Chapter 1.
General Information

Introduction

This manual covers the installation, theory of operation, and calibration of the SPM-A Synchronizers. The synchronizers are used in generator applications for speed and phase matching of the generator before paralleling with other generators or the utility bus. These synchronizers have adjustable dynamics to match the dynamics of the engine. Small- to medium-size diesel engines require a synchronizer with fast dynamics. Turbomachinery, large diesel, gas or gasoline engines, and steam and gas turbines require slower dynamics.

Two versions of SPM-A Synchronizers are available, with or without voltage matching. Both versions are designed for a wide range of generator applications.

For additional information on adjusting SPM-A Synchronizers used on lean-burn spark-ignited gas engines, see Application Note 01301.

Description

The SPM-A Synchronizer biases the speed of an off-line generator set so that the frequency and phase match those of another generator or the utility bus. Then it automatically issues a contact closure signal to close the circuit breaker between the two when frequency and phase are matched within limits for a specified match-up time.

The SPM-A is a phase-locked-loop synchronizer and strives for a perfect match of frequency and phase. The SPM-A Synchronizer with voltage matching generates additional raise and lower signals (relay contact closures) to the generator's voltage regulator. Voltages must match within the SPM-A's tolerance before breaker closure occurs.

For single-unit synchronization, installation of one synchronizer on each generator allows each unit to be individually paralleled to the bus. For multiple-unit synchronization, one synchronizer can synchronize up to seven paralleled generator units simultaneously to another bus.

Both synchronizers versions have three output options: high impedance, low impedance, and EPG. Select the high impedance output for single-unit synchronization when the engine is controlled by a Woodward 2301 control. Select the low impedance output for single-unit synchronization when the engine is controlled by a Woodward 2301A, 2500, or Electrically Powered Governor (EPG) control through a Generator Load Sensor. Use the EPG output when using a Woodward EPG control without load sensing. Both units have the following features:

- 120 or 208/240 Vac input
- 10 degree phase window
- 1/8, 1/4, 1/2, or 1 second dwell time (internally switch selectable, factory set for 1/2 second)

The SPM-A Synchronizer with voltage matching has a 1% voltage match as standard. See the part number chart for other options.

Option Chart			
Part Number	**Frequency**	**Phase Angle**	**Voltage Matching**
9905-001 9907-028	50/60 Hz	±10°	No
9905-002 9907-029	50/60 Hz	±10°	1%
9905-003	50/60 Hz	±10°	5%
9905-004	50/60 Hz	±5°	No
9905-005	50/60 Hz	±5°	1%
9905-006	50/60 Hz	±10°	0.5%
9905-008	400 Hz	±10°	1%
9905-009	50/60 Hz	±10°	10%
9905-107	50/60 Hz	±15°	5%

Theory of Operation

This section describes the general theory of operation of the two versions of the SPM-A Synchronizer. Figure 1-1 shows the SPM-A Synchronizer with voltage matching. Figure 1-2 shows a typical synchronizer system block diagram. Figure 1-3 shows a functional block diagram of the synchronizer.

Synchronizer Inputs

The SPM-A Synchronizer checks the phase angle and frequency of the bus and an off-line generator which is to be paralleled. The voltage inputs from the bus and generator are first applied to separate signal conditioner circuits. Each signal conditioner is a filter which changes the shape of the voltage input signals so they can be accurately measured. A phase offset potentiometer in the signal conditioner circuit is adjusted to compensate for phase errors. (This adjustment is factory set with identical bus and generator inputs. It should be readjusted only where a phase offset has been caused through the line transformers of the installation.) The signal conditioners also amplify the bus and generator signals and apply them to the phase detector.

Operating Modes

A user-installed mode switch (single-pole, four-position) controls the relay driver. The switch must be wired to synchronizer contacts 10 through 13 (see the plant wiring drawing). The four positions are OFF, RUN, CHECK, and PERMISSIVE.

When the switch is OFF, the synchronizer is out of operation.

The RUN mode allows normal synchronizer operation and breaker closure signals. The speed bias circuit continues to operate to maintain synchronization for one second to allow time for the breaker closure signal. When one second has elapsed, the lockout circuit activates to disable the synchronizer. The lockout circuit is reset automatically when the relative phase angle exceeds the window limit after the generator is disconnected from the bus.

The CHECK mode allows normal synchronizing and voltage matching, but does not permit a breaker closure signal.

The PERMISSIVE mode allows synchronizer checks for proper synchronization, but synchronizer operation does not affect the engine's speed (nor voltage, in the voltage matching version). If phase and frequency are within proper limits, the synchronizer issues the breaker closure command. (Voltage is not checked in the Permissive Mode.)

See Woodward Application Note 50511 for information on the prediction of the phase angle at paralleling breaker closure.

Synchronizing the Generator

The phase detector compares the two signals and determines any difference between the generator and bus phases. When there is a difference, the speed bias circuit sends a correction signal to the Load Sharing and Speed Control. The correction signal increases or decreases engine speed depending on whether the generator is lagging or leading the bus. Correction signal amplitude is proportional to the amount of lead or lag (phase difference).

The phase window, dwell time, and breaker close circuit receive inputs from the phase detector. Using signals derived from the generator and bus inputs, the phase window circuit checks the phase angle. When the phase angle is less than the selected angle (inside the window) the dwell time circuit begins to measure the amount of time (dwell) the input signals are in phase and makes sure the signals remain in phase during breaker closure. When phase angle and dwell time requirements are correct, the breaker closing circuit sends a signal to the relay driver/inhibitor. The enable circuit gives a secondary relative phase angle check and turns on an indicator. When both the breaker closure circuit and enable circuit say the conditions have been satisfied, a signal is sent to the breaker closure relay. Then the breaker changes state for about one second. Connections for normally open contacts are provided.

The synchronizer, with or without voltage matching, will not close the circuit breaker connecting the generator to a dead bus. If there is no voltage to the bus then no correction signal is sent to the Load Sharing and Speed Control and no breaker closure signal is sent to the breaker.

If a dead-bus relay is used to close the breaker, the synchronizer mode switch must be in the OFF position until the synchronizer is required to synchronize and close the breaker to a live bus.

Voltage Matching

The voltage comparator circuit compares the generator and bus voltages. If there is a difference, the circuits issue appropriate raise or lower commands to the voltage regulator through relay contacts (see Figures 1-3 and 1-4). A voltage offset potentiometer (factory set with identical bus and generator inputs) is included in the voltage matching circuit to compensate for internal circuit differences. This voltage offset should be readjusted only when the bus and generator are paralleled.

The voltage comparator circuit also provides input to the relay driver/inhibitor. Any voltage difference between the generator and bus must be within the selected voltage range before the close breaker command may be given.

The voltage matching circuit is disabled when the breaker closure signal is issued.