



# Directional Elements in L-PRO 4000



This Technical Note clarifies:

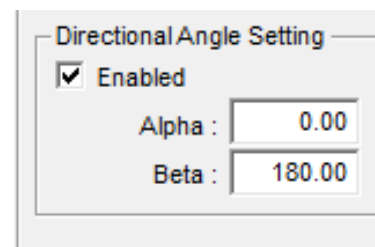
1. Directional Elements used in L-PRO 4000:
  - A. Default Directional Element
  - B. Default Directional Element Outputs
  - C. Default Directional Element Settings
  - D. Directional Control Used in Overcurrent Elements
  
2. How to Set Directional Control in Overcurrent Elements in L-PRO 4000

# 1. Directional Elements used in L-PRO

There are 2 Directional Elements in L-PRO:

- Default Directional Element - uses symmetrical component principle to supervise distance elements (21P, 21N) as well as overcurrent elements (50/51/67, 50N/51N/67, 46-50/46-51/67)  
(see section 1A, 1B and 1C)
- Directional Control used in Overcurrent Elements - uses alpha/beta angles to define manually directional operating region and just supervises overcurrent elements (50/51/67, 50N/51N/67, 46-50/46-51/67)

This directional control is an option to the default Direction Element and if enabled by the user, it will disable the default Directional Element  
(see section 1D and 2)



Directional Angle Setting

Enabled

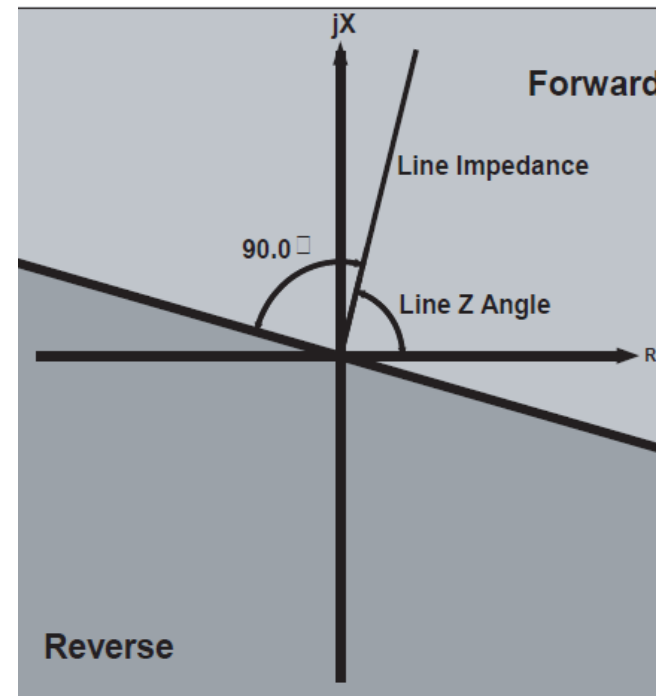
Alpha : 0.00

Beta : 180.00

# 1. Directional Elements used in L-PRO

## A. Default Directional Element:

- L-PRO 4000 includes a directional element to supervise directly the phase (21P) and ground (21N) distance elements, for all 5 zones (21P1 to 21P5, and 21N1 to 21N5)
- By default, this directional element will use the line impedance angle to define directionality for both Distance and Overcurrent elements



# 1. Directional Elements used in L-PRO

## A. Default Directional Element (continued):

- The directional element considers negative-sequence impedance, zero-sequence impedance, or positive-sequence impedance, depending on relay settings and system conditions at the time of the fault. The element declares a forward fault when the impedance determined by the directional element is within  $90^\circ$  of the line impedance.
- The directional element in the relay is always enabled
- The directional element consists of 3 separate internal elements: a negative-sequence element, a zero-sequence element, and a positive-sequence element. The negative-sequence and zero-sequence elements use directly measured currents and voltages.

