Application Note

Cable Impedance Measurement with COMPANO 100

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Date
Jan. 10, 2024

Related OMICRON Product
COMPANO 100

Application Area
Cable Impedance Measurements

Keywords
Cable Impedance, k-factor, Line Impedance

Version
v1.0

Document ID
ANS_23003_ENU

Abstract

This application note explains how the impedances and the k-factor of short power cables (up to 5 km) can be measured with COMPANO 100. Such cables are very common in urban distribution networks and industrial energy networks.
The results can be used for configuring protection relays, performing load calculations or for network simulations.

For longer cables or overhead lines, use CPC 100 + CP CU 1.

General information

OMICRON electronics GmbH, including all international branch offices, is henceforth referred to as OMICRON.

The product information, specifications, and technical data embodied in this application note represent the technical status at the time of writing and are subject to change without prior notice.

We have done our best to ensure that the information given in this application note is useful, accurate and entirely reliable. However, OMICRON does not assume responsibility for any inaccuracies which may be present.

OMICRON translates this application note from the source language English into a number of other languages. Any translation of this document is undertaken for local requirements, and in the event of a dispute between the English and a non-English version, the English version of this note shall govern.

Table of contents

1 Safety instructions

This application note may only be used in conjunction with the relevant product manuals which contain all safety instructions. The user is fully responsible for any application that makes use of OMICRON products.

Instructions are always characterized by a ▶ symbol, even if they are included in a safety instruction.

NOTICE

Possible equipment damage or data loss

- ▶ Carefully read and understand the content of this application note as well as the manuals for the systems involved before operating them.
- ▶ Please contact OMICRON support if you have any questions or doubts regarding the safety or operating instructions.
- ▶ Follow each instruction listed in the manuals, especially the safety instructions, since this is the only way to avoid the danger that can occur when working on high voltage or high current systems.
- ▶ Only use the equipment according to its intended purpose to guarantee safe operation.

Existing national safety standards for accident prevention and environmental protection may supplement the equipment's manual.

Before starting a test always make sure that the test signals are suitable for the system that you're testing.

Only experienced and competent professionals that are trained for working in high voltage or high current environments may implement this application note. The following qualifications are also required:

- Authorization for working in environments involving energy generation, transmission, or distribution, and familiarity with the approved operating practices for such environments.
- Familiarity with the five safety rules.
- Knowledgeable and proficient when working with COMPANO 100, CP GB 1

1.1 Safety accessories

OMICRON offers a range of accessories for added safety during the operation of our test systems. For further information and specifications, refer to the corresponding Supplementary Sheet or contact OMICRON Support.

1.2 General

- ▶ Do not touch any terminals without a visible connection to ground.
- ▶ Before handling the COMPANO 100 in any way, connect them with a solid connection of at least 6 mm2 cross-section to ground.
- ▶ Use the CP GB1 grounding box to connect the COMPANO 100 to short (< 5 km) medium voltage (< 36 kV) power cables only.
- ▶ Do not use COMPANO 100 with CP GB1 to measure on longer power cables or power cables with a higher operating voltage.
- ▶ Ground the CP GB1 near the place where the connection to the test object is made. Make sure that the grounding stud is in good condition, clean and free of oxidation.
- ▶ Make sure that all studs and cables of the CP GB1 are screwed tight.

- Do not open the CP GB1's housing.
- Do not repair, modify, extend, or adapt COMPANO 100, CP GB1 or any accessories.
- Use only original accessories available from OMICRON.
- Use the CP GB1 and their accessories only in a technically sound condition and when its use is in accordance with the regulations. In particular, avoid disruptions that could in turn affect safety.

1.3 Operating the measurement setup

- Before operating the COMPANO 100 and CP GB1 ground them as described in section 3 "Connecting COMPANO 100 and CP GB1 to a power cable" on page 11.
- Ground the CP GB1 near the place where the connection to the test object is made. Make sure that the grounding stud is in good condition, clean and free of oxidation.
- Life threatening voltages up to 600 V can appear on all CP GB1's contacts and on all clamps and cables connected to COMPANO 100 during the test. Keep safe distance from them.
- Use a grounding set to ground the power cable at the near end whenever you handle the measurement setup inside the danger zone (for example when changing connections at the CP GB1 between measurement loops).
- Use only 10 m (~30 ft) measurement leads supplied by OMICRON to connect COMPANO 100 to CP GB1.
- Before connecting the CP GB1 with COMPANO 100 or when changing the connection, press the Emergency Stop button. Release it only if you are outside the danger zone.
- In addition to the above safety rules follow the application-specific instructions in the following chapters.

1.4 Handling long cables

- The entire working environment, including the power supply of the test system, must not extend beyond the perimeter of the substation, except where this is not feasible due to the situation on site.
- Make sure the COMPANO 100, its cables and the device under test are properly grounded as described in this manual.
- Before unreeling any power extension cords to supply the COMPANO 100, make sure the respective cable is connected to a mains supply with protective earth (PE).
- Before unreeling any measurement, communication or interface cables of the COMPANO 100, make sure no cables are connected to an ungrounded device under test.
- Extra care should be taken that cables are placed as close as possible to ground level (this practice minimizes both electric and magnetic coupling).
- Any measurement, communication or interface cables of the COMPANO 100 shall be placed within an environment, where unauthorized or unintentional human entry are avoided during usage of the COMPANO 100 with any means necessary.

1.5 Orderly measures

The CP CU1 User Manual, which covers also the CP GB1, or alternatively the e-book in PDF format has always to be available on site where the CP GB1 or CP CU1 is being used. It must be read and observed by all users of the CP GB1 and CP CU1.

The CP GB1 may be used only as described in chapters 3, 4 and 5. Any other use is not in accordance with the regulations. The manufacturer and/or distributor is not liable for damage resulting from improper usage. The user alone assumes all responsibility and risk.

The person responsible for the work activity (for example a measurement) must coordinate clear communication with all persons and parties involved in work activities on and around the device under test,

especially before injecting voltages or currents.
Risks arising from overlapping work activities on the same installation need to be evaluated and clarified beforehand.

