Application Note

Testing the SEL Adaptive Slope Restraint Characteristic with Test Universe

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Abstract
The SEL 487 adaptive slope restraint characteristic presents unique challenges to the test engineer. The following application note outlines the special steps necessary to test the adaptive slope characteristic with OMICRON Test Universe software.

Content

Please use this note only in combination with the related product manual which contains several important safety instructions. The user is responsible for every application that makes use of an OMICRON product.

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1 Introduction

1.1 Requirements to use this application note

1.1.1 Safety Instructions

To use this application note it is very important to read and to understand the **Safety Instructions** of *Test Universe* and of the electrical equipment that is controlled by *Test Universe*. They can be found in the corresponding manuals.

DANGER – Life-hazardous voltages and currents!

- The OMICRON *Test Universe* software controls electrical equipment that can output life-hazardous voltages and currents.
- Before operating any such electrical equipment, carefully read the **Safety Instructions** section in the manual that was provided with the equipment.
- Do not use (or even turn on) any electrical equipment without understanding the information in its manual.
- Existing national safety standards for accident prevention and environmental protection may supplement the equipment's manual.
- Only trained personal should operate *RelaySimTest*.

NOTICE – Equipment damage!

- The OMICRON *Test Universe* software controls electrical equipment that can output voltages and currents which are able to damage equipment.
- Before operating any such electrical equipment, be sure that no equipment will be damaged.

1.1.2 General Requirements

Prior to using this application note, read the "Getting started" manual [1] of *Test Universe*. The following software tools are required to use this application note:

- Test Universe software with a Control Center Software and Advanced Differential software and license. A license for this product is included with many Test Universe software packages. If you have problems operating any of the advanced differential modules with your CMC, please contact technical support at 1-800 OMICRON with your CMC serial number for more information, to obtain a temporary license, or to purchase a license.

2 Basic Operation of the SEL Adaptive Slope Restraint Characteristic

Many SEL transformer differential relays, such as the SEL 387, 587, and 787 relays use a common pickup, slope 1, slope 1-2 breakpoint, and slope 2 characteristic.

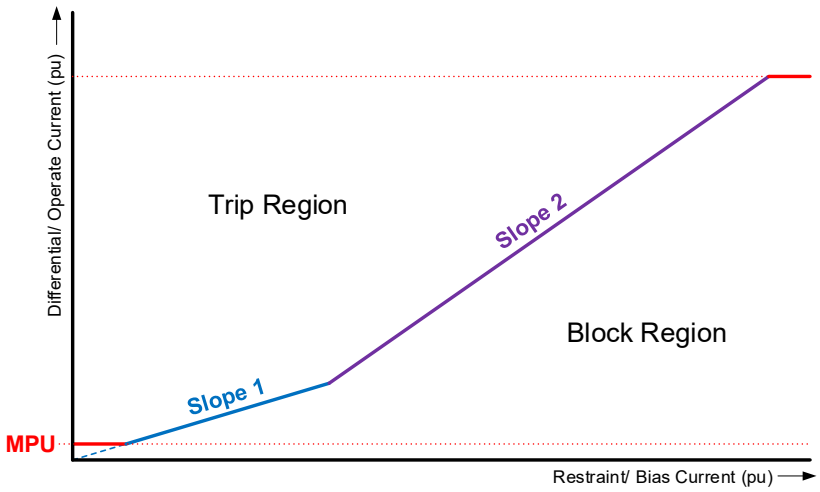
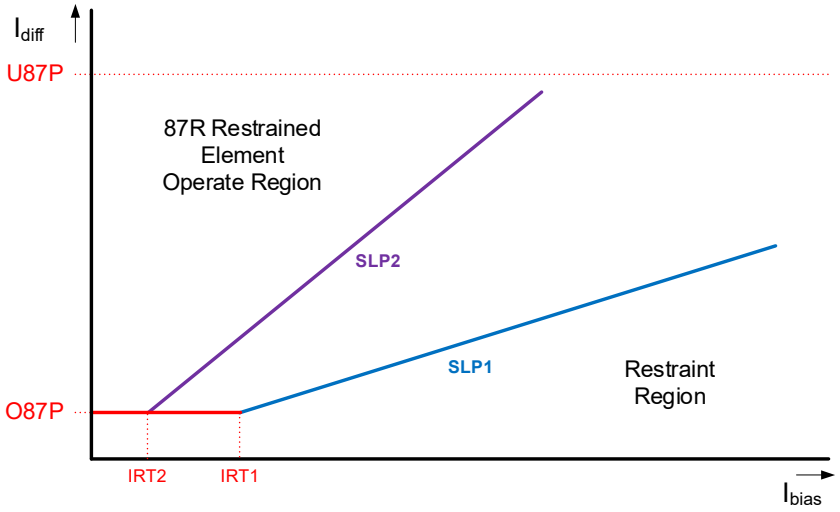


Fig 1: Traditional current differential slope characteristic for digital transformer differential relay devices

Conversely, the SEL 487 relay incorporates an adaptive slope characteristic. This characteristic features two slopes referencing the origin. Slope 1 is enabled for internal faults. Slope 2 is a high security mode that is enabled for external faults meeting certain criteria.



$$IRT2 = \frac{O87P}{SLP2} \times 100$$

$$IRT1 = \frac{O87P}{SLP1} \times 100$$

Fig 2: SEL Adaptive current differential slope characteristic

The current differential element active slope is dynamically selected by fault-sensing logic based on pre-fault conditions. To enable slope 2 for testing, several supervision elements must be satisfied. First, a pre-fault current must correctly simulate an external fault with the correct amplitude and duration. Second, a fault is simulated to verify the slope setting. For additional details, consult the applicable manual or SEL Application Guide “Testing the SEL-487E Relay Differential Elements”.

3 Testing the SEL 487 Adaptive Slope Restraint Characteristic

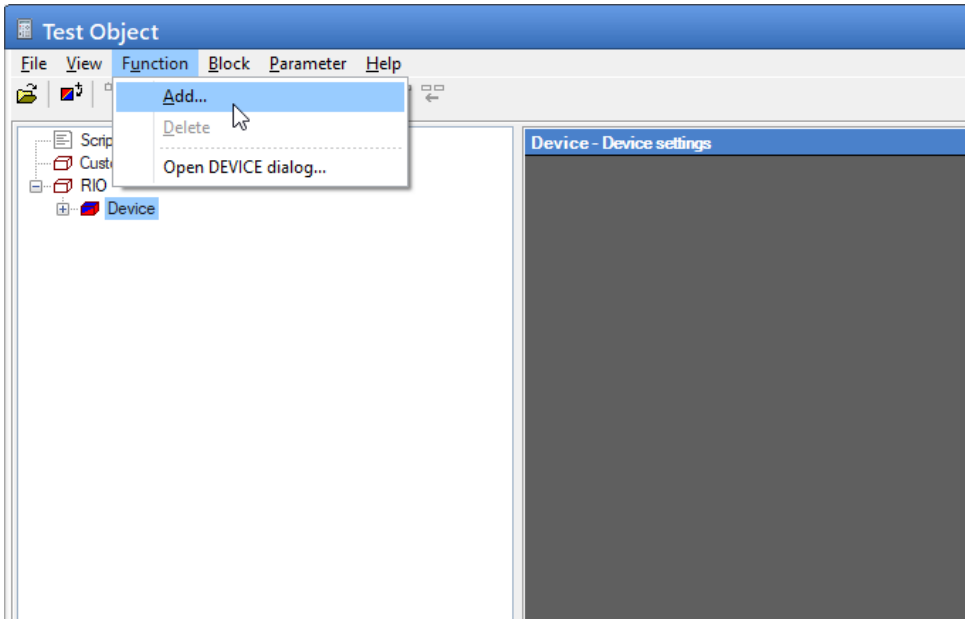
The following subsections of this application note describe the steps necessary to test the adaptive current differential slope characteristic of the SEL 487 relay with the OMICRON Test Universe software. For information on how to setup the OMICRON Test Universe software to test a digital transformer differential relay, refer to the Protection Testing Bulletin #3 Main Article or the “Examples of Use - Testing Transformer Differential Protection” PDF Document, accessible from the Test Universe Start Page.

