Synchrophasor Real-Time Control for Optimizing System Voltage Profiles

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INTRODUCTION

Many subtransmission-level power systems use three-phase on-load tap changer (OLTC) transformers and shunt capacitor banks (SCBs) to provide voltage regulation and VAR support. The OLTC provides system voltage regulation by adjusting the supplied voltage incrementally to maintain acceptable voltage levels. The OLTC control typically operates as a simple dead-band control, monitoring the voltage on the load side of the OLTC and maintaining the voltage at this point by raising and lowering the voltage taps within the OLTC mechanism. The SCB provides reactive (VAR) support and also typically uses a simple dead-band control for operation. Unlike the OLTC, the SCB provides all of its capacity at once, being switched into or out of the load as a single device.

In some applications, the OLTC and SCBs may be utilized on systems where simple radial load flow may not exist or where the SCB is located at a point where it is difficult to determine the amount of load current and resulting voltage levels needed to properly adjust the OLTC and SCB operating parameters. Apply synchrophasor-based real-time control logic in these applications to provide the necessary control inputs to optimize system voltage profiles and reduce OLTC and SCB switching operations. This improves system stability and reduces overall maintenance and operating costs for the system.

PROBLEM

Using the system shown in Figure 1 as an example of a nonradial system, it is easy to see that using standard dead-band control operations between the OLTC and SCB could result in unnecessary switching operations on both devices. It could possibly even result in conditions in which the OLTC and SCB controllers, operating without knowledge of the other control's impact on the system, could cause repetitive switching operations, also known as "hunting." Additionally, the OLTC control may take steps to increase system voltage levels by increasing the tap position, when the ideal control operation would be to suspend OLTC operations and switch in the SCB.

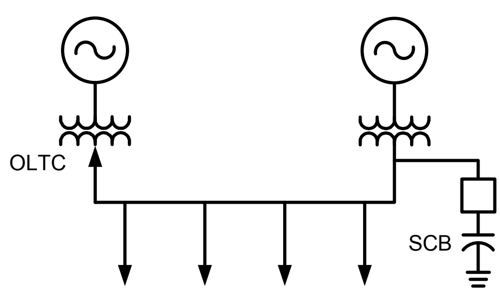

Figure 1 Example System

SEL SOLUTION

The SEL-487E Transformer Protection Relay and SEL-487V Capacitor Protection and Control System provide real-time control capability using IEEE C37.118 synchrophasor data. Each relay (operating as a synchrophasor data client) is capable of receiving serial IEEE C37.118 data from up to two separate synchrophasor servers. In this case, each relay operates as both data client and server of a real-time synchrophasor data.

As shown in Figure 2, the SEL-487E is utilized for the protection and control of an OLTC transformer. The SEL-487E measures system voltages and currents on both windings of the transformer and issues breaker and OLTC control signals. The SEL-487E provides IEEE C37.118 synchrophasor data, which include voltage magnitude and phase angle information relative to a common Global Positioning System-based time reference, to the SEL-487V.

The SEL-487V provides protection and control of the SCB at another substation. The SEL-487V measures system voltage magnitudes and angles and provides this synchrophasor information to the SEL-487E using IEEE C37.118 serial protocol.

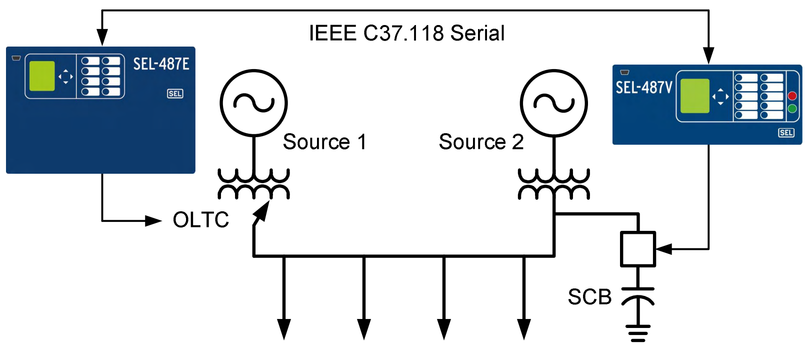

Figure 2 SEL-487E and SEL-487V Synchrophasor Real-Time Control

APPLYING SYNCHROPHASOR REAL-TIME CONTROL

In order to properly coordinate the control function of the OLTC and SCB, it is beneficial to monitor the voltage magnitude and VAR flow at the OLTC and SCB. These measurements provide useful information regarding the state of the system and the impact of any control operations that occur.

The SCB can be controlled by measuring the total VAR load of the system (VAR Source 1 + VAR Source 2 = total system VAR) and switching the SCB of known VAR rating into the system when the total inductive VAR load exceeds the SCB rating. The SCB control can also monitor system voltages. If there is a large drop in voltage measured at both the SCB and OLTC, the SCB control blocks OLTC operations and switches in the SCB to provide rapid system voltage recovery.

The OLTC can use the synchrophasor real-time control data from the SEL-487V to monitor phase voltage magnitudes and use these voltage measurements along with VAR directional flow to or from Source 2 to provide supervision of the OLTC operations at Source 1. This prevents unnecessary circulating currents from occurring between Source 1 and Source 2, while maintaining an ideal system voltage profile.

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