Unauthorized persons must be prevented from accessing and/or activating COMPANO 100, CP GB1 or any of its accessories.

Following the instructions provided in this User Manual is also considered part of being in accordance with the regulations.

1.6 Disclaimer

If the equipment is used in a manner not specified by the manufacturer, the protection provided by the equipment may be impaired.

2 Introduction

This application note describes the usage of COMPANO 100 together with CP GB1 for measuring cable impedance and k-factors on short power cables (up to 5 km) like used in urban and industrial environments.

Long cables and overhead lines can be not measured, as the COMPANO 100 test-set does not have sufficient output power for overhead lines.

Note

CPC 100 + CP CU1 is a suitable solution for longer power cables and overhead lines.

WARNING

Death or severe injury caused by high voltage or current possible.

- Never connect COMPANO 100 directly to overhead lines or long power cables. The open cable voltage on such systems is likely above the maximum allowed level.

2.1 Safety Concept

The grounding box CP GB1 protects the user from unexpected events on the cable by being capable of diverting high short-circuit currents. The insulation of the COMPANO 100 is designed to withstand far higher voltages than the CP GB1's surge arrestors do.

Always use measurement leads with a least 10 m / 30 ft length to connect COMPANO 100 to CP GB1, as shown below. This limits the transients till the CP GB1 surge arrestors react.

Mark a danger zone around CB GB1. In open air systems, this must be at least 5 m / 15 ft distance from CB GB1.

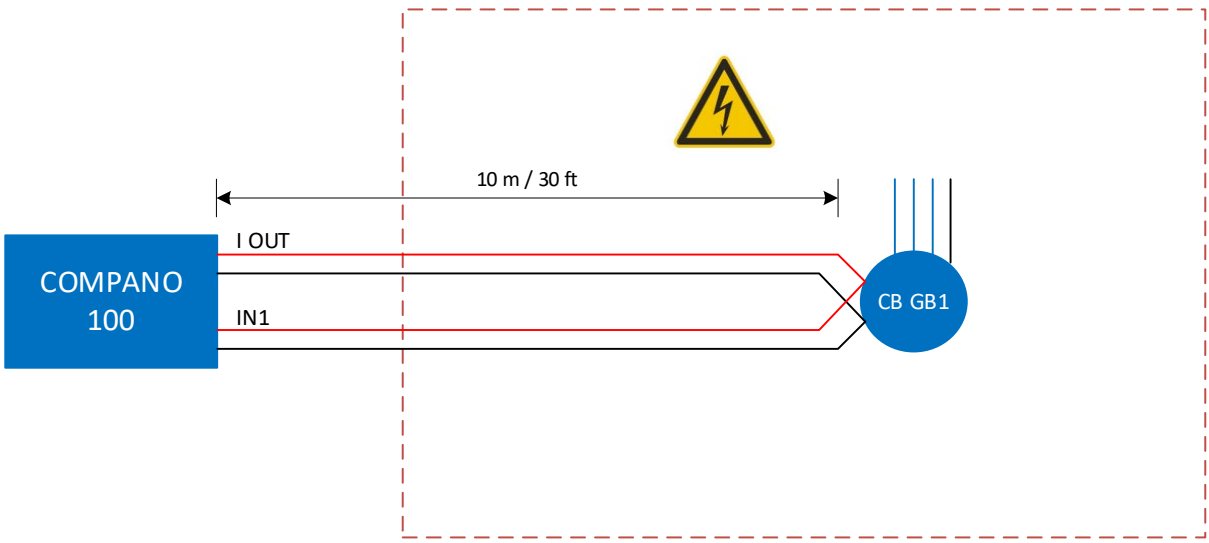


Figure 1: Connection of COMPANO 100 to CB GB1 and danger zone.

In buildings, like substations, this depends on the geometry. Ensure that you are in sufficient distance and not directly in front of the cabinet used for the test.

If the cable is accidentally energized during the test, the resulting high fault currents may lead to a high force, which can cause a considerable mechanical movement of the CB GB1. Always ensure that you are not near or direct in front of CB GB1 during the test, as shown in the two figures below.

Always use measurement leads with a least 10 m / 30 ft and a minimum distance of 5 m / 15 ft between CB GB1 and COMPANO 100.

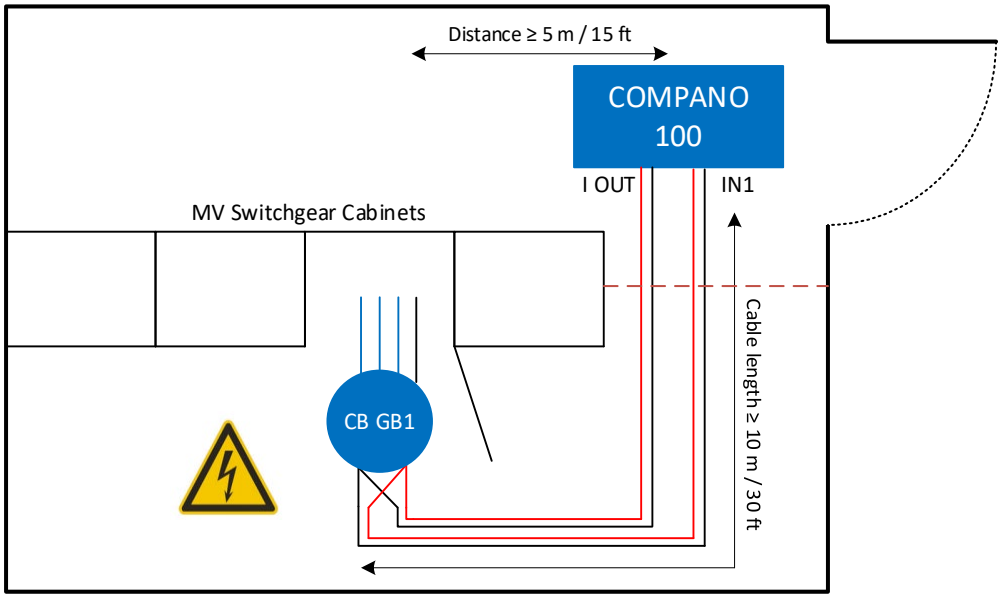


Figure 2: Possibility how to position COMPANO 100 outside the dangerous area.