3.1 Configure the Adaptive Slope in the Test Object

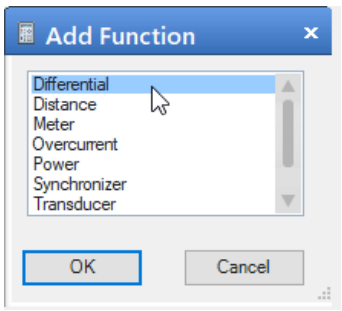
The first step is to configure the adaptive slope characteristic in the test plan test object. For this application note the following adaptive slope characteristic settings are used:

O87P = 0.3 pu
U87P = 3.5 pu
SLP1 = 34 %
SLP2 = 68 %
DIRTR = 1.2 pu

Open the test object and then select the option **Add…** from the **Function** tab.

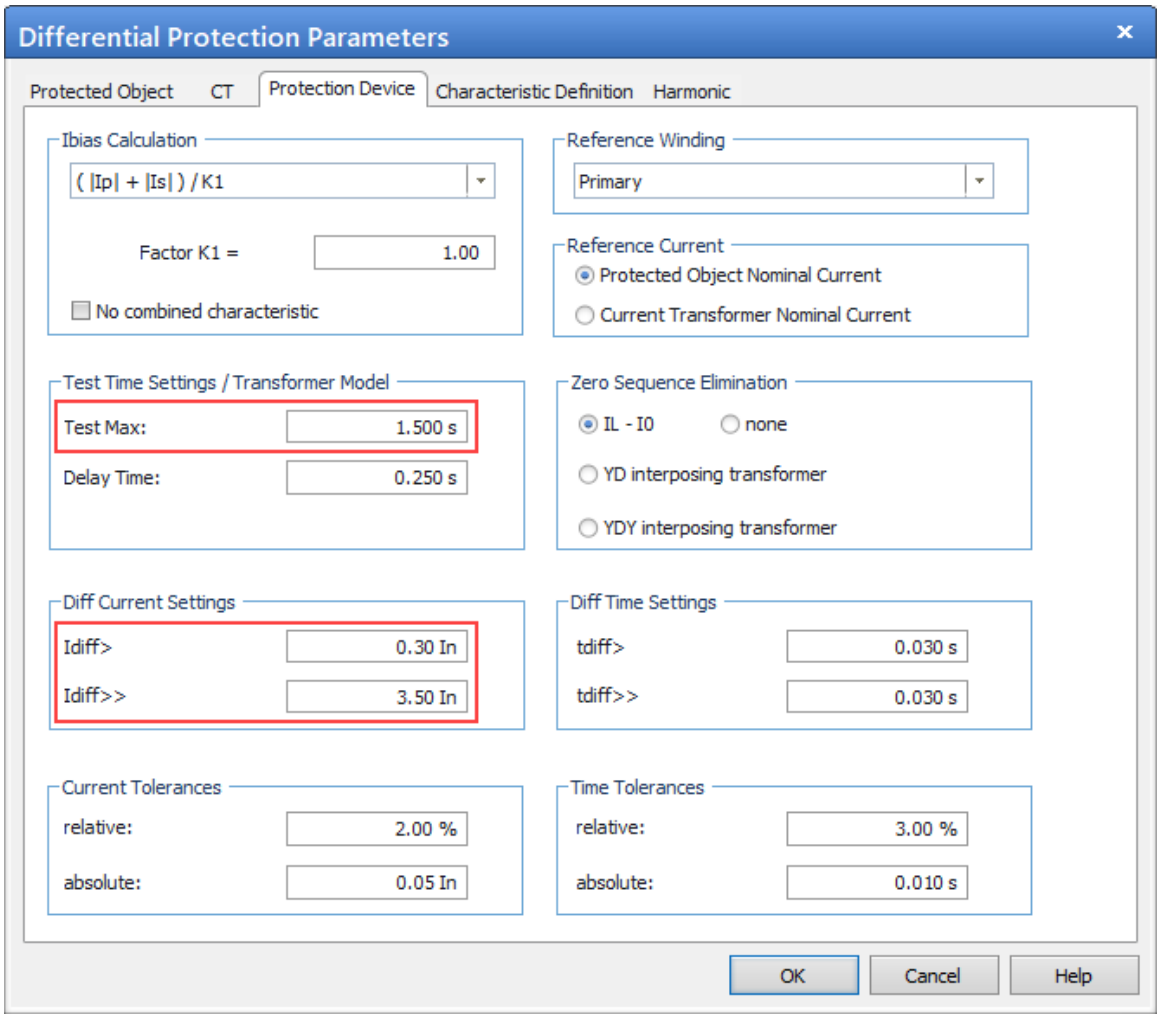


In the **Add Function** window select Differential and then click **OK**.



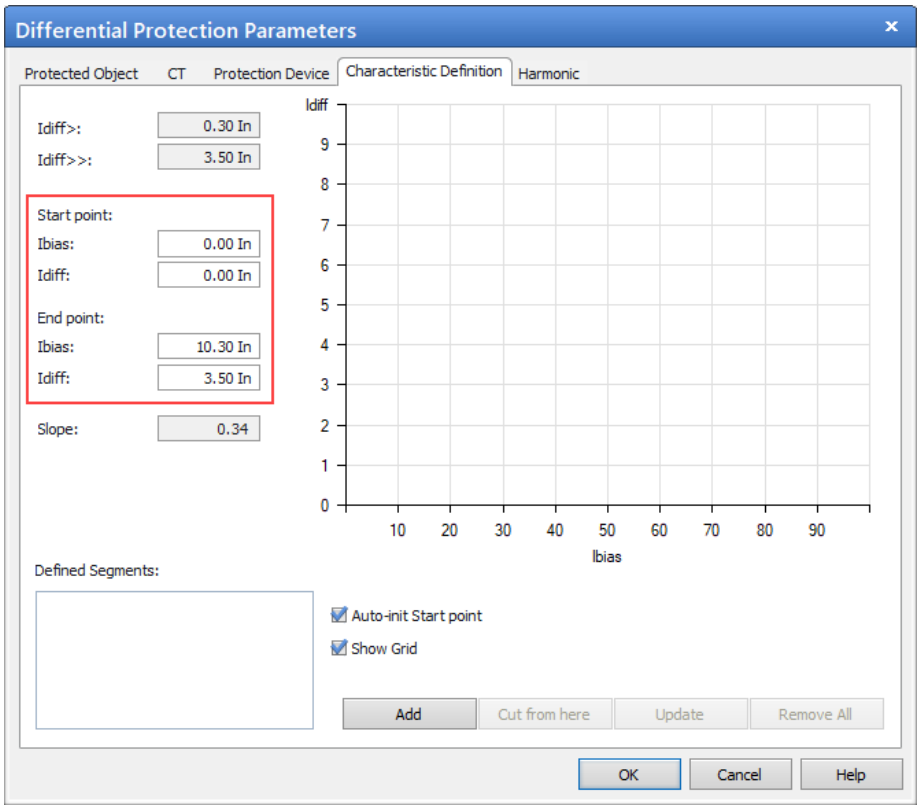
This adds a Differential function under the Test Object Device. The Differential function includes all the settings related to the transformer differential protection, including the definition of the current differential restraint characteristic.