# 1. Directional Elements used in L-PRO

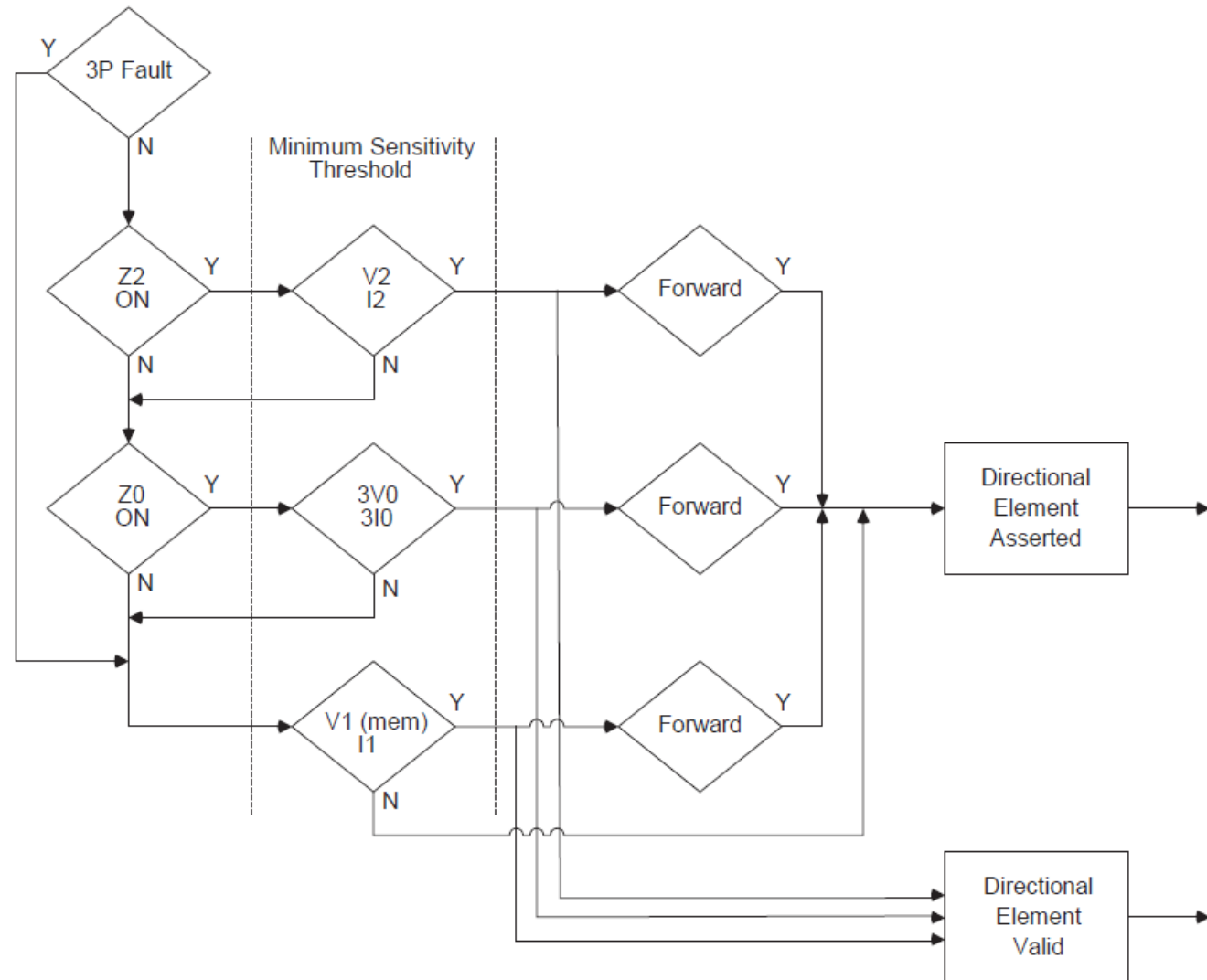
## A. Default Directional Element (continued):

- The positive-sequence element uses directly measured current, and a memory voltage from the ring filter
- The effect of the ring filter is to retain some voltage information for approximately 150 cycles, even if the measured system voltage is severely depressed by a fault
- The sensitivity for the negative and zero sequence elements may be set by the user, to correctly account for load conditions and system configuration. Both of these elements may be disabled as well. The positive-sequence element is always active.

# 1. Directional Elements used in L-PRO

## A. Default Directional Element (continued):

- Directional Element Logic



# 1. Directional Elements used in L-PRO

## B. Default Directional Element Outputs:

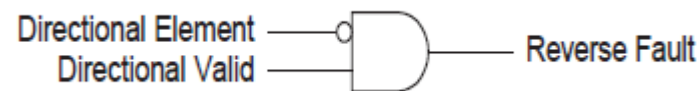
- The output of the Directional Element asserts when the direction is determined to be “forward”. This output is used internally by protection functions directly supervised by the element, and is also available as the “Directional Element” indication in ProLogic equations.
- The Directional Element also provides the “Directional Valid” output for use in ProLogic equations. This output asserts when any one of the active sequence impedance calculations has sufficient input quantities to make a valid direction determination, regardless of the actual direction.



