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Application Note

Understanding and Applying the Sync Check (25) Phase Angle Compensation in Basler Digital Relays

The sync check system in Basler Electric's digital relays (BE1-FLEX, IPS100, -GPS100, -700V, -951, and -1051) was designed to allow the relay to monitor voltages on two sides of a breaker, commonly with the one source input (e.g., $V_{ABC(N)}$) monitoring a 3 phase/3 wire VT, a 3 phase/4 wire VT, or an arbitrary single phase (V_{PH-N} or V_{PH-PH}) VT, and with the relay's additional single phase voltage sensing connected to an arbitrary V_{PH-N} or VPH-$P_{H\ VT}$ on the other side of the breaker. This range of possible connections will result in various phase angle relationships between the two voltages. Depending on these possible VT setups, the relay has to perform a variety of phase shifts to compensate and, hence, recognize proper synchronism conditions.

Tables 1 and 2 below show the Sync Angle calculation when $V_{SOURCE2}$ is single phase sensing. The Sync Angle is the calculated phase angle error between the two sources. Note that when V_{SOURCE} is configured to be a 4 wire VT (i.e., 3 VTs connected phase to ground), the relay uses V_{AN} as the reference for the sync check function. When V_{SOURCE} is configured to be a 3 wire VT (i.e., 2 VTs connected phase to phase), the relay uses VAB as the reference for the sync check function. A comparison of tables 1 and 2 shows that table 2 includes a 30° shift relative to table 1, which accounts for using VAB as the V_{SOURCE} reference rather than V_{AN}.

On some legacy Basler relays, the user should be aware that the relays cannot compensate for magnitude differences between the $V_{SOURCE\ 1}$ reference quantity (V_{AN} or V_{AB} as described above) and $V_{SOURCE\ 2}$. The magnitude errors must be eliminated by the user through judicious selection of VT ratios or auxiliary transformers on these devices. The BE1-FLEX can scale the voltage internally.

Table 1. $V_{SOURCE\ 1}$ = 4-Wire Connection (3 Ph-N VTs)			
$V_{SOURCE\ 1}$ Reference	$V_{SOURCE\ 2}$ Input	ABC Rotation (Figure 1)	ACB Rotation (Figure 2)
V_{AN}	V_{AN}	SyncAngle = $\angle V_{AN} - (\angle V_{SOURCE\ 2}+0)$	SyncAngle = $\angle V_{AN} - (\angle V_{SOURCE\ 2}+0)$
V_{AN}	V_{BN}	SyncAngle = $\angle V_{AN} - (\angle V_{SOURCE\ 2}+120)$	SyncAngle = $\angle V_{AN} - (\angle V_{SOURCE\ 2}-120)$
V_{AN}	V_{CN}	SyncAngle = $\angle V_{AN} - (\angle V_{SOURCE\ 2}-120)$	SyncAngle = $\angle V_{AN} - (\angle V_{SOURCE\ 2}+120)$
V_{AN}	V_{AB}	SyncAngle = $\angle V_{AN} - (\angle V_{SOURCE\ 2}-30)$	SyncAngle = $\angle V_{AN} - (\angle V_{SOURCE\ 2}+30)$
V_{AN}	V_{BC}	SyncAngle = $\angle V_{AN} - (\angle V_{SOURCE\ 2}+90)$	SyncAngle = $\angle V_{AN} - (\angle V_{SOURCE\ 2}-90)$
V_{AN}	V_{CA}	SyncAngle = $\angle V_{AN} - (\angle V_{SOURCE\ 2}-150)$	SyncAngle = $\angle V_{AN} - (\angle V_{SOURCE\ 2}+150)$