Double click on the Differential function to open its configuration window. Navigate to the tab **Protection Device.** In the **Diff Current Settings** section enter the restrained pickup value in the **Idiff>** input box and the unrestrained pickup value in the **Idiff>>** input box. In the **Test Time Settings / Transformer Model** set the **Test Max** to a value greater than 1 second (e.g. 1.5 s). This is the maximum time that Test Universe waits for the relay to send the trip command after applying a fault. Setting the **Test Max** to a value greater than 1 second resets the relay external fault word bits (CONA, CONB, and CONC) in case they assert in the pre-fault state of a slope 1 test.

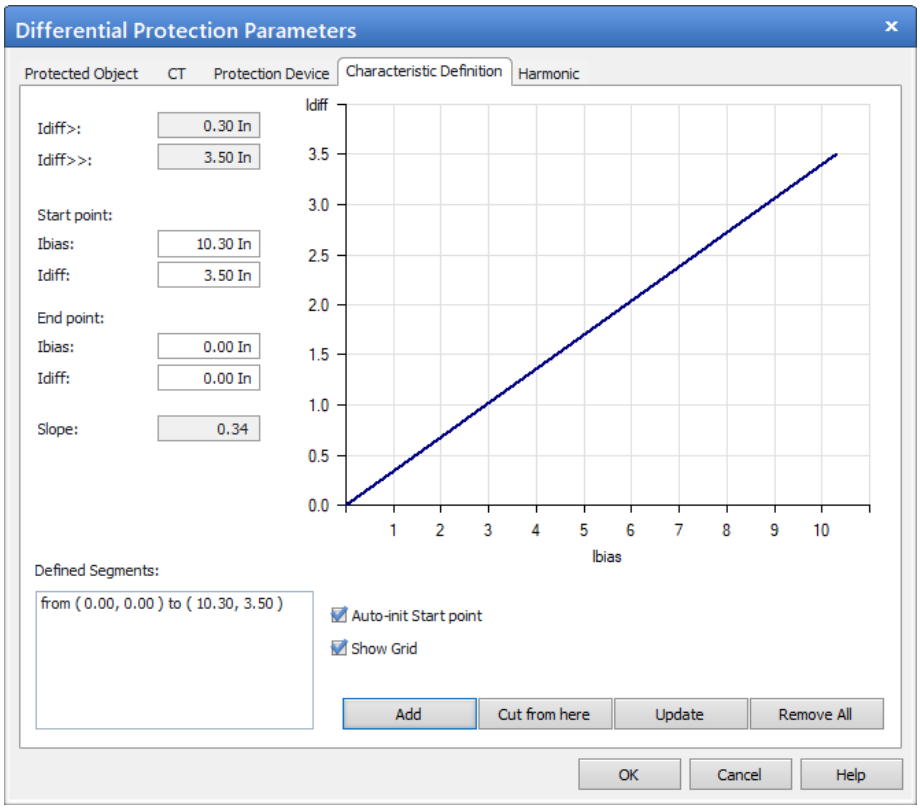


Now select the Characteristic Definition tab. Click on **Remove All** to clear the default characteristic. Enter the slope 1 characteristic by specifying the start point and end point of the line on the I_{diff}/I_{bias} plane. The start point is the origin of the plane (I_{bias} = 0, I_{diff} = 0). The end point I_{diff} is equal to the Idiff>> setting (unrestrained pickup value) and the end point I_{bias} is calculated as follows:

$$I_{bias,endpoint} = \frac{I_{diff,endpoint}}{SLP1} = \frac{3.5\ pu}{0.34} = 10.3$$



Note that Test Universe automatically calculates the resulting slope from the entered start and end point. After specifying the start and end point click on **Add** to add the slope 1 characteristic to the test object.

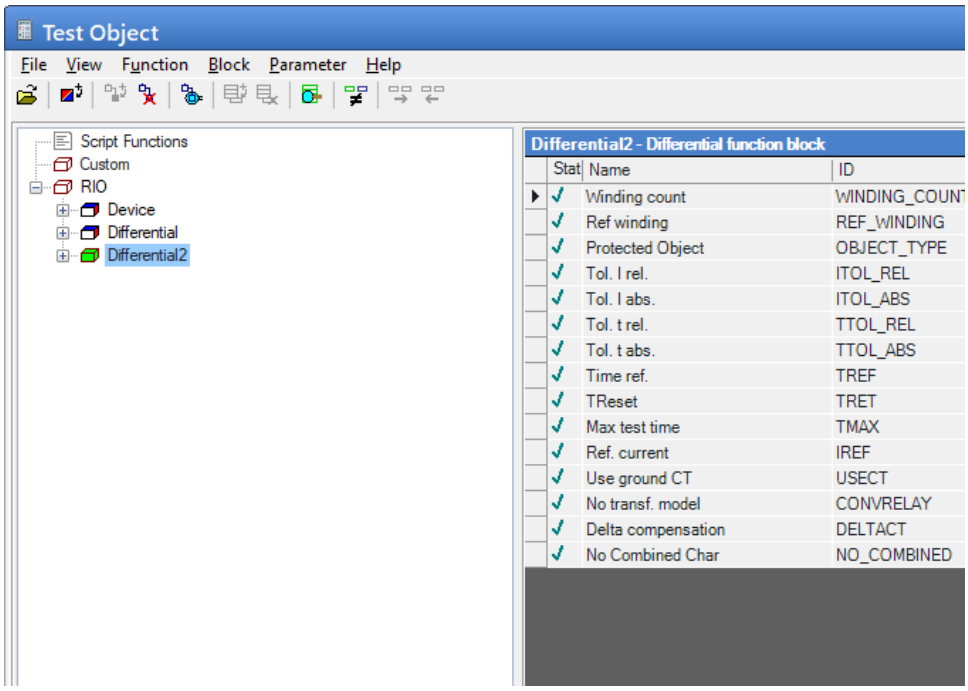


Click on **OK** to save the changes and go back to the Test Object window.

To add the slope 2 characteristic to the test object a second Differential function is needed. Right click the Differential function and then select **Copy**. Right click on RIO and the select **Paste**. This adds a copy of the Differential function to the test object.