# 1. Directional Elements used in L-PRO

## B. Default Directional Element Outputs (continued):

- The “Directional Valid” output will always be asserted, except in the rare case where system voltage has gone to 0 for more than 30 cycles, as previously described
- The 2 outputs can be combined in a ProLogic equation to secure reverse directional output from the relay, as shown below:



# 1. Directional Elements used in L-PRO

## C. Default Directional Element Settings:

- The default setting of the Directional Element in the relay should be correct for most applications. The default settings enable both the negative-sequence and zero-sequence calculations, with the minimum sensitivities as described.
- There are some applications where it may be advisable to change the sensitivity thresholds for the negative-sequence or zero-sequence calculations, or it may be desirable to disable one or both of these elements.

# 1. Directional Elements used in L-PRO

## C. Default Directional Element Settings (continued):

- Selecting “Directional Element Override Enabled” allows user settings for the negative-sequence and zero-sequence directional elements

**Directional Element**

Directional Element Override

Negative Sequence Directional Element

Enabled

V2 Sensitivity Level:  V

I2 Sensitivity Level:  A

Zero Sequence Directional Element

Enabled

3V0 Sensitivity Level:  V

3I0 Sensitivity Level:  A

Override Enabled	Enable/Disable
Negative-Sequence	Enable/Disable
V2 Sensitivity Level (V secondary)	0.5 to 5.0
I2 Sensitivity Level (A secondary)	0.1 to 1.0 (5 A) 0.02 to 0.20 (1 A)
Zero Sequence	Enable/Disable
3V0 Sensitivity Level (V secondary)	1.0 to 10.0
3I0 Sensitivity Level (A secondary)	0.2 to 2.0 (5 A) 0.04 to 0.40 (1 A)

# 1. Directional Elements used in L-PRO

## D. Directional Control used in Overcurrent Elements:

- In addition to the default Directional Element that uses the line impedance angle to determine directionality (described previously), Overcurrent Elements (50/51/67, 50N/51N/67 and 46-50/46-51/67) can be monitored alternatively by the directional control functions that operate based on Alpha and Beta settings.
- This option enables the user to manually set the forward/reverse operating region in the backup overcurrent elements

## 2. How to Set Directional Control in Overcurrent Elements

- The Forward direction is determined by 2 user-defined Positive Sequence Impedance angle setting parameters: “Alpha” and “Beta”
- The positive sequence impedance angle is the measured positive sequence current angle, subtracted from the positive sequence memory voltage angle
- Figure 1 shows boundaries of the Alpha and Beta:

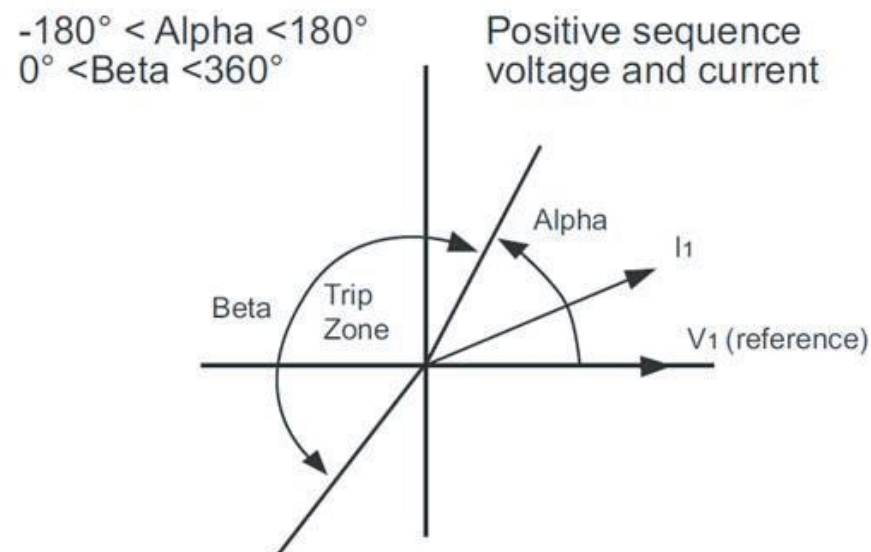


Figure 1

## 2. How to Set Directional Control in Overcurrent Elements



Simply stated, the Forward region:

- Starts at Alpha
  - Alpha is the angle by which current leads or lags the positive real axis of V1 ref
  - Alpha is a positive in value if current leads V1 ref. and vice versa
  - Alpha can be any angle from  $-180^{\circ}$  to  $+180^{\circ}$
- Ends at Alpha + Beta
  - Beta, is the scope of the forward region and can only be positive,  $0^{\circ}$  to  $+360^{\circ}$

## 2. How to Set Directional Control in Overcurrent Elements

Figure 2 clearly illustrates the affect of Alpha and Beta settings in the  $(\pm R \pm jX)$  impedance plane. In each case, the shaded area shall be the defined Forward direction to be used by all 67 elements.