Table 2. $V_{SOURCE\ 1}$ = 3-Wire Connection (2 Ph-Ph VTs)			
$V_{SOURCE\ 1}$ Reference	$V_{SOURCE\ 2}$ Input	ABC Rotation (Figure 3)	ACB Rotation (Figure 4)
V_{AB}	V_{AN}	SyncAngle = $\angle V_{AB} - (\angle V_{SOURCE\ 2}+30)$	SyncAngle = $\angle V_{AB} - (\angle V_{SOURCE\ 2}-30)$
V_{AB}	V_{BN}	SyncAngle = $\angle V_{AB} - (\angle V_{SOURCE\ 2}+150)$	SyncAngle = $\angle V_{AB} - (\angle V_{SOURCE\ 2}-150)$
V_{AB}	V_{CN}	SyncAngle = $\angle V_{AB} - (\angle V_{SOURCE\ 2}-90)$	SyncAngle = $\angle V_{AB} - (\angle V_{SOURCE\ 2}+90)$
V_{AB}	V_{AB}	SyncAngle = $\angle V_{AB} - (\angle V_{SOURCE\ 2}+0)$	SyncAngle = $\angle V_{AB} - (\angle V_{SOURCE\ 2}+0)$
V_{AB}	V_{BC}	SyncAngle = $\angle V_{AB} - (\angle V_{SOURCE\ 2}+120)$	SyncAngle = $\angle V_{AB} - (\angle V_{SOURCE\ 2}-120)$
V_{AB}	V_{CA}	SyncAngle = $\angle V_{AB} - (\angle V_{SOURCE\ 2}-120)$	SyncAngle = $\angle V_{AB} - (\angle V_{SOURCE\ 2}+120)$

Table 3 shows the equations used when only a single phase voltage is brought to the $V_{SOURCE\ 1}$ input:

Table 3. $V_{SOURCE\ 1}$ = Single-Phase VT			
Phase Input	$V_{SOURCE\ 2}$ Input	ABC Rotation (Figure 3)	ACB Rotation (Figure 4)
V_{AN}	V_{AN}	SyncAngle = $\angle V_{AN} - (\angle V_{SOURCE\ 2} + 0)$	SyncAngle = $\angle V_{AN} - (\angle V_{SOURCE\ 2} + 0)$
V_{AN}	V_{BN}	SyncAngle = $\angle V_{AN} - (\angle V_{SOURCE\ 2} + 120)$	SyncAngle = $\angle V_{AN} - (\angle V_{SOURCE\ 2} - 120)$
V_{AN}	V_{CN}	SyncAngle = $\angle V_{AN} - (\angle V_{SOURCE\ 2} - 120)$	SyncAngle = $\angle V_{AN} - (\angle V_{SOURCE\ 2} + 120)$
V_{AN}	V_{AB}	SyncAngle = $\angle V_{AN} - (\angle V_{SOURCE\ 2} - 30)$	SyncAngle = $\angle V_{AN} - (\angle V_{SOURCE\ 2} + 30)$
V_{AN}	V_{BC}	SyncAngle = $\angle V_{AN} - (\angle V_{SOURCE\ 2} + 90)$	SyncAngle = $\angle V_{AN} - (\angle V_{SOURCE\ 2} - 90)$
V_{AN}	V_{CA}	SyncAngle = $\angle V_{AN} - (\angle V_{SOURCE\ 2} - 150)$	SyncAngle = $\angle V_{AN} - (\angle V_{SOURCE\ 2} + 150)$
V_{BN}	V_{AN}	SyncAngle = $\angle V_{BN} - (\angle V_{SOURCE\ 2} - 120)$	SyncAngle = $\angle V_{BN} - (\angle V_{SOURCE\ 2} + 120)$
V_{BN}	V_{BN}	SyncAngle = $\angle V_{BN} - (\angle V_{SOURCE\ 2} + 0)$	SyncAngle = $\angle V_{BN} - (\angle V_{SOURCE\ 2} + 0)$
V_{BN}	V_{CN}	SyncAngle = $\angle V_{BN} - (\angle V_{SOURCE\ 2} + 120)$	SyncAngle = $\angle V_{BN} - (\angle V_{SOURCE\ 2} - 120)$
V_{BN}	V_{AB}	SyncAngle = $\angle V_{BN} - (\angle V_{SOURCE\ 2} - 150)$	SyncAngle = $\angle V_{BN} - (\angle V_{SOURCE\ 2} + 150)$
V_{BN}	V_{BC}	SyncAngle = $\angle V_{BN} - (\angle V_{SOURCE\ 2} - 30)$	SyncAngle = $\angle V_{BN} - (\angle V_{SOURCE\ 2} + 30)$
V_{BN}	V_{CA}	SyncAngle = $\angle V_{BN} - (\angle V_{SOURCE\ 2} + 90)$	SyncAngle = $\angle V_{BN} - (\angle V_{SOURCE\ 2} - 90)$
V_{CN}	V_{AN}	SyncAngle = $\angle V_{CN} - (\angle V_{SOURCE\ 2} + 120)$	SyncAngle = $\angle V_{CN} - (\angle V_{SOURCE\ 2} - 120)$
V_{CN}	V_{BN}	SyncAngle = $\angle V_{CN} - (\angle V_{SOURCE\ 2} - 120)$	SyncAngle = $\angle V_{CN} - (\angle V_{SOURCE\ 2} + 120)$
V_{CN}	V_{CN}	SyncAngle = $\angle V_{CN} - (\angle V_{SOURCE\ 2} + 0)$	SyncAngle = $\angle V_{CN} - (\angle V_{SOURCE\ 2} + 0)$
V_{CN}	V_{AB}	SyncAngle = $\angle V_{CN} - (\angle V_{SOURCE\ 2} + 90)$	SyncAngle = $\angle V_{CN} - (\angle V_{SOURCE\ 2} - 90)$
V_{CN}	V_{BC}	SyncAngle = $\angle V_{CN} - (\angle V_{SOURCE\ 2} - 150)$	SyncAngle = $\angle V_{CN} - (\angle V_{SOURCE\ 2} + 150)$
V_{CN}	V_{CA}	SyncAngle = $\angle V_{CN} - (\angle V_{SOURCE\ 2} - 30)$	SyncAngle = $\angle V_{CN} - (\angle V_{SOURCE\ 2} + 30)$