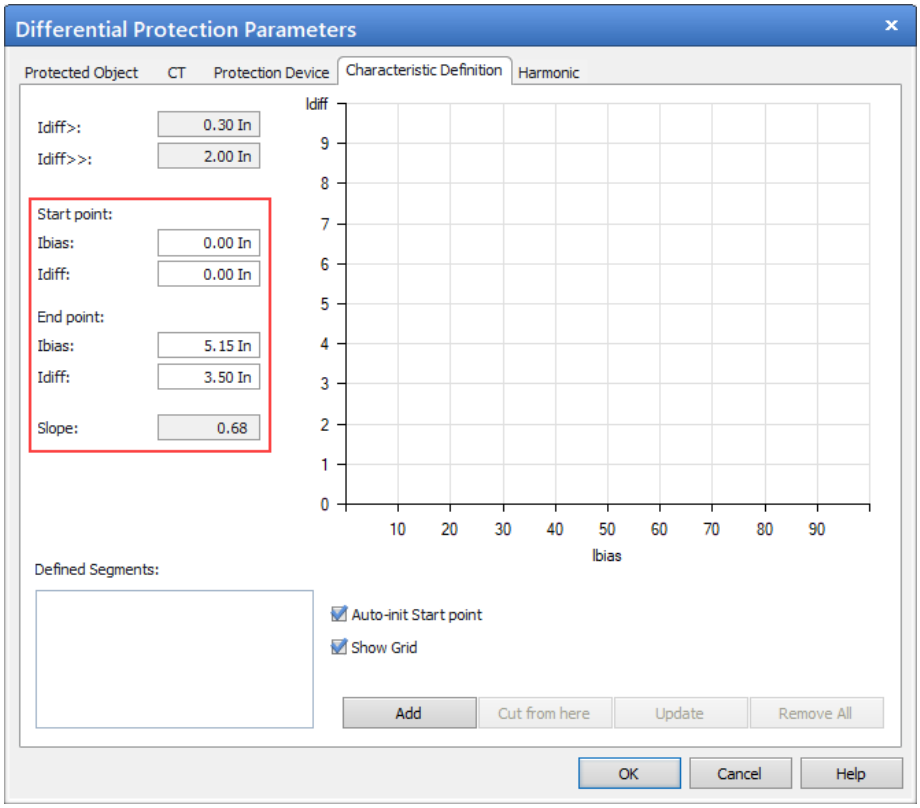
> NOTE: To be able to copy and paste functions the advanced view must be enabled in the Test Object.

Right click on the new Differential function and select **Details**. In the Details window change the name of the function to indicate that this Differential function corresponds to the slope 2 characteristic (e.g. “Differential2”).

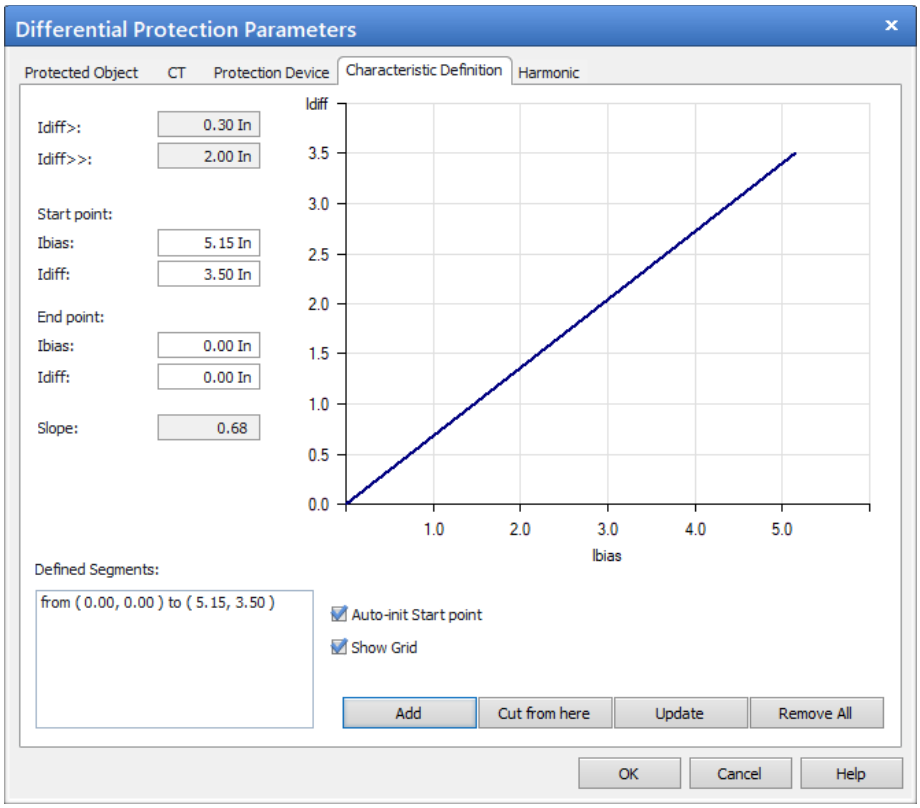


Double click the Differential2 function to open its configuration window. Only the definition of the line characteristic and test time settings needs to be changed in the Differential2 function. Navigate to the **Characteristic Definition** tab and click on **Remove All** to remove the slope 1 characteristic. Specify the start point and end point of the slope 2 characteristic. The start point is the origin of the I_{diff}/I_{bias} plane. The end point I_{diff} is equal to the Idiff>> setting (unrestrained pickup value) and the end point I_{bias} is calculated as follows:

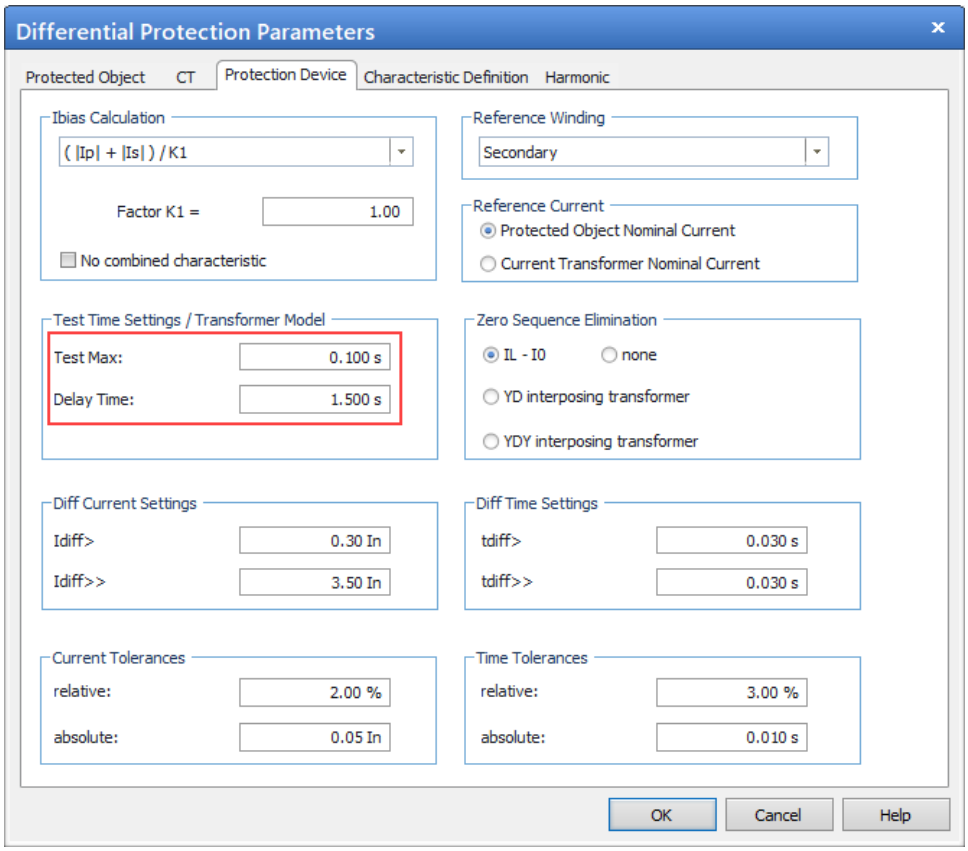
$$I_{bias,endpoint} = \frac{I_{diff,endpoint}}{SLP2} = \frac{3.5\ pu}{0.68} = 5.15$$



Click on **Add** to add the slope 2 characteristic to the test object.