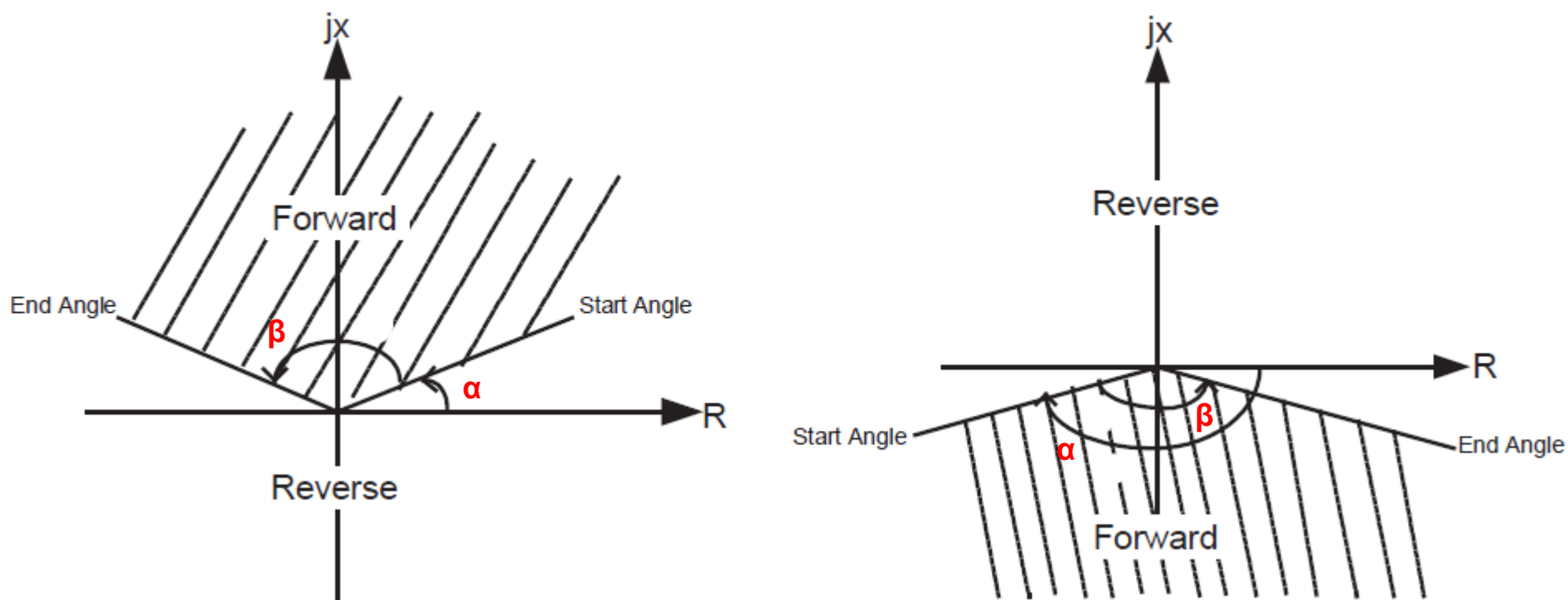


Figure 2

## 2. How to Set Directional Control in Overcurrent Elements



The directional function for overcurrent elements consists of following options:

*(see screenshot on next slide)*

- **Directional**
  - Directional control is applied. Since the positive sequence voltage is used, directionality is accurate even under 2-phase LOP conditions. Under 3-phase LOP conditions, function goes into the block mode.
- **Non-Directional**
  - Directional control is disabled
- **Combined**
  - Works as the directional option under all conditions except, 3-phase LOP. Under 3-phase LOP conditions, function goes into the non-directional mode.



# 2. How to Set Directional Control in Overcurrent Elements

## 50/51/67 settings in L-PRO 4000

### 50/51/67 - Phase Overcurrent

50 Enabled

Directional: directional

Pickup: non-directional

Pickup Delay: directional

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51 Enabled

Directional: directional

Pickup: 7.50 A

Curve Type: IEC std. inverse

TMS: 1.00

A: 0.14

B: 0

p: 0.02

TR: 13.50

- Pickup threshold alarm is not time delayed  
- To activate A, B, and p, you must select "User Defined" as Curve Type.

