# Application Note AN2013-11

# *Detect Transformer Inrush and Improve Protection Security on Feeders Using Second-Harmonic Blocking Logic in the SEL-351 and SEL-351S*

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## INTRODUCTION

Distribution feeders are often loaded with many transformers. Interconnection of distributed generation on a distribution system may increase the number of transformers tied to a given feeder. With an increase in the number of connected transformers, there is an increase in the magnetizing inrush currents. Increased inrush current can cause sensitive overcurrent elements to operate. This application note identifies how harmonic detection elements in the SEL-351 and SEL-351S Protection Systems can be used to modify relay settings and improve feeder protection security during the energization of transformers.

## PROBLEM

Transformer energization is the main cause of inrush currents, and voltage recovery following the clearing of an external fault is another. The nature of the magnetizing inrush current results in the presence of harmonics.

The fundamental magnitude of this inrush current is often multiples of the rated transformer load current. Depending on the sensitivity of the feeder overcurrent element, inrush current can result in an undesired feeder protection operation.

## SEL SOLUTION

The presence of second harmonics in the magnetizing inrush current can be used to identify transformer inrush currents. As shown in Figure 1, the SEL-351 and SEL-351S Relays use the measured ratio of the second-harmonic content of each phase to the fundamental current of the same phase to calculate the percent second harmonic. If the percent second harmonic exceeds the setting HBL2P, the second-harmonic element will assert as long as other supervisory conditions are met.

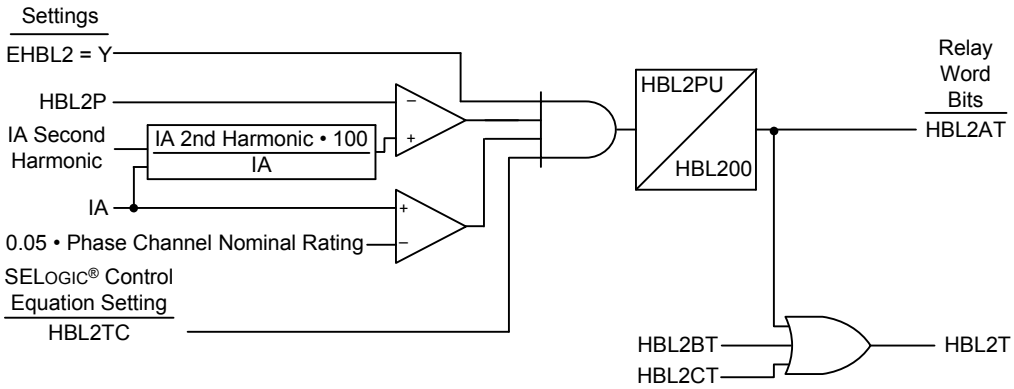


**Figure 1 Second-Harmonic Blocking Logic**

The setting EHBL2 must be set to Y to enable the second-harmonic blocking logic. Note that the SELOGIC control equation torque HBL2TC must evaluate to logical 1, and the fundamental current must be above 0.25 A for a 5 A relay. With the previous conditions met, the second-harmonic content must exceed the adjustable pickup threshold HBL2P before the pickup timer HBL2PU can begin to time. If the second-harmonic content remains above the settable threshold, allowing the time delay on pickup time HBL2PU to expire, Relay Word bit HBL2T asserts.

## SEL-351 AND SEL-351S SETTINGS EXAMPLE

A common application is to set a sensitive Level 1 element (50P1P) along with a high-set Level 2 element (50P2P). In this case, the 50P1P element may operate for transformer inrush. Therefore, it is blocked by the HBL2T Relay Word bit to prevent misoperation. SELOGIC control equation 67P1TC is set equal to the inverse of HBL2T (67P1TC = !HBL2T). Note that a Level 1 time delay is set to allow time for the blocking element HBL2T to assert. The 50P1P time delay 67P1D is set equal to 2 cycles (67P1D = 2.0).

The 50P2P is then set above the inrush current but low enough to operate for high-current faults that can result in current transformer (CT) saturation because the harmonics present in the saturated waveform can block the Level 1 element. Therefore, the Level 2 element is not blocked by the HBL2T element (67P2C = 1) thus ensuring that adequate protection is still enabled while the sensitive Level 1 element is blocked. Both 67P1T and 67P2T are included in the tripping equation (TR = …67P1T + 67P2T…).

The ER event report trigger SELOGIC control equation is modified to include the rising edge of HBL2T (ER = …+ /HBLT…) to trigger an event if the second-harmonic element blocks 67P1T from asserting TRIP. This event is used to evaluate the effectiveness of the harmonic blocking for the application and to determine if threshold adjustments are required. It is important to note that feeder protection relays measure harmonic content from one side of a transformer and are measuring the total load current of the feeder. It is suggested that the harmonic content of the load current be measured to ensure the chosen second-harmonic threshold for inrush detection is above the maximum feeder load current second-harmonic content.



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