V_{AB}	V_{AN}	SyncAngle = $\angle V_{AB} - (\angle V_{SOURCE\ 2} + 30)$	SyncAngle = $\angle V_{AB} - (\angle V_{SOURCE\ 2} - 30)$
V_{AB}	V_{BN}	SyncAngle = $\angle V_{AB} - (\angle V_{SOURCE\ 2} + 150)$	SyncAngle = $\angle V_{AB} - (\angle V_{SOURCE\ 2} - 150)$
V_{AB}	V_{CN}	SyncAngle = $\angle V_{AB} - (\angle V_{SOURCE\ 2} - 90)$	SyncAngle = $\angle V_{AB} - (\angle V_{SOURCE\ 2} + 90)$
V_{AB}	V_{AB}	SyncAngle = $\angle V_{AB} - (\angle V_{SOURCE\ 2} + 0)$	SyncAngle = $\angle V_{AB} - (\angle V_{SOURCE\ 2} + 0)$
V_{AB}	V_{BC}	SyncAngle = $\angle V_{AB} - (\angle V_{SOURCE\ 2} + 120)$	SyncAngle = $\angle V_{AB} - (\angle V_{SOURCE\ 2} - 120)$
V_{AB}	V_{CA}	SyncAngle = $\angle V_{AB} - (\angle V_{SOURCE\ 2} - 120)$	SyncAngle = $\angle V_{AB} - (\angle V_{SOURCE\ 2} + 120)$
V_{BC}	V_{AN}	SyncAngle = $\angle V_{BC} - (\angle V_{SOURCE\ 2} - 90)$	SyncAngle = $\angle V_{BC} - (\angle V_{SOURCE\ 2} + 90)$
V_{BC}	V_{BN}	SyncAngle = $\angle V_{BC} - (\angle V_{SOURCE\ 2} - 30)$	SyncAngle = $\angle V_{BC} - (\angle V_{SOURCE\ 2} + 30)$
V_{BC}	V_{CN}	SyncAngle = $\angle V_{BC} - (\angle V_{SOURCE\ 2} + 150)$	SyncAngle = $\angle V_{BC} - (\angle V_{SOURCE\ 2} - 150)$
V_{BC}	V_{AB}	SyncAngle = $\angle V_{BC} - (\angle V_{SOURCE\ 2} - 120)$	SyncAngle = $\angle V_{BC} - (\angle V_{SOURCE\ 2} + 120)$
V_{BC}	V_{BC}	SyncAngle = $\angle V_{BC} - (\angle V_{SOURCE\ 2} + 0)$	SyncAngle = $\angle V_{BC} - (\angle V_{SOURCE\ 2} + 0)$
V_{BC}	V_{CA}	SyncAngle = $\angle V_{BC} - (\angle V_{SOURCE\ 2} + 120)$	SyncAngle = $\angle V_{BC} - (\angle V_{SOURCE\ 2} - 120)$
V_{CA}	V_{AN}	SyncAngle = $\angle V_{CA} - (\angle V_{SOURCE\ 2} + 150)$	SyncAngle = $\angle V_{CA} - (\angle V_{SOURCE\ 2} - 150)$
V_{CA}	V_{BN}	SyncAngle = $\angle V_{CA} - (\angle V_{SOURCE\ 2} - 90)$	SyncAngle = $\angle V_{CA} - (\angle V_{SOURCE\ 2} + 90)$
V_{CA}	V_{CN}	SyncAngle = $\angle V_{CA} - (\angle V_{SOURCE\ 2} + 30)$	SyncAngle = $\angle V_{CA} - (\angle V_{SOURCE\ 2} - 30)$
V_{CA}	V_{AB}	SyncAngle = $\angle V_{CA} - (\angle V_{SOURCE\ 2} + 120)$	SyncAngle = $\angle V_{CA} - (\angle V_{SOURCE\ 2} - 120)$
V_{CA}	V_{BC}	SyncAngle = $\angle V_{CA} - (\angle V_{SOURCE\ 2} - 120)$	SyncAngle = $\angle V_{CA} - (\angle V_{SOURCE\ 2} + 120)$
V_{CA}	V_{CA}	SyncAngle = $\angle V_{CA} - (\angle V_{SOURCE\ 2} + 0)$	SyncAngle = $\angle V_{CA} - (\angle V_{SOURCE\ 2} + 0)$

