GCX51B, Phase to Phase, Three Zones Reactance / Distance Relay
120 Volt, 5 Amp, 60 HZ Relay with a 1 second thermal rating of 225 Amps

Zone 1 and Zone 2 protection are Reactance Characteristics set for a calculated amount of reactance and when represented on an R-X diagram are straight lines parallel with the R axis.
This reactance measuring unit is the middle unit of the relay and is called the ohm unit.

Zone 3 is an impedance measuring unit with a circle characteristic that passes through the origin and has its center on the angle-of-maximum-torque line of the unit. This unit sets at the bottom of the relay and is called the mho unit.

The top unit of the relay consists of the OHM unit transfer auxiliary called the “OX” relay, an instantaneous plunger type overcurrent relay, a target and seal-in relay, the tapped autotransformer that determines the reach of the OHM & MHO units and the transactor associated with the OHM unit potential circuit.

Zone 3 is the furthest reaching element and is directional. It supervises the tripping of the non-directional OHM unit and initiates a zone timer for faults within its reach. This zone timer initiated by zone 3 also controls the energization of the “OX” telephone relay. After a small time delay the “OX” relay picks up and transfers the OHM unit from Zone 1 measurement to Zone 2. If the fault was within Zone 1 it would have cleared before this time delay expired. If not it initiates Zone 2 measurement by picking up the “OX” relay.

You need three relays to have complete phase to phase distance protection.

A-B phase relay has:	A phase voltage on 17 & jumpered to 19 and B phase voltage on 18 & jumpered to 20.
	A phase current in on 5 & out on 7 and B phase current in on 10 & out on 8.
B-C phase relay has:	B phase voltage on 17 & jumpered to 19 and C phase voltage on 18 & jumpered to 20.
	B phase current in on 5 & out on 7 and C phase current in on 10 & out on 8.
C-A phase relay has:	C phase voltage on 17 & jumpered to 19 and A phase voltage on 18 & jumpered to 20.
	C phase current in on 5 & out on 7 and A phase current in on 10 & out on 8.

The OHM unit / Reactance Unit (Zone 1 & Zone 2), reactance “X” reach settings are at 90 deg, I lags E. Maximum Torque Angle (MTA) is 90 deg, I lags E as well. Impedance at any angle is equal to “X”/sin of that angle. Example; Zone 1 reach = 1.5 ohms @ 90 deg, what is the reach at 45 deg? 1.5 ohms / sin of 45 deg. 1.5 ohms / .707 = 2.12 ohms reach at 45 deg.

To set the Zone 1 reach of 1.5 ohms at 90 deg you need to tap the autotransformer correctly using the taps labeled NO 1. There is a course tap in 10 % increments and a fine tap in 1% increments. You also need to choose the correct Basic Tap on the transactors in the current circuit. In this case with a desired reach of 1.5 ohms you would set the Basic Taps on each transactor to 1.0 ohms minimum reach. The equation for calculating the restraint tap is; (Basic Tap / Desired Reach) * 100 = Restraint Tap and in this case the Restraint Tap = NO 1 tap setting in percent.
(1.0/1.5ohms)*100=67 %. To achieve this 67 % you would place the lower NO 1 position to the 60 % point and the upper NO 1 position to the 7 % point.

Zone 2 is similar and 2.5 ohms at 90 deg is the desired reach which uses the taps labeled NO 2. (Basic Tap / Desired Reach) * 100 = Restraint Tap and in this case the Restraint Tap = NO 2 tap setting in percent.
(1.0/2.5ohms)*100=40 %. To achieve this 40 % you would place the lower NO 2 position to the 40 % point and the upper NO 2 position to the 0 % point.

Zone 3 is a mho unit with a MTA of 60 degrees and a minimum reach of 2.5 ohms fixed and stamped on the nameplate in the form of a range. “2.5 to 10 ohms mho unit”. Zone 3 Restraint Taps are labeled ER. The equation for calculating the restraint tap is; (Z3 Min Ohms / Desired Reach @ the MTA) * 100 = Restraint Tap and in this case the Restraint Tap = ER tap setting in percent. Our desired reach = 7.0 ohms.
(2.5/7.0ohms)*100=36 %. To achieve this 36 % you would place the lower ER position to the 30 % point and the upper NO 1 position to the 6 % point.

Test Connections using one AC Voltage Source, one DC Voltage Source and one AC Current Source:
AC Voltage polarity on 17 and non-polarity on 18. DC Voltage negative on 12 and positive on 13.
AC Current, polarity on 5 and non-polarity on 10, jumper 7 to 8. Monitor 11 to 1 for Zone 1 or eyeball contact. Monitor 11 to 2 for Zone 2 or eyeball contact. Monitor 11 to 3 for Zone 3 or eyeball contact.

Note, the instantaneous OC rly contact is jumpered closed as it is not being used.

Note, angles are with I lagging E.

Z = Eph-ph (Voltage on terminal 17 & 18) / I (In on terminal 5 & out on terminal 10) * 2
You have to multiply the current times two because you are pumping current in to two phases of current coil primaries (Transactors), and they are 180 degrees out from each other because of above connections. This is just like what happens during a phase to phase fault and this is a phase to phase relay.

To test Zone 1 & Zone 2 ohm unit you want to have at least 5 amps on the unit and so we will vary the voltage and keep 5 amps constant. This is to ensure enough operating current to make calibration decisions. For example, to test the Zone 1, 1.5 ohm pickup at the MTA of 90 deg (I lags E), calculate the voltage with 5 amps test current. Eph-ph = Z*I*2 = 1.5 * 5 * 2 = 15 Volts
You would put greater than 15 volts on the relay with 5 amps on the relay and ramp the voltage down until zone 1 picked up.