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Directional Angle Setting

Enabled

Alpha: 0.00

Beta: 180.00

D245: 51 Characteristics - IEC standard inverse

Pickup: 7.50, TR: 13.50, B: 0.0000, A: 0.1400, p: 0.02, TMS: 1.00

Grid On   Refresh   Print Graph

Pickup:  $T(I) = TMS \left[ B + \frac{A}{\left( \frac{I}{I_{Pickup}} \right)^p - 1} \right]$      Reset:  $T(I) = TMS \left[ \frac{TR}{1 - \left( \frac{I}{I_{Pickup}} \right)^2} \right]$

## 2. How to Set Directional Control in Overcurrent Elements



- This directional control for overcurrent elements is coming from bus and transformer protection practice (used in our B-PRO and T-PRO relays). An important consideration for setting this Directional Element is to ensure that the CT polarity convention is observed in defining the forward direction.
- For bus protection, the relay will normally be connected as in Figure 3 with CT connection defined for current flowing into the bus, rather than way from the bus. This opposes the expected connection of the line protection, as shown in Figure 4 (see *next slide*)

## 2. How to Set Directional Control in Overcurrent Elements

### CT connection in Bus and Line Protection

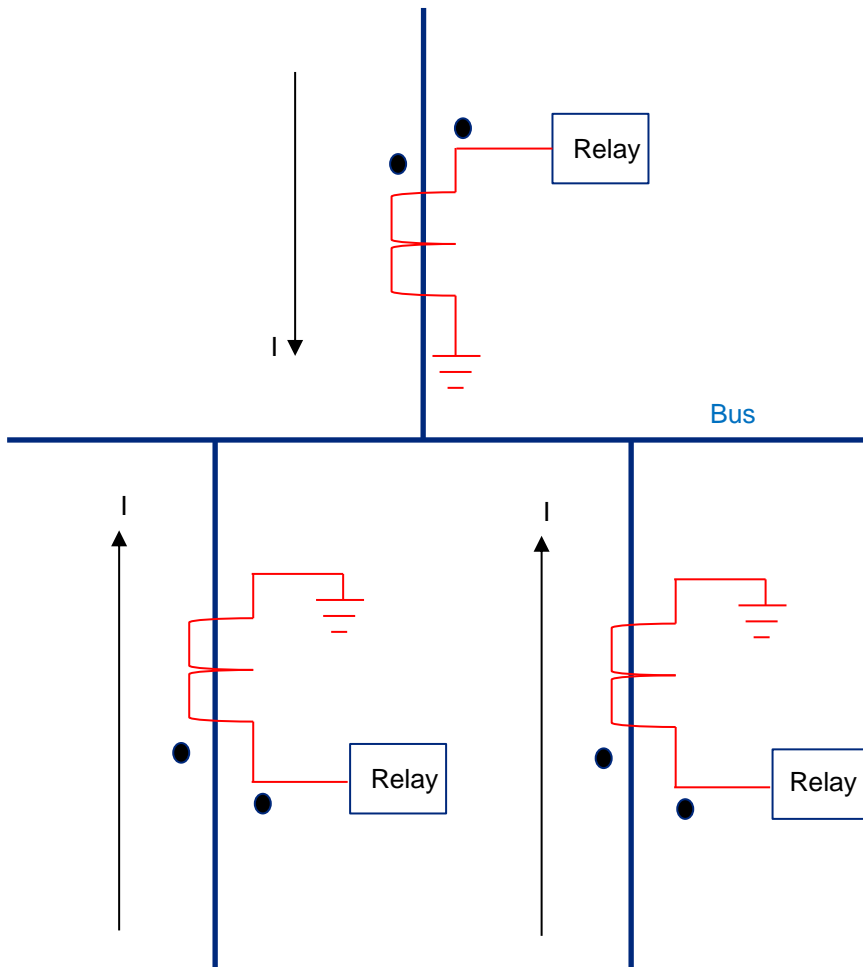


Figure 3

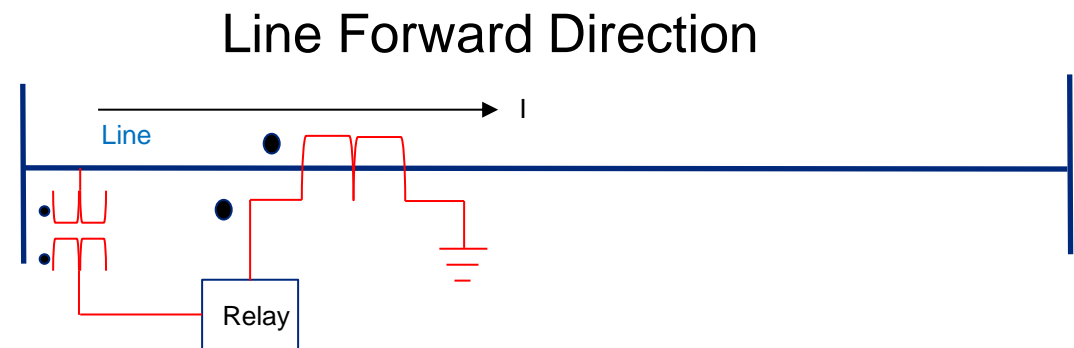


Figure 4

## 2. How to Set Directional Control in Overcurrent Elements



- So if the relay current connections are similar to Figure 4 and if the user is setting the Directional Overcurrent element to declare Line Faults as forward faults (to match the directional convention of the line protection relay), then the current phasor should be considered in  $-jX$  plane. In other words, for a typical line angle of  $80^\circ$  ( $Z1=V1/I1$ ), we need to mirror  $Z1$  in the R-axis to get the forward direction for Directional Overcurrent element in L-PRO, as shown in Figure 5 (*next slide*).
- In this scenario, and in order to get the forward direction centered at line angle and within  $90^\circ$ , we may simply set Alpha to  $-80^\circ$  less  $90^\circ = -170^\circ$  and Beta to  $+180^\circ$