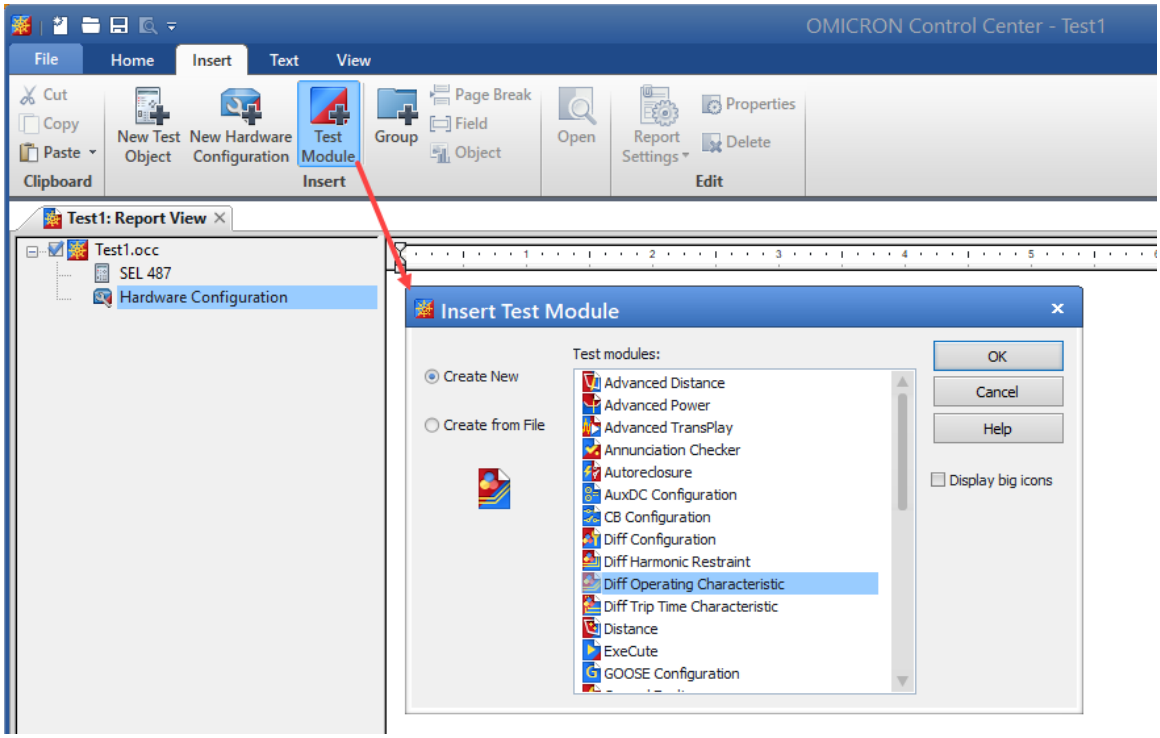
To change the test time settings, navigate to the **Protection Device** tab. In the **Test Time Settings / Transformer Model** set the **Test Max** to any value above the max expected trip time and below 1 second (e.g. 0.1 s) and set the **Delay Time** to any value above 1 second (e.g. 1.5 s). The delay time is the time that Test Universe waits in between the end of one test and the beginning of the next. Setting the delay time to a value above 1 second resets the relay external fault word bits (CONA, CONB, and CONC) before each test.



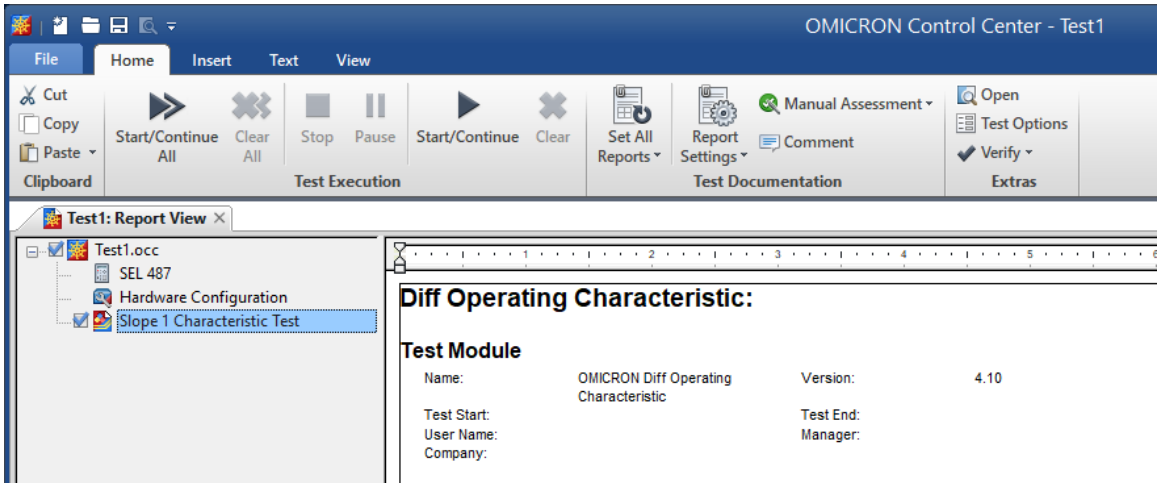
Click **OK** to save the changes and go back to the test object window. Click **OK** to close the test object window and go back to the test plan.

