Application Note AN2006-11

Estimating Power System Frequency With Synchronized Measurement

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INTRODUCTION

This application note demonstrates how synchrophasor measurement in the SEL-421/-451 Relay can provide additional information to enhance protection and control of power systems. IEEE Communication Protocol Standard C37.118 defines the transmission of data related to synchronized measurement as well as supplementation of data in either analog or digital form.

APPLICATIONS

Basic frequency is an important and sensitive parameter for appropriate operation, control, and protection of an electric power system. There are many frequency-estimation algorithms that provide acceptable accuracy if the voltage waveforms are not distorted. However, when the voltage waveforms include higher harmonics, algorithms can yield different results.

SEL SOLUTIONS

Consider an SEL-421/-451 Relay protecting the power line. Voltage input (Y) of the relay is wired to a potential transformer and time-synchronized with a high-accuracy GPS clock, such as the SEL-2401 or SEL-2407. The relay protects the power line and provides synchronized phasor measurements. The synchrophasors are available as analog quantities and can be used in SELOGIC® control equations (internal relay programming). The power voltage frequency can either be estimated by determining periods between zero crossings of the voltage waveform or based on the change of a rotating phasor.

The following programming is an example of frequency estimation for a range between 30 and 90 Hz through detection of change in a time-synchronized, positive-sequence voltage angle. This algorithm is complete and can be downloaded to SEL-421/-451 Relays.

SET L

```
PMV01: = 1000.000000 * V1LPMA   ### V1LPMA – ANGLE OF TIME-SYNCHRONIZED POSITIVE-SEQUENCE VOLTAGE
PMV02: = PMV01 - PMV03   ### V1 ANGLE CHANGE
PMV03: = PMV01
PMV04: = ABS (PMV02)
PSV01: = PMV04 > 0.100000
PSV02: = NOT PSV01
PSV03: = PMV02 > 180000.000000
PSV04: = NOT PSV03
PMV05: = -180000.000000
PSV05: = PMV02 < PMV05
PSV06: = NOT PSV05
PMV06: = PMV02 * PSV01 * PSV04 * PSV06
```

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```
PMV07: = (PMV02 + 360000.000000) * PSV01 * PSV05
PMV08: = (PMV02 - 360000.000000) * PSV01 * PSV03
PMV09: = PMV10
PMV10: = PMV09 * PSV02 + PMV06 + PMV07 + PMV08
PMV12: = PMV10 * 60.000000 / 360000.000000 + 60.000000  ### RAW FREQUENCY FROM V1
PMV13: = PMV14
PMV15: = 0.8
PMV14: = PMV15 * PMV13 + (1.000000 – PMV15) * PMV12  ### SMOOTH FREQUENCY FROM V1; PMV15 –
SMOOTHING PARAMETER
PMV16: = V1LPMM / PTRY   ### SECONDARY POSITIVE VOLTAGE MAGNITUDE
PSV07: = PMV16 > 10   ### MINIMUM SECONDARY V1 MAGNITUDE
PMV64: = 1000.000000 * PMV12 * PSV07  ### RAW FREQUENCY FROM V1 [IN MILLIHERTZ]
PMV63: = 1000.000000 * PMV14 * PSV07  ### SMOOTH FREQUENCY FROM V1 [IN MILLIHERTZ]
PSV64: = TSOK
```

The program measures the rate of change of the positive-sequence voltage angle over one nominal power frequency cycle. Because these are raw data, an IIR filter is used to smooth the results. Calculate the frequency, and then include the value in the synchrophasor message as an analog value for display, using visualization software such as SYNCHROWAVE™ Console SEL-5078 Software. To increase the measurement resolution, multiply the results by 1,000 to display in mHz.

Figure 1 shows the results for a signal with frequency varying from 30 to 90 Hz. Because being synchronized to a high-accuracy time source is crucial for accurate measurement, the right-side window displays the status of the synchronization TIME-SYNCHRONIZED OK (TSOK). Figure 2 shows the effect of the IIR smoothing algorithm.

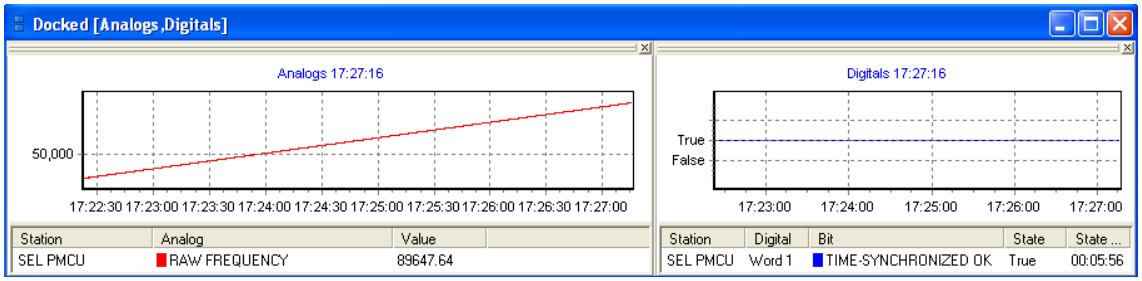

Figure 1 SYNCHROWAVE Console Software Displays Calculated Frequency and High-Accuracy Time-Synchronization Bit TSOK

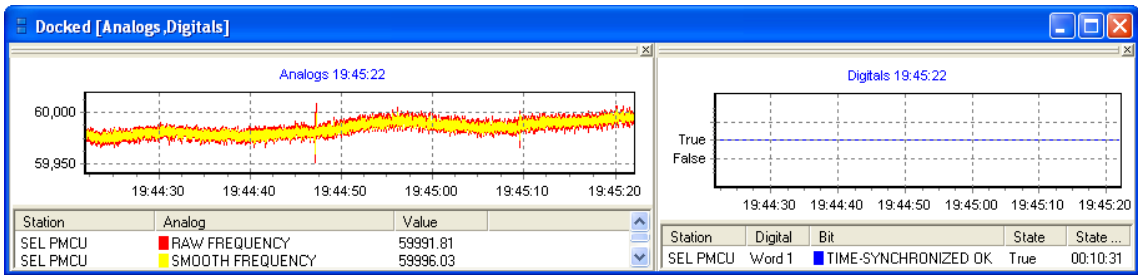

Figure 2 Raw and Smoothed Calculated Frequencies

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