Zone 1 tests: Reach @ the MTA, Reach @ + & - 15 deg off of the MTA (105 & 75 degrees), Reach @ + & - 30 deg off of the MTA (120 & 60 degrees) and a MTA test.

Reach @ 15deg off of the MTA = 1.5ohms / sin of 75deg = 1.55ohms & 1.5ohms / sin of 105deg = 1.55ohms
Reach @ 30deg off of the MTA = 1.5ohms / sin of 60deg = 1.73ohms & 1.5ohms / sin of 120deg = 1.73ohms
For Reach @ the MTA & with 5amps constant test current the voltage should be 1.50ohms * 5amps * 2 = 15.0volts. Start above 15.5 volts and ramp voltage down.
For Reach @ 15deg off of the MTA & with 5amps constant test current the voltage should be 1.55ohms * 5amps * 2 = 15.5volts. Start above 15.5 volts and ramp voltage down.
For Reach @ 30deg off of the MTA & with 5amps constant test current the voltage should be 1.73ohms * 5amps * 2 = 17.3volts. Start above 17.3 volts and ramp voltage down.

MTA test should be conducted at 30 deg or less off of the MTA and no more than that displacement. Start out at the MTA of 90deg with 5amps and 17.3 volts on the relay. Swing the angle that I lags E one way until the relay just picks up & record that value. Now swing it the other way from the MTA until the relay just picks up & record that value. Let’s say the two values are 62deg & 121deg. add those up and divide by two. This equals 91.5deg and you want 90deg. This is close enough. + or – 2deg off of the desired MTA is acceptable. If the Reach or the MTA is out of tolerance keep adjusting both until both are within tolerance. Reach is +/– 5%. Than retest other points and record.

Zone 2 tests are similar but with the 2.5 ohm reach at the MTA of 90 deg (I lags E). And you need to apply proper DC voltage to terminals 12 & 13. The “OX” relay tap is set at 125Vdc on these relays, so put 125Vdc on terminals 12 & 13 which picks up the “OX” relay and so now you are testing the same OHM unit but with the Zone 2 Reach of 2.5ohms at the MTA of 90 deg (I lags E).

Zone 3 is a MHO unit circle impedance characteristic that passes through the origin. You define the circle impedance characteristic by setting the MTA and the Reach @ the MTA. On our relay it is a 60deg MTA and the Reach @ the MTA = (2.5ohms minimum ohms / 36%) * 100 = 6.94ohms @ 60deg. You can now calculate the reach at any other point on the circle using this relationship:
Reach at other angle = Reach @ MTA * cos |MTA-other angle|
Example; You want to know the reach @ 90deg. Reach @ 90deg = Reach @ MTA * cos |MTA-90deg|
Reach @ 90deg = 6.94ohms * cos |60-90| = 6.94ohms * cos 30deg = 6.01ohms.
Reach @ 30deg = 6.94ohms * cos |60-30| = 6.94ohms * cos 30deg = 6.01ohms as well.
Zone 3 continued on next page.

Zone 3 tests: Reach @ the MTA, Reach @ + & - 15 deg off of the MTA (75 & 45 degrees), Reach @ + & - 30 deg off of the MTA (90 & 30 degrees) and a MTA test.

Note; Reach @ the MTA is the furthest reaching point on the circle. We need at least 5 amps at any given point to be able to make calibration decisions. So calculate a fault voltage that gives you 5 amps for testing reach @ the MTA. In this case the fault voltage will be Zreach @ MTA * 5 amps * 2 = 6.94 * 5 * 2 = 69.4 V
Keep this fault voltage at 69.4 volts for testing the rest of the points given above. We already calculated Reach @ + & - 30 deg off of the MTA. Let's calculate Reach @ + & - 15 deg off of the MTA.
Reach @ 75deg = 6.94ohms * cos |60-75| = 6.94ohms * cos 15deg = 6.70 ohms.
Reach @ 45deg = 6.94ohms * cos |60-45| = 6.94ohms * cos 15deg = 6.70 ohms as well.
Expected Current @ 90 & 30deg = 69.4V / (6.01ohms*2) = 5.77amps
Expected Current @ 75 & 45deg = 69.4V / (6.70ohms*2) = 5.18amps

MTA test should be conducted at 30 deg or less off of the MTA and no more than that displacement. Start out at the MTA of 60deg with 5.77amps and 69.4 volts on the relay. Note that this is the expected pickup @ 30deg off of the MTA. Swing the angle that I lags E one way until the relay just drops out & record that value. Now swing it the other way from the MTA until the relay just drops out & record that value. Let's say the two values are 32deg & 92deg. add those up and divide by two. This equals 62.0deg and you want 60deg. This is close enough. + or – 2deg off of the desired MTA is acceptable. If the Reach or the MTA is out of tolerance keep adjusting both until both are within tolerance. Reach is +/– 5%.
Than retest other points and record.

Set and test the Instantaneous Plunger style Over Current relay to pick up at 6.0 amps. Put current in on terminal 5 and out on terminal 6 to test. Once you have it set and tested, hit with 40 amps momentarily and see that the plunger resets. 40 amps goes on and then right back off.

See that the "OX" relay picks up at 80% of tap voltage. Ours are tapped at 125Vdc and so 80% would be 100Vdc. Negative on terminal 12 and positive on terminal 13.

Test the Target and Seal-In unit.

Move Restraint Taps , calculate new reaches and re-test as time allows!

This should do it.