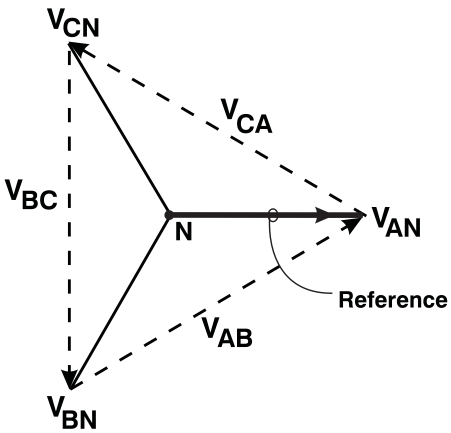

Figure 1 - 4 Wire, 3 VT, ABC

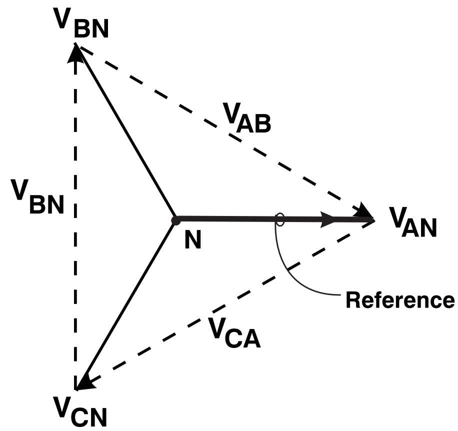

Figure 2 - 4 Wire, 3 VT, ACB

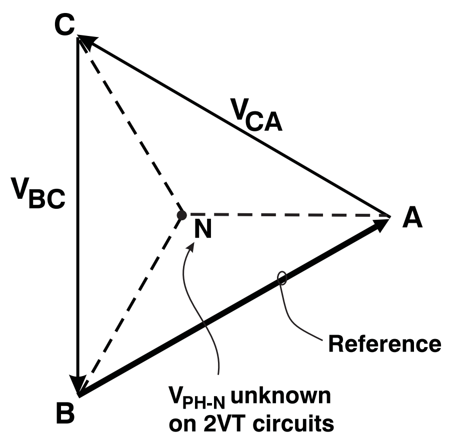

Figure 3 - 3 Wire, 2 VT, ABC

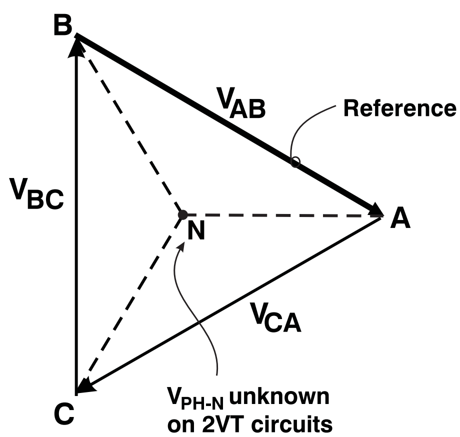

Figure 4 - 3 Wire, 2 VT, ACB

Application to Sync Check Across a Delta Wye Transformer

Occasionally, the need arises to apply the sync check function built into the digital relays across a delta-wye power transformer. This requires the relay to compensate for the phase shift effects of the transformer. This can be done, but it does require some thought on the part of the user. To understand how to handle the application, one needs to understand what the relays are doing internally with the VT configuration settings and phase rotation settings, which was given above. Then, by examining the equations used by the relay, one can find settings to enter to allow the sync check function to accommodate the ±30° phase shift created by the delta wye transformation. The concept is best understood by working through an example. See Figure 5 on the back page.

Let us determine how to configure the relay so that the relay will correctly see sync conditions for the circuit shown in figure 5. In this circuit we see that V_{AN} on the 13.2kV wye side is -30° (lagging) relative to V_{AN} on the 69kV delta side. The relay $V_{SOURCE\ 1}$ is sensing the 69kV system voltages via a 4 wire VT configuration; therefore, we know from table 1 that the relay is using V_{AN} as the $V_{SOURCE\ 1}$ reference. The questions we need to answer are, "Which voltage on the 13.2kV side shall we hook to the single phase $V_{SOURCE\ 2}$ input?" and "What setting shall we enter for the $V_{SOURCE\ 2}$ input configuration?" Examining table 1, and knowing that $V_{SOURCE\ 2}$ lags by 30°, we want an equation that adds +30° to the $V_{SOURCE\ 2}$ input. There is no such equation. (There might be some temptation to see the -30° compensation associated with setting the $V_{SOURCE\ 2}$ configuration to V_{AB}, but we need a compensation that adds 30°, not subtracts 30°.) However, there are other means to work with the relay. One answer (there are others) is to bring $-V_{AN}$ from the

13.2kV VT to $V_{SOURCE\ 2}$ (i.e., we will give the $V_{SOURCE2}$ input a 180° phase shift by connecting V_A to $V_{SOURCE\ 2}$ (non-polarity), and V_N to $V_{SOURCE\ 2}$' (polarity)), and then will tell the relay that $V_{SOURCE\ 2}$ is connected V_{CA}. The V_{CA} setting introduces a -150° compensation factor. The -150° compensation, plus a +180° phase shift from the phase inversion of the $V_{SOURCE\ 2}$ input, gives us the desired equation of $V_{SOURCE\ 2}$ + 30°.

Because there are so many possible permutations of how both $V_{SOURCE\ 1}$ and $V_{SOURCE\ 2}$ might be connected and whether $V_{SOURCE\ 2}$ is connected to the side of the transformer that leads or lags $V_{SOURCE\ 1}$ we cannot state how to configure the Basler digital relay for every condition. However, knowing the compensation equations in the relay, studying the phasors in one's applications, and thinking through the matter, one should be able to find a means to have the Basler relay work with the ±30° phase shift of a delta wye transformer.