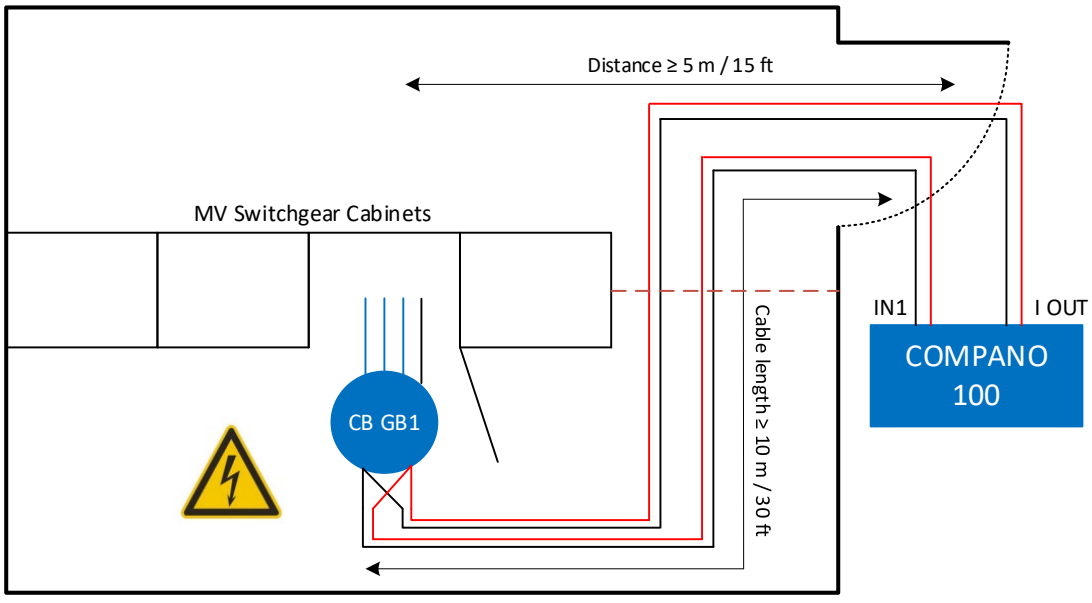


Figure 3: Best way to position COMPANO 100 outside the dangerous area.

NOTICE

Possible equipment damage or data loss

This safety concept was type tested and ensures the operators safety in the worst case, namely when the cable is accidentally energized during the measurement.

- The voltages on the housing of COMPANO 100 will be limited to a safe level.
- The voltages in COMPANO 100 may damage the equipment irreversible, if the is accidentally energized or the cable length or open-loop voltage is far too high.

To protect the equipment, it's essential to follow all instructions in the following chapters.

DANGER

Death or severe injury caused by high voltage or current.

- ▶ Only enter the high-voltage area when a safe state of the test setup can be assured.
- ▶ Before entering the high-voltage area, make sure that no hazardous voltage is present and all voltage carrying parts have visible, appropriate and safe connection to ground potential.

DANGER

Death or severe injury caused by mechanical impact.

Currents flowing from the CP GB1 into the ground can result in considerable mechanical movement of the CP GB1.

- ▶ Place the CP GB1 at least 10 m away from COMPANO 100.
- ▶ If possible, securely mount the CP GB1 to reduce the possibility of movement.

2.2 Handling of the CP GB1 Grounding Box

The handling and maintenance of the CP GB1 Grounding Box is described in Section 2.4 of the *CP CU1 user manual* [2].

It describes how to install the suitable ground studs and connect the CP GB1 to the cable.

Carefully read this section in the *CP CU1 user manual* before continuing.

2.3 Measurement Method

COMPANO 100 uses the so-called frequency selective method to measure the cable impedance.

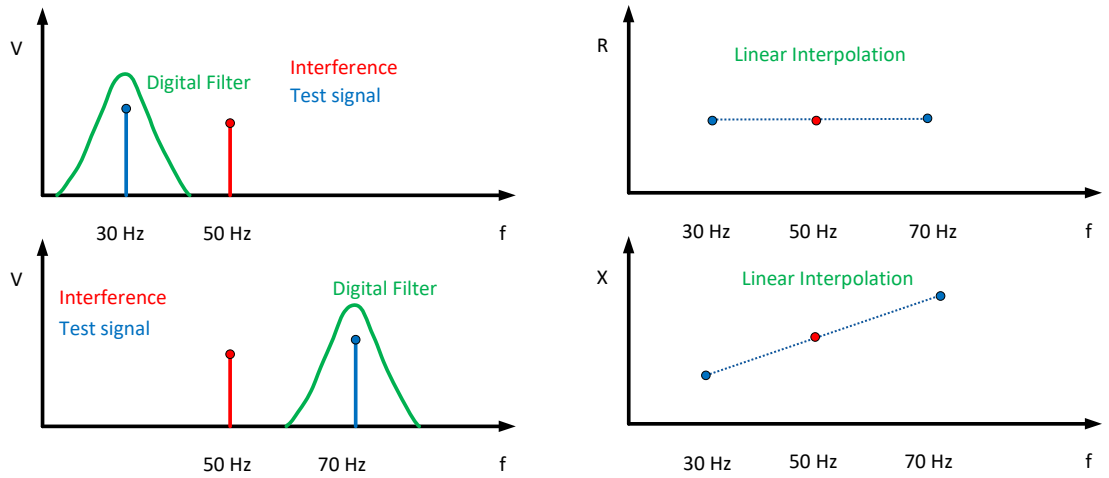
A test current with a frequency of 30 Hz and 70 Hz at 50 Hz systems or 40 Hz and 80 Hz at 60 Hz systems is injected.

Then, the voltage drop caused by this test current is measured frequency selective to the output frequency.

Therefore, distortions at mains frequency or harmonics will have virtually no impact on the accuracy of the measurement result.