3.2 Test Slope 1 Characteristic

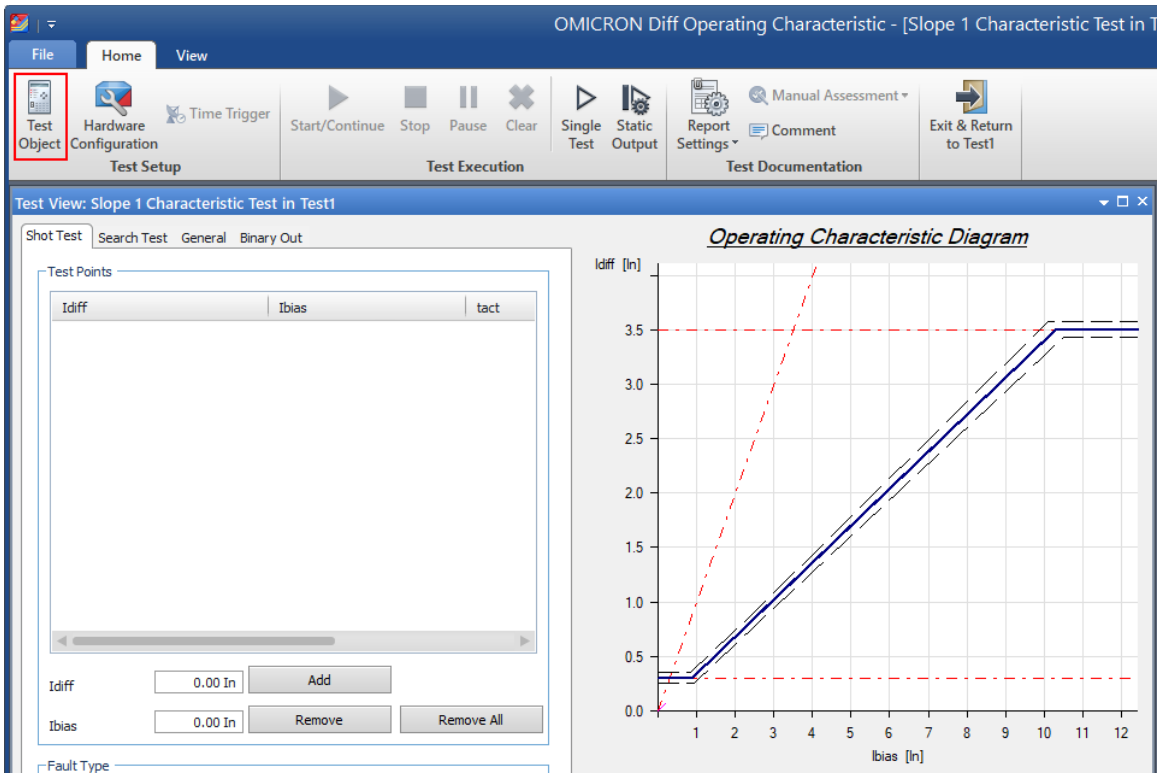
Navigate to the **Insert** tab on the top ribbon bar of the test plan file and then click on the **Insert Test Module** button. In the Insert Test Module window search for **Diff Operating Characteristic** and then click **OK**.



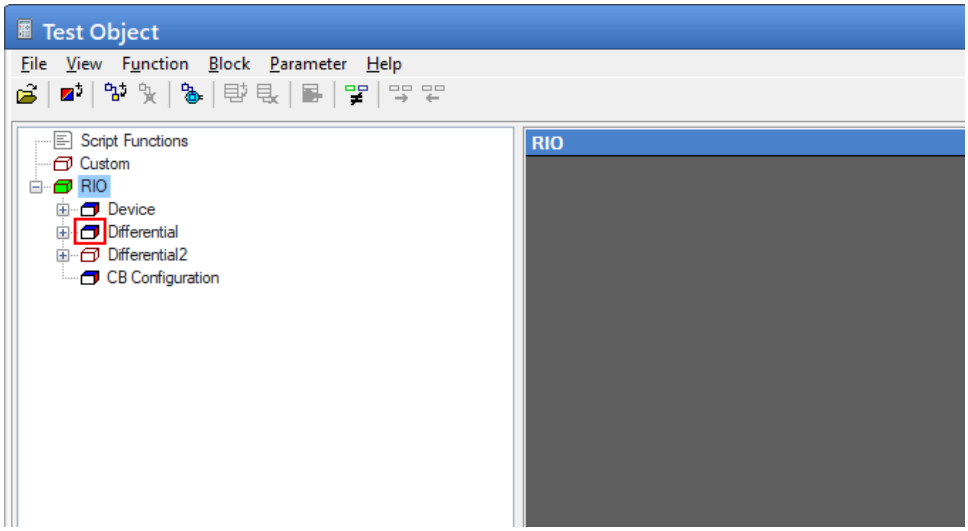
Rename the Diff Operating Characteristic module to “Slope 1 Characteristic Test” (or any other name that indicates that this module is used to test the slope 1 characteristic).



Double click the Slope 1 Characteristic Test to open the module. In the test module, click on the Test Object button on the top ribbon bar to open the test object.

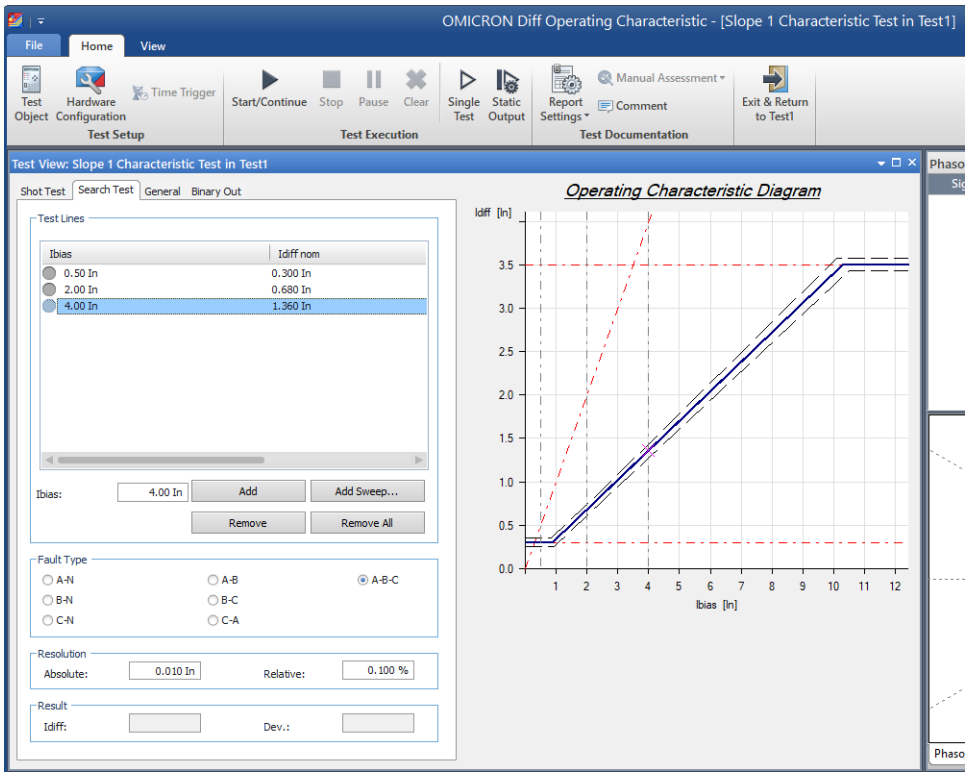


In the test object notice that the cube icon next to the Differential module is colored and the cube icon next to the Differential2 function is not.