For More Information

For more information, see www.basler.com or contact Technical Support at 618-654-2341.

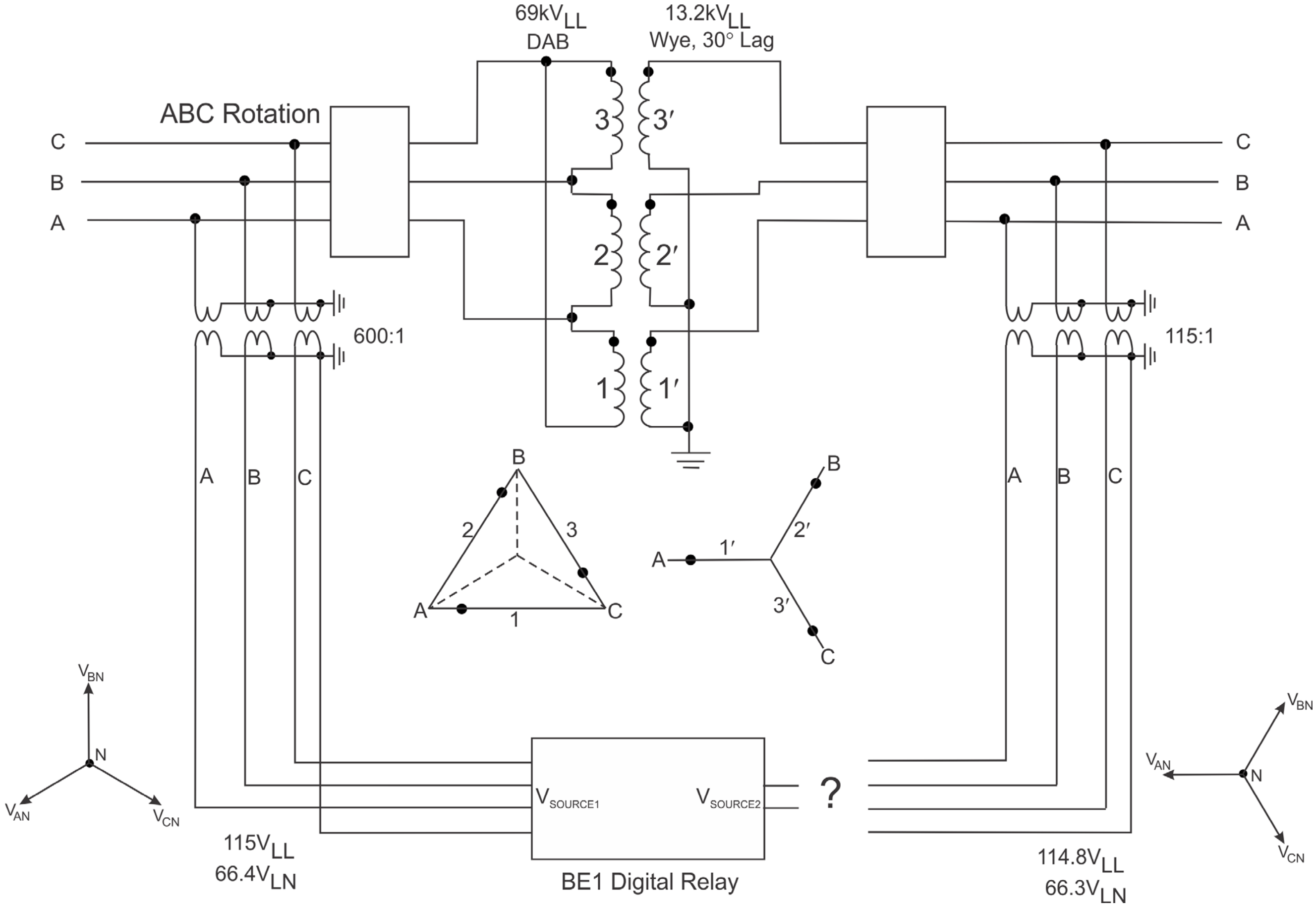

Figure 5 - Example System with Sync Potentials from Different Sides of a D-Y Transformer

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