Based on current and voltage, R and X will be calculated for 30 Hz and 70 Hz or 40 Hz and 80 Hz. Both R and X will be linear interpolated to get the impedance at mains frequency.

Example for 50 Hz:



This is possible as R is almost independent from the measurement frequency and X is almost linear dependent of the measurement frequency.

The measurements will be repeated for different current-loops and the single results will be combined to calculate the parameters of different line models as well as the k-factors using a provides Excel Template.

3 Connecting COMPANO 100 and CP GB1 to a power cable

WARNING

Death or severe injury caused by high voltage or current possible.

For measurements on power cables COMPANO 100 must be connected to the test object through the CP GB1 grounding box with at measurement leads of at least 10 m / 30 ft length.

For cable impedance testing COMPANO 100 must be connected to a power cable. Due to the fact that the near end of the cable must be disconnected from ground, there is a high danger potential and the risk for persons and test equipment to be exposed to hazardous voltages. The following scenarios are leading to voltages which are diverted to ground by the CP GB1 to protect the test equipment and operating staff:

- The cable under test could carry high voltage due to interference from adjacent live systems.

WARNING

Death or severe injury caused by high voltage or current possible.

- Due to miscommunication, the grounding switch at the far end could be opened accidentally.
- Due to miscommunication, the line could also be energized from the far end.

Note: This is a severe violation of the safety rule “Secure against re-connection”!

- ▶ Establish the responsibilities of everybody working on the asset under test.
- ▶ Make sure that everybody is made aware of the measurement on the respective power cable.
- ▶ Provide two-way communication between the near and far ends of the power cable.

In order to estimate the interference and check if COMPANO 100 and CU GB1 can be used for the measurement, the following steps are recommended for preparation of the measurement. All together, four criteria have to be checked:

- Line length
- Estimated open-line voltage
- Measured open-line voltage
- Injected test current

3.1 First criterion

- Check if the cable to test has a length with is less than 5 km / 3 miles.

Note

For longer lines, the output power of COMPANO 100 might be not sufficient, especially in case of interferences or coupling from parallel systems.

3.2 Second criterion: Estimated open-cable voltage.

Figure 4 below illustrates the estimation of the open-cable voltage. In principal, the circular current which is caused by the interference of a parallel system is measured in all three phases.

WARNING

Death or severe injury caused by high voltage or current possible.

- Before grounding a power cable, make sure that the cable is not powered with the life-dead-life test as follows:
  1. Use a certified voltage tester, approved for the voltage tests to be performed.
  2. Verify on a life system that the voltage tester is operational.
  3. Verify on the cable to be unpowered that it is dead, using the voltage tester.
  4. Verify on the life system again that the voltage tester is still working.
- When grounding a power cable, observe the five safety rules.

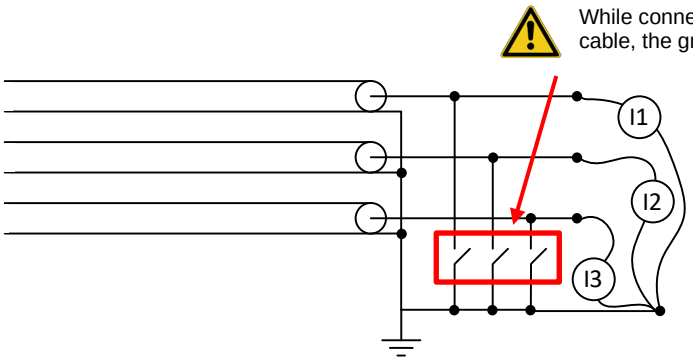


Figure 4: Estimating the open-line voltage

In order to allow a circular current, both ends of the cable must be grounded. With a standard current clamp it is usually not possible to measure the current directly at the grounding switch. Therefore, the following procedure by using a grounding set is recommended:

1. Switch off, short-circuit and ground the power cable on both sides, using an installed grounding switch or, if no grounding switch is available on site, using grounding cables (further on, the grounding switch or these extra grounding cables are referred to as grounding switch).

2. Make sure that the connection to ground at the far end of the power line is not removed during the complete test procedure.

3. In addition to the grounding switch, ground the cable at the near end, using a grounding set consisting of three cables rated for the maximum short-circuit current possible on the line. Now the circular current is split between the near grounding switch and the grounding set.

4. Open the near grounding switch in order to measure the entire circular current via the grounding set.

5. Then measure the current in each of the three phases of the grounding set with a common current clamp and note the values. Depending on the geometry of the line the values for the currents could slightly differ.

6. Close the grounding switch again.

7. Disconnect the grounding set from the power cable and ground.

Alternatively, the circular currents can also be measured directly at the grounding switch by using a Rogowski coil or other suitable measuring devices. Then the grounding set is not needed for the measurement of the circular currents. One advantage of the measurement is the possibility to detect contact problems at the grounding switch. If one of the measured currents is much lower than the others, this could indicate a contact problem at the grounding switch of that respective phase (this of course only refers to the measuring method using a Rogowski coil).

DANGER

Death or severe injury caused by high voltage or current.

Make sure all the contacts at the grounding switch are in good condition (free of oxidation). **Note**: If no voltage is measured on any of the phases, this does not necessarily mean that the grounding switch is working properly!

The estimated voltage can now be calculated according to equation Eq. 1 or 2 below by using the highest of the three measured currents.

Note: If line length is measured in kilometers use Eq. 1. For miles use Eq. 2.

$$U_{est} = l_{line} \cdot 2 \cdot 0.4 \cdot \frac{\Omega}{\text{km}} \cdot \max(I_1, I_2, I_3) \quad \text{(Eq. 1)}$$

$$U_{est} = l_{line} \cdot 2 \cdot 0.64 \cdot \frac{\Omega}{\text{mi}} \cdot \max(I_1, I_2, I_3) \quad \text{(Eq. 2)}$$

Maximum allowed voltage U_{est}: 20 V.

Note: If the calculated voltage U_{est} exceeds 20 V, the measurement cannot be performed, since the current output of COMPANO 100 is not designed for driver higher voltages! If this is the case, please consider the following options:

- Try to reduce the interference from parallel cables by
  a) reducing the load flow on parallel cables,
  b) de-energizing parallel systems.
- Perform the measurements at another time, when load flow is lower.

