H3	X2-X0
	H2-H1	X3-X0
	H3-H2	X1-X0
Dy5	H1-H3	X3-(X1+X2)
	H2-H1	X1-(X2+X3)
	H3-H2	X2-(X3+X1)
Dyn5	H1-H3	X3-X0
	H2-H1	X1-X0
	H3-H2	X3-X0
Dy7	H1-H3	(X2+X3)-X1
	H2-H1	(X1+X3-X2
	H3-H2	(X1+X2)-X3
Dyn7	H1-H3	X0-X1
	H2-H1	X0-X2
	H3-H2	X0-X3
Dy9	H1-H3	X2-(X3+X1)
	H2-H1	X3-(X1+X2)
	H3-H2	X1-(X2+X3)
Dyn9	H1-H3	X2-X0
	H2-H1	X3-X0
	H3-H2	X1-X0
Dy11	H1-H3	X1-(X2+X3)
	H2-H1	X2-(X3+X1)
	H3-H2	X3-(X1+X2)
Dyn11	H1-H3	X1-X0
	H2-H1	X2-X0
	H3-H2	X3-X0

Test connections (ANSI) for dynamic voltage measurements.

5.2 Three-phase measurements

Three-phase measurements are normally performed to check synchronization between phases by comparing OLTC start and operating times between phases.

Dynamic resistance measurements



Connection diagram for single-phase dynamic resistance measurements on a three-phase YNy or YNd transformer. Test current is the same as the three measured currents from LTC135.

Note *3-phase dynamic resistance measurements are not recommended to perform on HV delta configurations. The measured voltage is combined response from all three phases (one LTC in parallel with two LTC's in series).*

Dynamic voltage measurements

For dynamic voltage measurements; Remove LV short and connect voltage measurement to the corresponding/adjacent winding to the LTC winding (LV if LTC on HV) according to Table X or Y.

Dynamic current measurements

For 3-phase dynamic current measurements

1] Short all LV terminals.

2] Use 3 x 1 A test current and connect each source individually to H1, H2, H3 and N.

3] Connect 3 voltage measurement channels to the appropriate current shunt outputs on LTC.

4] Operate OLTC and measure.

5 Specifications

Specifications LTC135

Specifications are valid at fully charged batteries and an ambient temperature of +25°C, (77°F). Specifications are subject to change without notice.

Environment

Application field	For use in high-voltage substations and industrial environments.
Temperature	
Operation	-20°C to +45°C (-4°F to +113°F) *)
Storage	-40°C to +70°C (-40°F to +158°F)
Relative humidity %RH	5%-95%, non condensing

CE-marking

LVD	2014/35/EU
EMC	2014/30/EU
RoHS	2011/65/EU

General

Mains voltage	100 - 240 V AC, 50 / 60 Hz
Power consumption	300 VA
Dimensions	360 x 195 x 300 mm 14.2 x 7.7 x 11.8 in.
Weight	6.5 kg (14.3 lbs) instrument only 10.9 kg (24 lbs) with accessories and carrying case

Outputs

Output current	3 x 0.1 A	3 x 1 A	1 x 5 A
Open circuit voltage	48 V	48 V	48 V
Output impedance	480 Ω	48 Ω	9.6 Ω
Shunt output	1 V/0.1 A	1 V/1 A	1 V/5 A
Shunt inaccuracy	0.1%	0.3%	0.1%

Resistance measurement range

EGIL and TM1600 (4 V)	0 - 44 Ω	0 - 4.4 Ω	0 - 850 mΩ
TM1700/1800 (15 V)	0 - 200 Ω	0 - 20 Ω	0 - 4 Ω

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