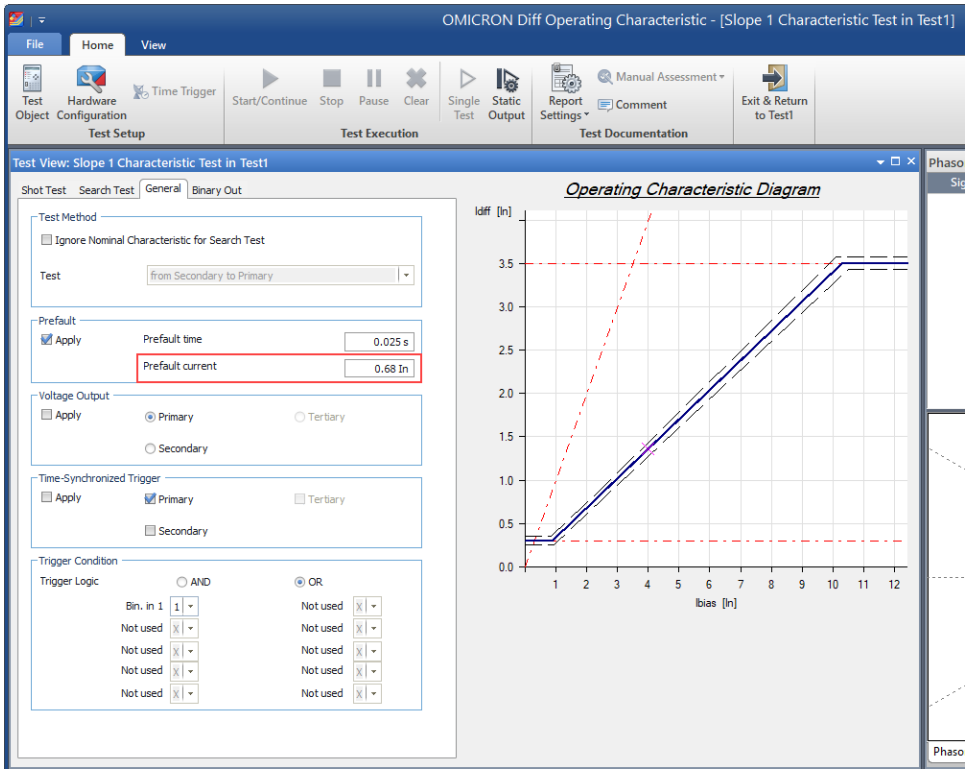


This indicates that the Slope 1 Characteristic Test module is using the first differential function of the test object (named “Differential” in this example) to define its differential restraint characteristic and all other transformer differential protection settings. Click **OK** to close the test object and go back to the test module.

In the **Test View** of the test module navigate to the **Search Test** tab. To test the slope 1 characteristic, add one search test at an I_{bias} value before the intersection of the restrained pickup value (O87P) and the slope 1 line and at least two search tests at I_{bias} values above the intersection point (e.g. 0.5 I_n, 2.0 I_n, and 4.0 I_n). In the **Fault Type** section select the fault type for the search tests.



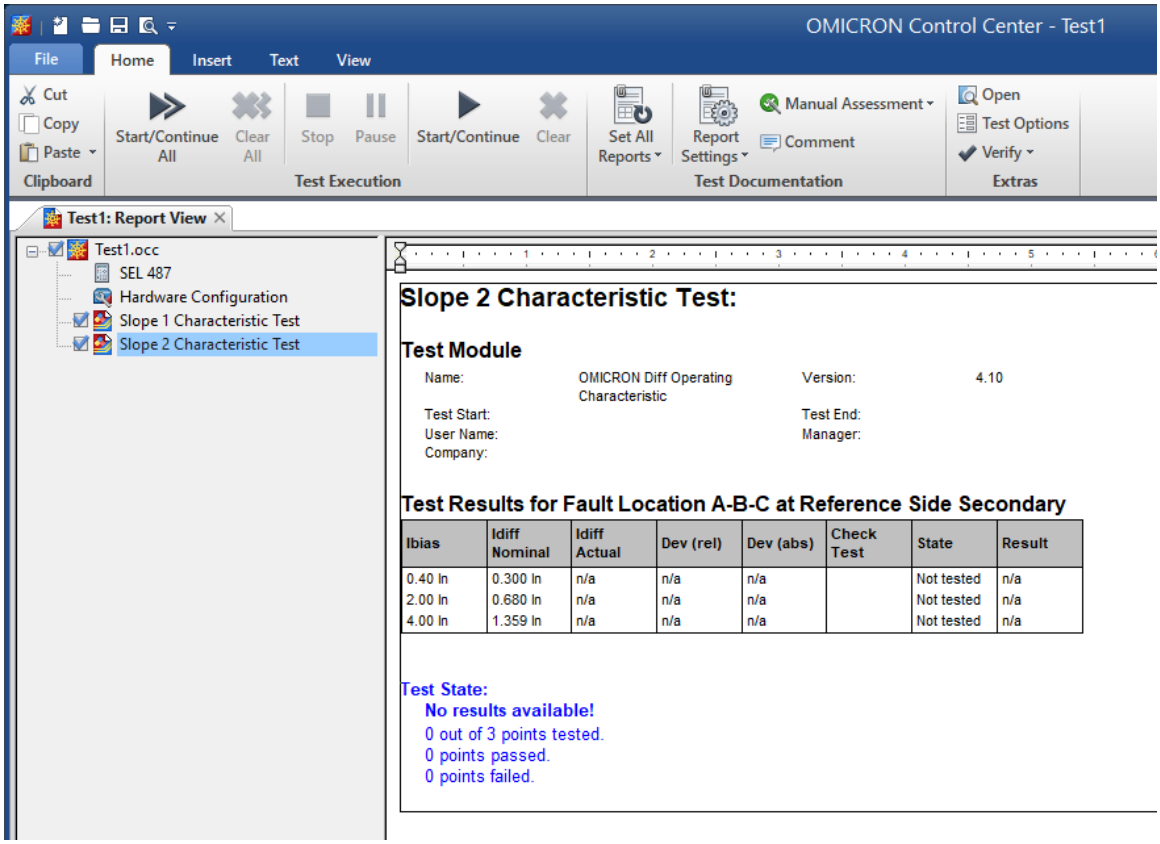
Under the General tab, ensure that any pre-fault current selected is less than the relay setting DIRTR divided by square root of 2 (e.g. $0.8 * \frac{DIRTR}{\sqrt{2}}$).



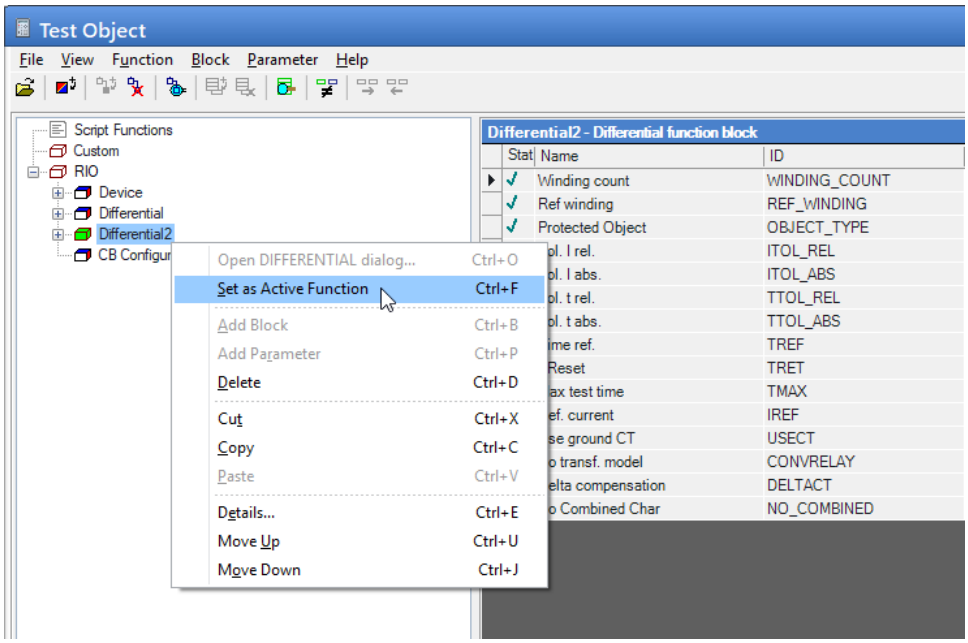
Click on the **Start/Continue** button on the top ribbon bar to start the test. Once the test is finished, click on the **Exit & Return** button on the top ribbon bar to save the test results, close the test module, and go back to the test plan.