If none of the above is successful, consider using CPC 100 + CP CU1 + CP GB1 as alternative measurement solution, which can be used for voltages up to 500 V.

3.3 Third criterion: Measured open-line voltage

After the estimation of the open-line voltage, CP GB1 can now be connected to the cable under test, in order to measure the actual open-line voltage and verify the estimation.

- ▶ Set up a voltmeter according to Figure 5. The Kelvin clamps on the grounding box must be connected to the phase where the highest circular current has been measured and ground.

In the example in Figure 5 the Voltmeter is connected to L1 and ground.

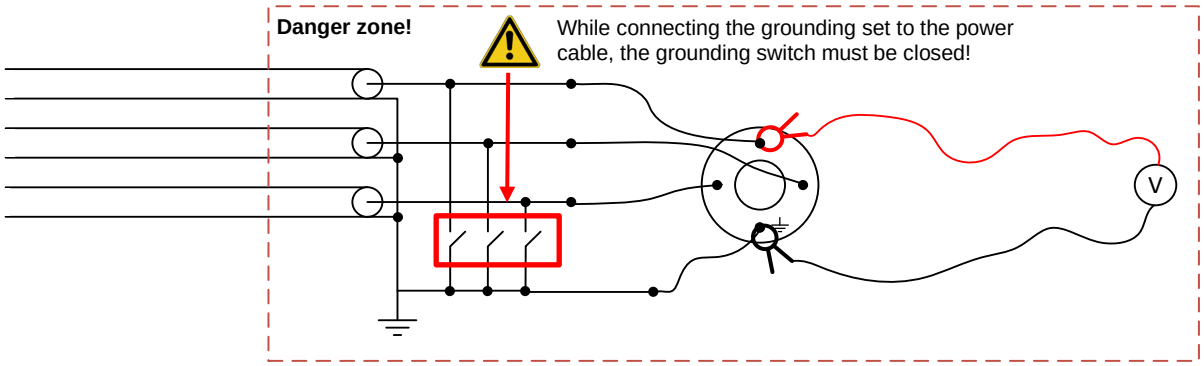


Figure 5: Measuring the coupled voltage with a voltmeter.

To measure the open-line voltage, perform the following steps:

1. Make sure the grounding switch is closed!

WARNING

Death or severe injury caused by high voltage or current possible.

Connecting grounding socket clamps of one type to a grounding point of another type is highly dangerous on both the connection of the grounding set to the CP GB1 and the connection of the CP GB1 to the grounding point in the substation. The 16 to 20 mm grounding socket clamp is designed and tested for fault currents up to 26.5 kA, the 25 mm (1 inch) grounding socket clamp for fault currents up to 30 kA, both for a maximum duration of 100 ms.

- ▶ Make sure to use the proper grounding socket clamp and that the grounding stud is in good condition, clean and free of oxidation!
- ▶ On locations where higher fault currents are possible than the grounding socket clamps are designed for, the CP GB1 must not be used!

2. Connect the CP GB1 to ground near the place where the connection to the power line is made. Use the cable delivered with the CP GB1 and the proper grounding socket clamp.

3. Connect the cables of the grounding set used for estimating the open-line voltage (see 3.2 Second criterion: Estimated open-cable voltage.) to the GB1.

4. Connect the other ends of the grounding set to the three phases of the power cable.

WARNING

Death or severe injury caused by high voltage or current possible.

- ▶ Stay outside the danger zone during the measurement.
- ▶ Use a voltmeter with a 1000 V AC range and a suitable protection level.

Note: Since the voltmeter is placed in the danger zone, it must be positioned in a way to be able to read the voltage.

5. Connect the voltmeter to the CP GB1 as shown in Figure 5.
6. Select the 1000 V AC range.
7. Leave the danger zone and open the grounding switch.

WARNING

Death or severe injury caused by high voltage or current possible.

- ▶ If you see or hear anything uncommon in the test equipment, for example, noise of electric discharge or lightening of surge arrestors in the CP GB1, close the grounding switch before touching the measurement setup.

8. Read the voltage at the voltmeter from outside the danger zone.
9. Close the grounding switch again!

Note: If the measured voltage exceeds 20 V, the measurement cannot be performed, since the current output of COMPANO 100 is not designed for driver higher voltages! If this is the case, please consider the following options:

- Try to reduce the interference from parallel cables by
  - c) reducing the load flow on parallel cables,
  - d) de-energizing parallel systems.
- Perform the measurements at another time, when load flow is lower.

If none of the above is successful, consider using CPC 100 + CP CU1 + CP GB1 as alternative measurement solution, which can be used for voltages up to 500 V.

3.4 Forth criterion: Injected test current

After the measurement of the open-line voltage, COMPANO 100 can now be connected to the CP GB1.

In the example in Figure 6 COMPANO 100 is connected to L1 and L2.

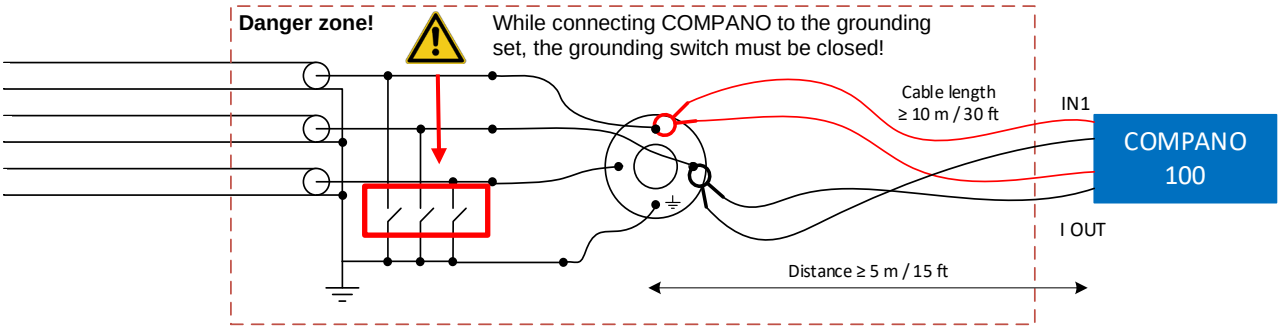


Figure 6: Connecting COMPANO 100 to CP GB1

To connect COMPANO 100 to CP GB1, perform the following steps:

1. Make sure the grounding switch is closed!

WARNING

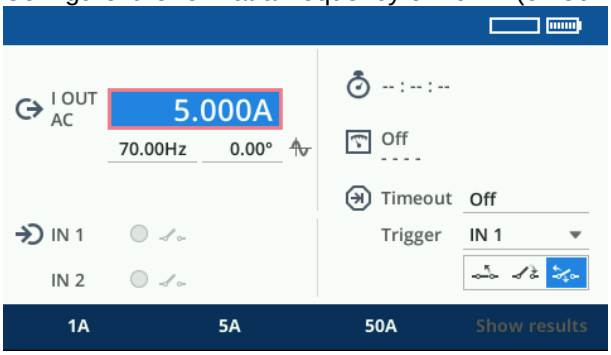
Death or severe injury caused by high voltage or current possible.

- Position COMPANO 100 outside the danger zone. Keep a distance of at least 5 m / 15 ft between CP GB1 and COMPANO 100.
- Use measurement leads of at least 10 m / 30 ft length.

2. Position COMPANO 100 outside the danger zone, at least 5 m / 15 ft from the CP GB1.
3. Ground COMPANO 100, using a cable of at least 6 mm² cross-section, close to the position of the operator.
4. Connect COMPANO 100 to CP GB1 as shown in Figure 6 using measurement leads of at least 10 m / 30 ft length.
5. Leave the danger zone and open the grounding switch.

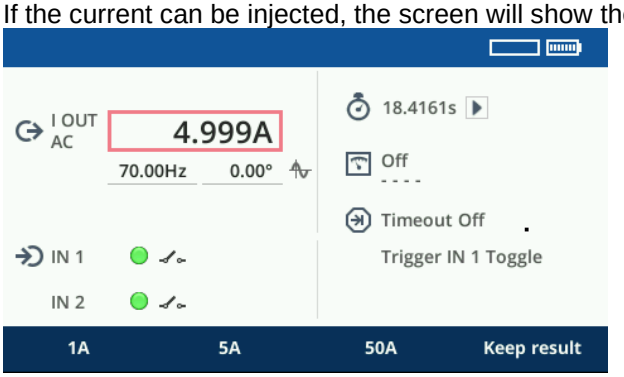
To inject the test current, perform the following steps:

1. Select the COMPANO 100 QUICK application module.
2. Configure it for 5 A at a frequency of 70 Hz (on 50 Hz systems) or 80 Hz (on 60 Hz systems).



3. Start the output.
4. Wait a few seconds till the reading settled.
5. Stop the output.

- If the current can be injected, the screen will show the measured current.

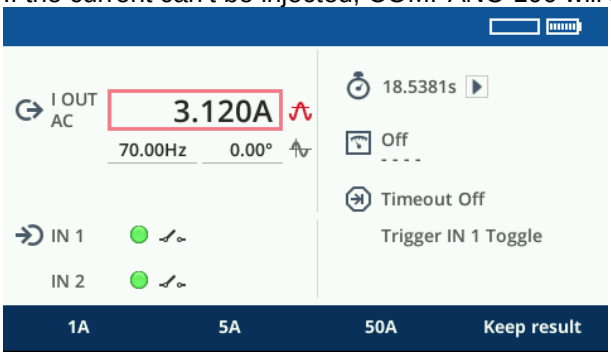


Note

Press the wheel on COMPANO 100 to switch between set-point (blue background) and measured value (white background).

Now you can continue with the actual measurement in the next chapter.

- If the current can't be injected, COMPANO 100 will show an overload indicator.



This usually happens if the cable impedance is too high to drive the configured current.

Reduce the current and repeat the test.

4 Cable impedance measurements

The following section describes how to perform the actual cable impedance measurement.

Chapter 4 of the *CP CU1 User Manual* [2] contains a detailed explanation how the model parameters and the k-factors for protection relays are calculated.

4.1 Setup

WARNING

Death or severe injury caused by high voltage or current possible.

- Ensure that you follow all safety rules in this application note and the according product manuals for COMPANO 100 and CP GB1 (described in the CP CU1 product manual).
- Do not perform the measurement before you have successfully completed all necessary steps described in chapter 3 .
- Use a grounding set to ground the power line at the near end whenever you handle the measurement setup inside the danger zone (for example when changing connections at the CP GB1 between measurement loops).

- Follow the instructions in chapter 3 *Connecting COMPANO 100 and CP GB1 to a power cable* on page 11 in order to connect the CP CU1 to the power cable under test and check the four criteria.

4.2 Load Template

This application note comes with two pre-defined COMPANO configuration profiles for 50 Hz and 60 Hz mains frequency.

File	Mains Frequency	Test Frequency 1	Test Frequency 2
CABLE-50.occp	50 Hz	30 Hz	70 Hz
CABLE-60.occp	60 Hz	40 Hz	80 Hz

Table 1: Measurement frequencies and configuration profiles

- Select the applicable file, deepening on the mains frequency.
- Copy the file to a USB flash drive.
- Insert the USB flash drive on COMPANO 100.
- Load the configuration profile (See *COMPANO 100 User Manual* [1] for more information).

For the measurement, the previously loaded FLEX sequence is used.

- Select the FLEX application module.