## 2. How to Set Directional Control in Overcurrent Elements

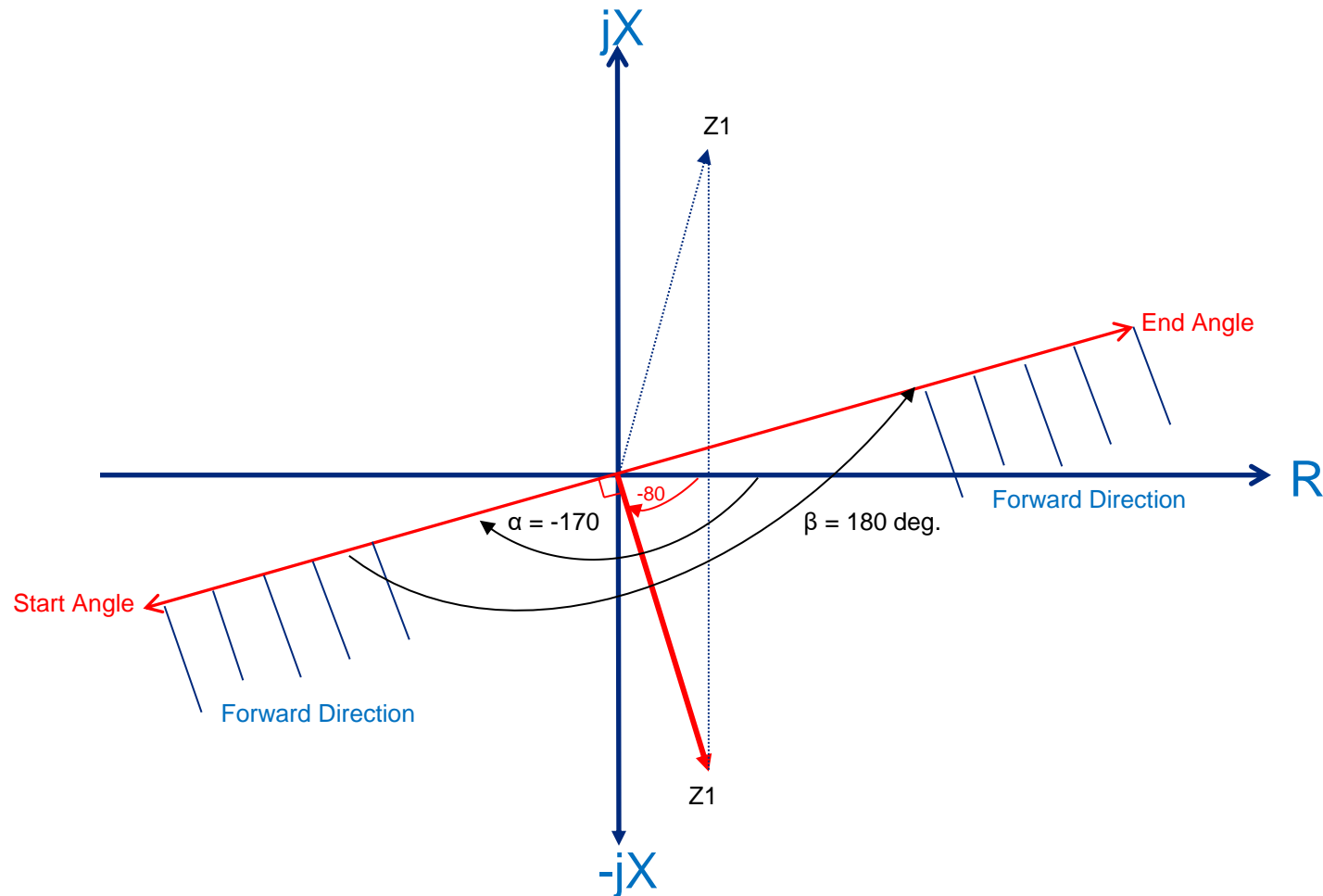


Figure 5. Directional Overcurrent Control in L-PRO

## 2. How to Set Directional Control in Overcurrent Elements

- For a typical fault current with  $I_1$  lagging  $V_1$  by  $75^\circ$  in line protection practice, we may simply set the Alpha ( $-75^\circ$  