3.3 Test Slope 2 Characteristic

To test the slope 2 characteristic, copy and paste the test module of the slope 1 characteristic. To copy a test module right click on it and then select **Copy**. To paste it, right click anywhere on the test plan workflow and then select **Paste**. Rename the copied test module to “Slope 2 Characteristic Test” (or any other name that indicates that this module is used to test the slope 2 characteristic).

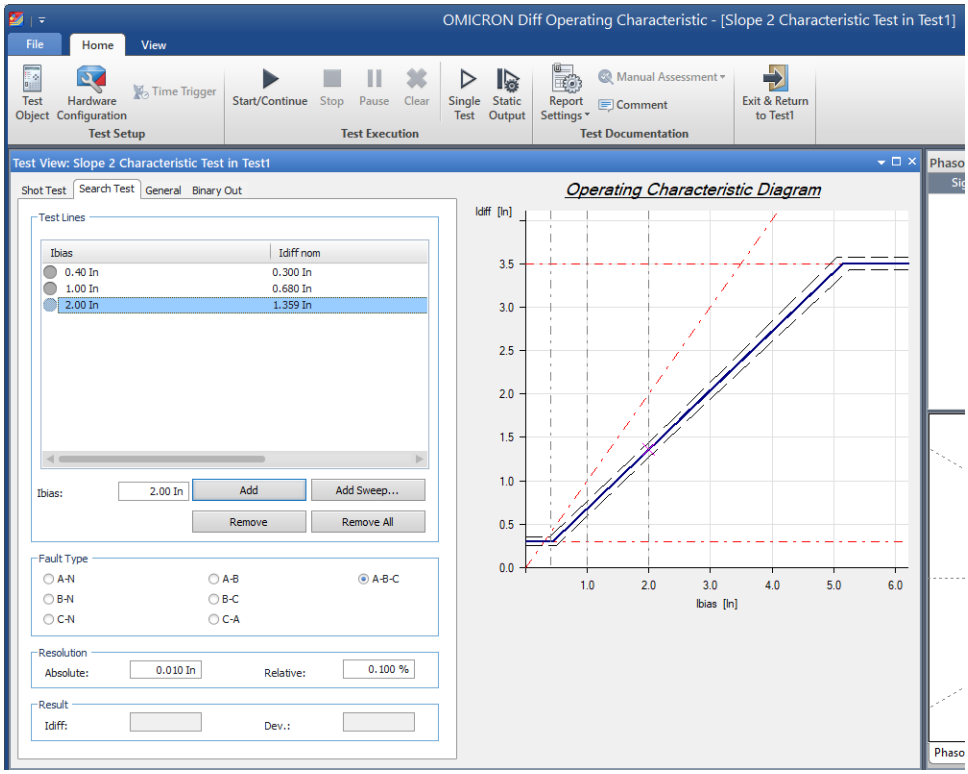


Double click the Slope 2 Characteristic Test module to open it. In the Slope 2 Characteristic Test module click the **Test Object** button on the top ribbon bar to open the test object. In the test object right click on the Differential2 function and then select **Set as Active Function**.



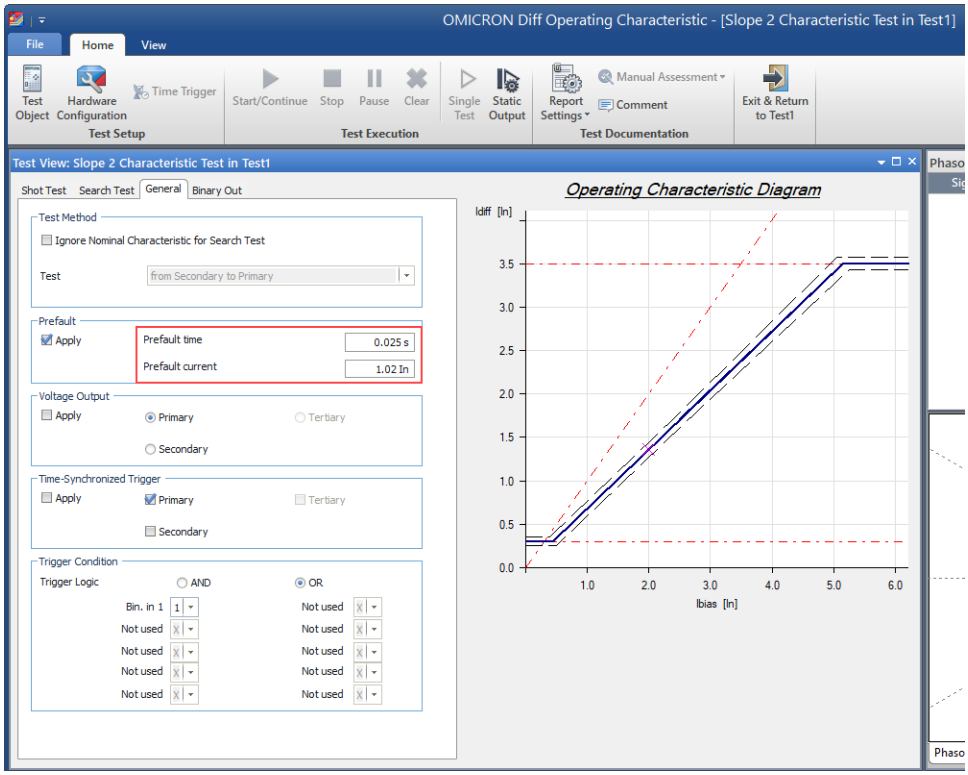
This sets the Differential2 function as the active transformer differential protection function for the Slope 2 Characteristic Test module. Notice how the cube icon next to Differential2 becomes colored after setting it as the active function. Now, the Slope 2 Characteristic Test module will use the slope 2 characteristic defined in the Differential2 function. Click **OK** to save the changes and go back to the test module.

In the **Test View** of the test module navigate to the **Search Test** tab. Modify the search tests that were copied from Slope 1 Characteristic Test module to properly test the slope 2 characteristic. In this case, the search tests on the slope 2 characteristic are set at I_{bias} = 0.4 I_n, I_{bias} = 1 I_n, and I_{bias} = 2 I_n.



In order to test slope 2, the relay must be in high security mode. During actual operation, the relay enters high security mode for three cycles following a through fault event of sufficient current magnitude. That current magnitude is set by relay setting DIRTR. To test this slope 2, we apply a balanced differential pre-fault current (i.e. pre-fault current with zero differential) to greater than DIRTR for less than 3 cycles. High security mode can be verified after a test by checking for relay word bits CONA, CONB, or CONC as appropriate with the sequence of events (SER) function.

To simulate a through fault with the Differential Operating Characteristic Module, in the **Test View**, navigate to the **General** tab. In the **Prefault** section, set the pre-fault time to less than three cycles (e.g. 25 ms) and the pre-fault current to a value greater than the relay DIRTR setting divided by square root of 2 (e.g. $1.2 * \frac{DIRTR}{\sqrt{2}}$).



Click on the **Start/Continue** button on the top ribbon bar to start the test. Once the test is finished, click on the **Exit & Return** button on the top ribbon bar to save the test results, close the test module, and go back to the test plan.