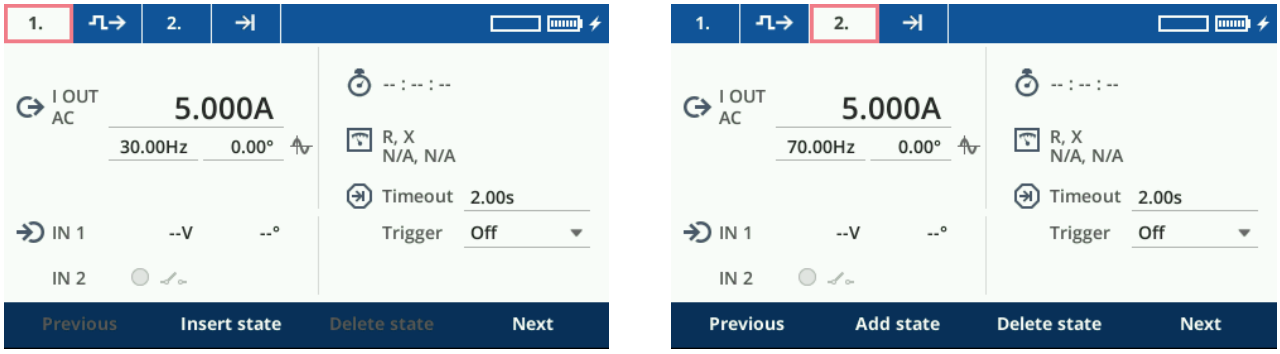


Figure 7: Test sequence for 50 Hz (CABLE-50.occp)

Above configuration profiles are pre-configured for 5 A test current. This should be suitable for most cables with a length of up to 5 km.

- If the current was reduced during the injecting the test current as described in chapter 3.4 , it must be also reduced in state 1 and state 2 of the loaded configuration profile.

4.3 Perform Measurement

The measurement must be performed 7 times, with different current loops, as shown in Table 2.

Current Loop	Kelvin Clamp 1 (Red)	Kelvin Clamp 2 (Black)	Suggested File Name Prefix
L1 – L2	L1	L2	L1-L2
L1 – L3	L1	L3	L1-L3
L2 – L3	L2	L3	L2-L3
L1 – E	L1	Earth / Ground Stud	L1-E
L2 – E	L2	Earth / Ground Stud	L2-E
L3 – E	L3	Earth / Ground Stud	L3-E
L1+L2+L3 – E	Bridged L1, L2 and L3	Earth / Ground Stud	L123-E

Table 2: Required measurement loops

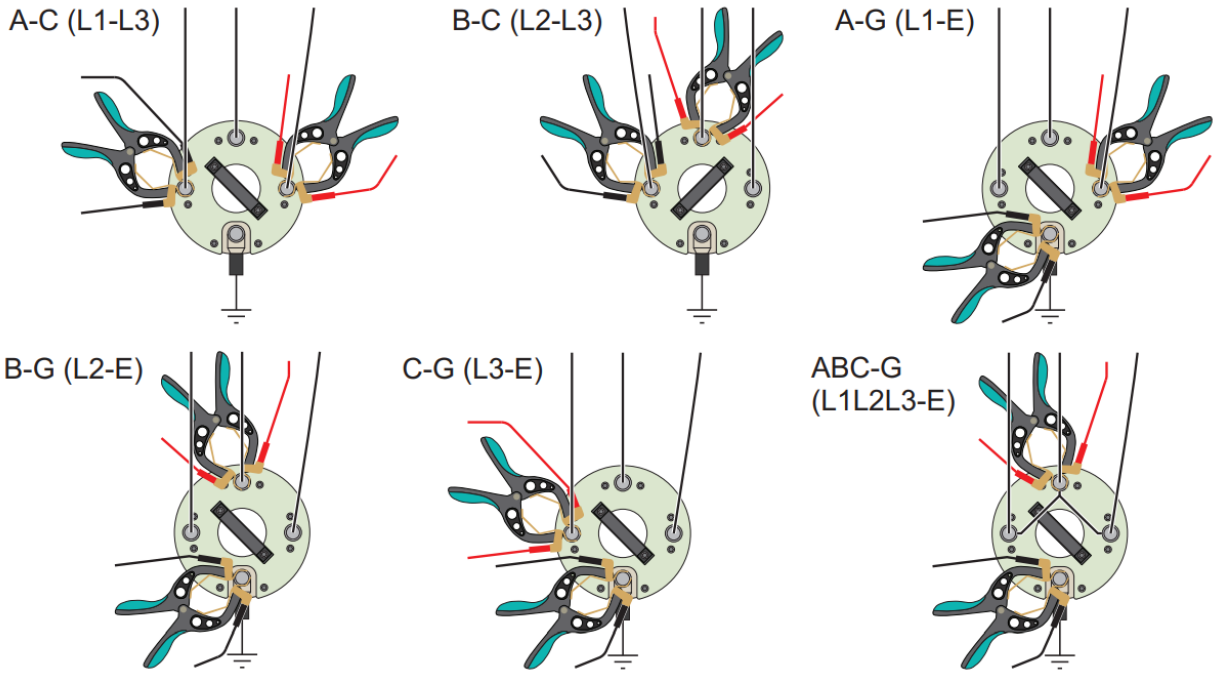


Figure 8: Clamp connections for measurement loops 2-7.

For each measurement loop do:

1. Press the emergency stop button on COMPANO 100.
2. Connect the red and black kelvin clamps to the listed studs (see Table 2 and Figure 8: Clamp connections for measurement loops 2-7.).
   If stated, bridge L1, L2 and L3 with the bridge cable.
3. Release the emergency stop button on COMPANO 100 and wait till the device is ready
4. Start the output by pushing the start button.
5. Wait till the two measurements are done. The device will stop the output after 4 seconds.
6. Store the measurement results on the USB flash drive using the file name, suggested in Table 2.
7. Clear the measurement results.
8. Continue with the next current loop.

