Application Note AN2006-08

Generator Black-Start Restoration Using Synchronized Measurement

Mirek Wronski

INTRODUCTION

This application note demonstrates synchrophasor measurement in the SEL-421/-451 and SEL-311A, B, C, and L Relays and how it can provide valuable information during a generator black-start procedure.

APPLICATIONS

Restoring generating units after a power outage is more difficult if the power grid is unavailable at the time of the restoration, because then it is necessary to start generating units without access to the external power grid. Often, small diesel generators supply power to start hydroelectric generating stations, which are then used to start coal-fired stations. Once the coal-fired generator is operational, it can be synchronized and reconnected to the power grid. If the power grid is energized, reconnecting the generator is only possible if the generator voltage is synchronized with the power grid voltage. The North American Electric Reliability Council (NERC) recommends evaluating procedures and plans to assure effective black-start and restoration capabilities. To evaluate these procedures, it is necessary to conduct a black-start procedure exercise.

SEL SOLUTIONS

Consider the simplified power system shown in Figure 1.

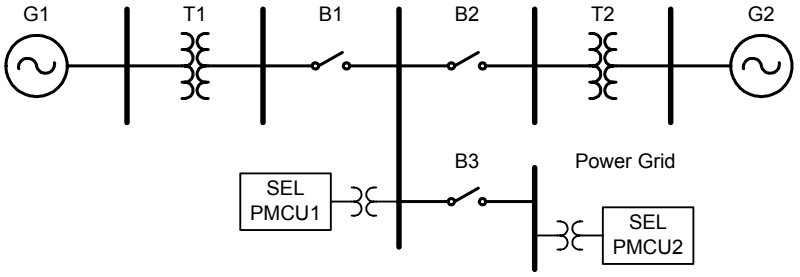

Figure 1 Simplified Power System for a Black-Start Exercise

G1 represents hydrogeneration, T1 is a step-up transformer, and B1 is the circuit breaker. G2 represents thermal generation, with T2 as a step-up transformer and B2 as a circuit breaker. B3 is a circuit breaker connecting local generation to an external power grid. SEL PMCU1 and SEL PMCU2 are two phasor measurement control units used to synchronize the two systems.

A simplified sequence for a black-start routine follows:

- Use the power from the diesel generator to bring the hydroelectric generating station into operation.
- Close circuit breakers B1 and B2 (Figure 1) to connect the hydrogeneration to the thermal generation.
- Use the power from the hydrodam to start the coal-fired units.
- Reconnect the coal-fired units to an energized power grid through a synchronized-switching procedure (across circuit breaker B3 in Figure 1).

Instead of installing separate PMCUs, we can use synchrophasor measurement in the SEL-421/-451 and SEL-311A, B, C, and L Relays to synchronize the two systems. For proper operation, time-synchronize these relays with a high-accuracy GPS clock, such as the SEL-2401 or SEL-2407. The clock must provide extended binary information as specified in the IEEE 37.118 Standard.

The PMCUs monitor both of the electrical systems and provide the frequency and positive-sequence voltage information necessary to synchronize the two systems. Figure 2 shows an example of the SYNCHROWAVE™ Console SEL-5078 Software display.

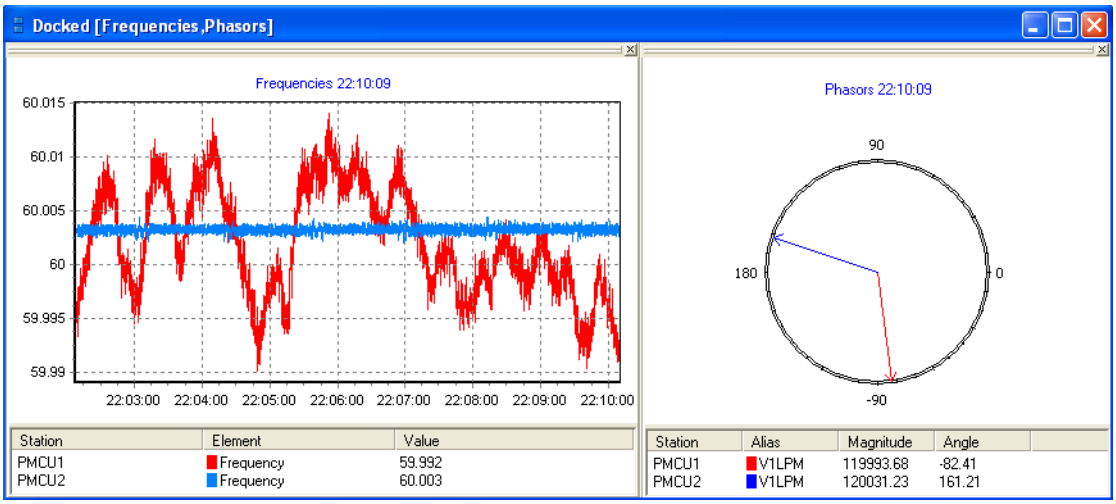

Figure 2 SYNCHROWAVE Console Software Displays Frequency and Positive Voltage Vectors From PMCU1 and PMCU2

With the information available on the display window, it is easy to determine the positions of the rotating voltage vectors relative to each other. When the angle between the two vectors is at a minimum, the circuit breaker (B3) can be closed with very little stress to the system.

SCHWEITZER ENGINEERING LABORATORIES, INC.
2350 NE Hopkins Court • Pullman, WA 99163-5603 USA
Tel: 509.332.1890 • Fax: 509.332.7990
www.selinc.com • info@selinc.com

LAN2006-08