minus  $90^\circ = -165^\circ$ ) and Beta  $= +180^\circ$  to get a forward direction centered in the fault current vector

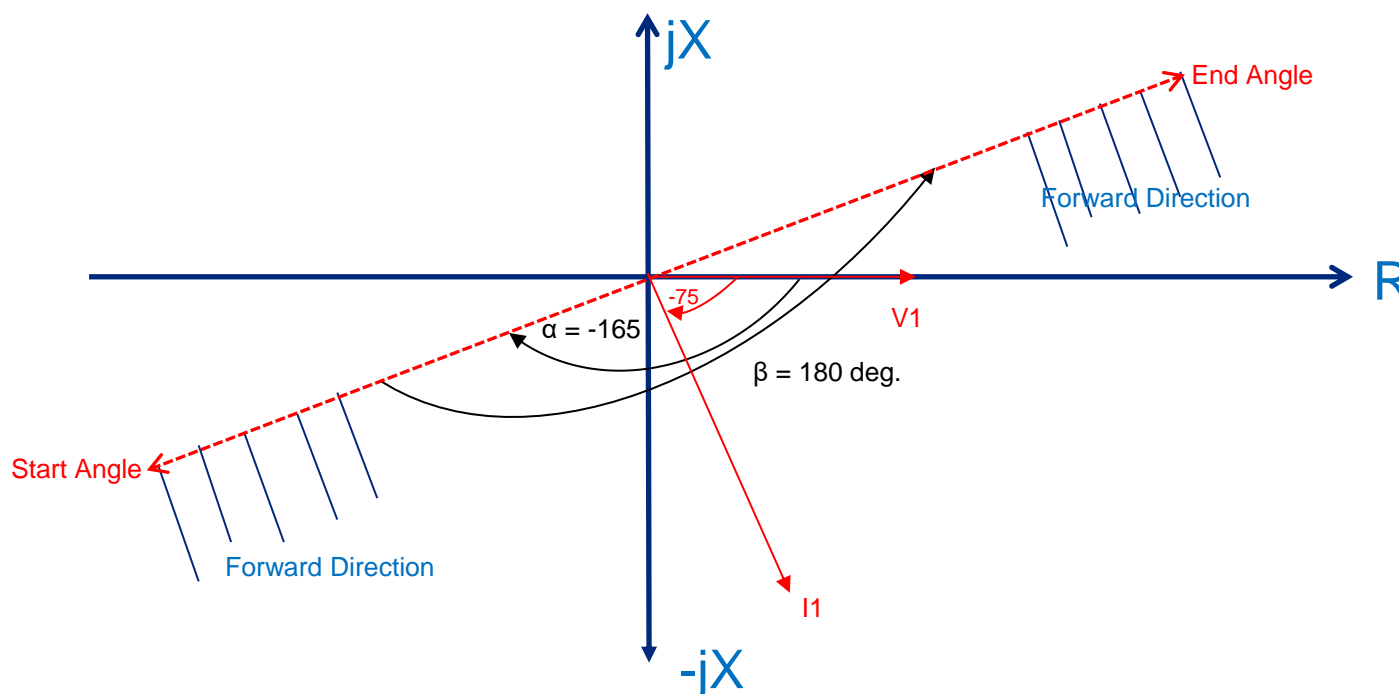


Figure 6

## 2. How to Set Directional Control in Overcurrent Elements

- Figure 7 shows Alpha set to  $-160^\circ$  and Beta to  $+140^\circ$  to get the forward impedance centered at  $90^\circ$