If you're done with the measurement:

1. Press the emergency stop button.
2. Ground the cable with a grounding set.
3. Disconnect CP GB1 from COMPANO 100
4. Disconnect CP GB1 from the cable under test first.
5. Dismantle the test setup

4.4 Evaluation of Measurements

This application note comes with an Excel report spreadsheet, named *COMPANO-Template-Cable-Impedance-Measurement-2023-ENU.xlsm.*

- Open the file *COMPANO-Template-Cable-Impedance-Measurement-2023-ENU.xlsm*

	A	B	C	D	E	F	G	H
1								
2		**Cable Impedance Measurement Report**					OMICRON	
3		**For Single Circuit Cables**						
4								
5	Template:	COMPANO-Template-Cable-Impedance-Measurement-2023-ENU						
6	Version:	1.00						
7								
8	Substation:				Coordinates:			
9	Name of Cable:				Cable Length:		5,000	km
10	Characterization of cable:							
11								
12	Remote Substation:				Coordinates:			
13	Test Engineer:				Test Date:			
14	Measurement Temperature:		20 °C		Reference Temperature:		20 °C	
15	Conductor Material:		Al		Correction Factor:		1,000	
16	Frequency 1:		30 Hz		Results for Frequency:		50 Hz	
17	Frequency 2:		70 Hz					

- Fill the blue fields, including cable length and used measurement frequencies (see Table 1).
- Open the COMPANO Excel File loader in Windows Start menu:
  Start → OMICRON COMPANO 100 → COMPANO 100 Excel File Loader

	A	B	C	D	E	F
1						
2		**COMPANO 100 Excel File Loader**				
3		Template version	2.40			
4						
5		Load XML file				
6						
7						
8						
9						

Perform the following steps for each of the seven results files (see Table 2).

- Select the “Welcome” sheet
- Press “Load XML file”
- Load the according result file from the USB flash drive. They are stored in the COMPANO_100_Reports folder.

  E.g. **L1-L3**_COMPANO_100_2023-02-27_11.05.28.499.xml
- Select the “FLEX” sheet
- Copy the R / X value from the first line into the R / X fields with the lower frequency (e.g. 30 Hz) in the column for the according current loop (e.g. $Z_{L1\text{-}L3}$ for L1-L3) in the cable impedance report.

- Copy the R / X value from the second line into the R / X fields for the higher frequency (e.g. 70 Hz) in the column for the according current loop (e.g. Z_{L1-L3} for L1-L3) in the cable impedance report.

	AJ	AK	AL	AM	AN	AO	AP	AQ
					Calc. Meas.			
atus	Operand 1		Operand 2		Calcula	Result	Result	ou
d	I OUT	AC current	IN 1	AC voltage	Impedance RX	2,489Ω	0,003Ω	2,000
d	I OUT	AC current	IN 1	AC voltage	Impedan X	2,489Ω	0,004Ω	00

1 2 3 4

Figure 9: Result file of a single measurement loop

18								
19	Measured Impedances							
20		Z_{L1-L2}	Z_{L2-L3}	Z_{L1-L3}	Z_{L1-E}	Z_{L2-E}	Z_{L3-E}	$Z_{L1L2L3-E}$
21	30Hz: R / Ω	2,480	2,471	2,489	4,580	4,606	4,579	3,768
22	30Hz: X / Ω	0,002	0,003	0,003	0,003	0,003	0,002	0,002
23	70Hz: R / Ω	2,480	2,471	2,489	4,580	4,606	4,579	3,768
24	70Hz: X / Ω	0,003	0,004	0,004	0,006	0,006	0,006	0,005
25								
26	Measured Impedances							
27		Z_{L1-L2}	Z_{L2-L3}	Z_{L1-L3}	Z_{L1-E}	Z_{L2-E}	Z_{L3-E}	$Z_{L1L2L3-E}$
28	R / Ω	2,480	2,471	2,489	4,580	4,606	4,579	3,768
29	X / Ω	0,003	0,004	0,004	0,005	0,005	0,004	0,003
30	Z / Ω	2,480	2,471	2,489	4,580	4,606	4,579	3,768
31	φ / °	0,06	0,08	0,08	0,06	0,06	0,06	0,05
32								

1 2 3 4

Figure 10: COMPANO Template for calculating the cable impedance

- Repeat this for the result files of all seven measurement loops.

4.5 Results

The final results can be found on the lower half of the Cable Impedance Measurement Template.

34	Physical Model Impedances						
35		Z_{P11}	Z_{P22}	Z_{P33}	Z_{P12}	Z_{P23}	Z_{P13}
36	R / Ω	4,580	4,606	4,579	3,353	3,357	3,335
37	X / Ω	0,005	0,005	0,004	0,003	0,003	0,003
38	Z / Ω	4,580	4,606	4,579	3,353	3,357	3,335
39	φ / °	0,06	0,06	0,06	0,06	0,05	0,05
40							
41							
42	Symmetrical Components and Line Model with Z_E						
43		$Z_1 = Z_L$ / Ω	Z_0 / Ω	Z_E / Ω	Z'1 / Ω/km	Z'0 / Ω/km	Z'E / Ω/km	$Z_{0,calc}$ / Ω
44	R	1,240	11,304	3,355	0,248	2,261	0,671	11,285
45	X	0,002	0,010	0,003	0,000	0,002	0,001	0,011
46	Z	1,240	11,304	3,355	0,248	2,261	0,671	11,285
47	φ / °	0,07	0,05	0,05	0,07	0,05	0,05	0,05
48							
49							
50	k-Factors						
51	$k_L = Z_E / Z_L$			R_E / R_L and X_E / X_L			$k_0 = Z_0 / Z_L$	
52	Abs	φ / °		R_E / R_L	X_E / X_L		Abs	φ / °
53	2,705	-0,02		2,705	1,853		9,116	-0,02
54								
55								
56	Error Calculation							
57				$Z_1 = Z_L$		Z0	
58	Calculated Value:			R / Ω	X / Ω	R / Ω	X / Ω
59							
60	Error (ref. to measured value) / %:						

Figure 11:Results of the measurements in the COMPANO 100 Cable Impedance Template

The $\underline{Z}_0$ impedance will be calculated from different measurements. The results in the $\underline{Z}_0$ cells must be approximately the same than the results in the $\underline{Z}_{0,calc}$ cells, otherwise the measurement is considered invalid.

5 List of literature

[1] COMPANO 100 User Manual

[2] CP CU1 User Manual

Support

When you are working with our products, we want to provide you with the greatest possible benefits. If you need any support, we are here to assist you.

OMICRON Support – get in touch

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Americas: +1 713 830-4660 or +1 800-OMICRON
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