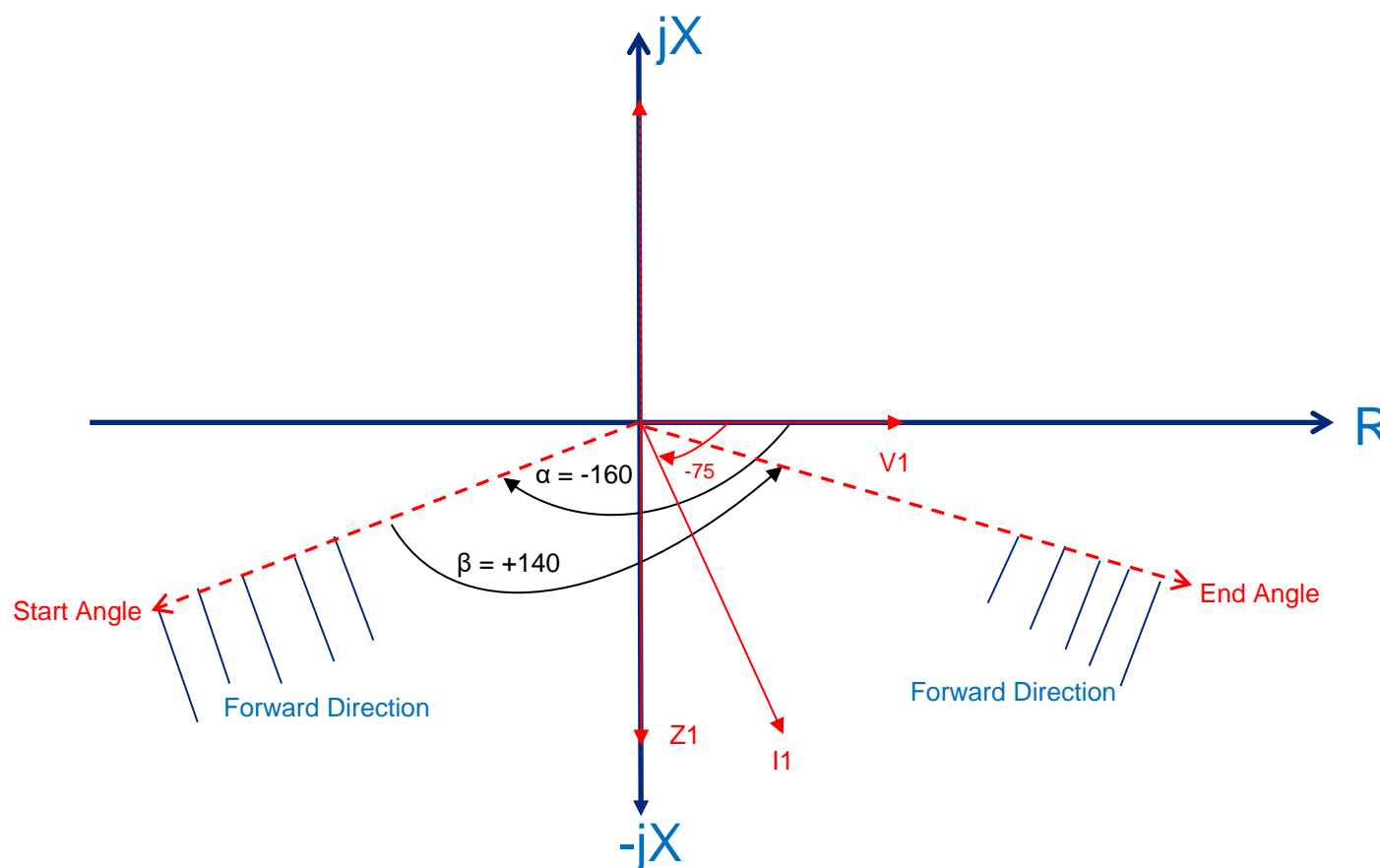


Figure 7



If you need any further assistance,  
please contact

ERLPhase Customer Service at +1 204-477-0591  
or  
[support@erlphase.com](mailto:support@erlphase.com)