Bulletin 1402
Line Synchronization Module (LSM)

(Catalog No. 1402-LS51)

Product Data

Description

The Line Synchronization Module (LSM) is a two slot Bulletin 1771 compatible plug-in module, which provides four key features for a PLC-5® integrated power generator, control solution or system. The PLC-5 based LSM provides a high performance cost effective solution for the retrofit of existing power generation control equipment and for new installations. Use of the LSM reduces the application cost and complexity when compared to conventional dedicated relay and "box" technology. The LSM, through the use of state of the art multilayered, multimode, circuit boards and electronics, increases system speed, accuracy, and overall performance while reducing the integration time, cost, space, and hardware parts count required.

Capabilities

Following is a list of capabilities, features and benefits:

- **Synchronization**
- **Anti-Motoring**
- **Load Sharing**
- **Power Monitoring**

Features and Benefits

- Installs in a Bulletin 1771 I/O chassis for PLC-5 compatibility
- Microprocessor controlled for very fast response time
- High accuracy for surgeless transfer
- Digital measurement for precise repeatability of operations
- #12 ring lugs for CT inputs, internal unbroken lugged CT circuit for long maintenance free service life and high surge withstand
- User configurable for unparalleled flexibility in applications
- Integrated synchronizer, load sharer, and Powermonitor Module for lower cost

General Functionality

This two slot PLC-5 compatible Line Synchronization Module is designed to meet the needs of manufacturers of industrial and commercial standby and cogeneration systems, retrofitter requirements, and those of emergency backup generator control suppliers. The product specifically performs four functions:

1. Generator to Live Bus Synchronization

This feature facilitates the connection of a cogeneration plant or a closed transfer standby generator. A "Breaker Closure Command" is issued from the Line Synchronization Module via the PLC backplane when all synchronization conditions are met. These conditions are:

- Voltage match bus to bus
- Frequency match bus to bus
- Phase angle match bus to bus

The following block transfer data is available to the PLC® backplane during synchronization and load sharing:

- Voltage Match Error (in steps of 0.05 percent)
- Frequency Match Error, or slip (in steps of 0.01 Hz)
- Synchronizing Bus to Reference Bus Phase Match Error (in steps of 1 degree)
- Load Sharing Error (scalar quantity between 0.000 and $\pm$ 1.000)
- Synchronization Status
  - Frequency, Voltage, and Phase Within Limits
  - Synchronization Mode Conflict Failure
  - Phase Rotation Mismatch Failure
  - No Reference or Synchronizing Bus Voltage Present Failure
  - Reference or Synchronizing Bus Over Voltage Failure

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General Functionality Continued

If the Line Synchronization Module recognizes a parameter mismatch, the module issues both discrete and Block Transfer inputs to the PLC. The PLC may then modify the instantaneous performance of the prime mover. Through the use of control circuit wiring to PLC cards, derivatives of this function may be utilized by the system integrator to provide a synchronization check and other speed control functions.

2. Anti-Motoring security while connecting to the live bus

The Line Synchronization Module executes critical measurements simultaneously then digitizes the time synchronized signals. This allows the selection of breaker closure acceptance windows asymmetrically about the zero phase angle. By skewing an acceptable closure window to insure that the generator frequency and phase angle are greater than the bus, the LSM can provide anti-motoring protection during the connection process. Once breaker closure has been established, data from the LSM can be used for analysis for reverse energy flow.

3. Load Sharing

The Line Synchronization Module has a special purpose analog input/output port that is compatible with many common load sharing inputs on governor modules. The analog load share output may also be used with a custom or PLC based controller. The output voltage will run and is configurable for a range from zero to anywhere between two and four volts.

4. Power Monitoring

In addition to the synchronization function, the LSM provides an extensive array of monitoring information for systems wired in Wye, Delta, or Open Delta. This monitor data is listed on Page 5.

The Line Synchronization Module executes continuous power monitoring functions as Block Transfer Reads through outputs to the PLC backplane. Update time is one second during the synchronization process, and 200 milliseconds when synchronization is not active. The Block Transfer Data available to the PLC is listed on Page 5.

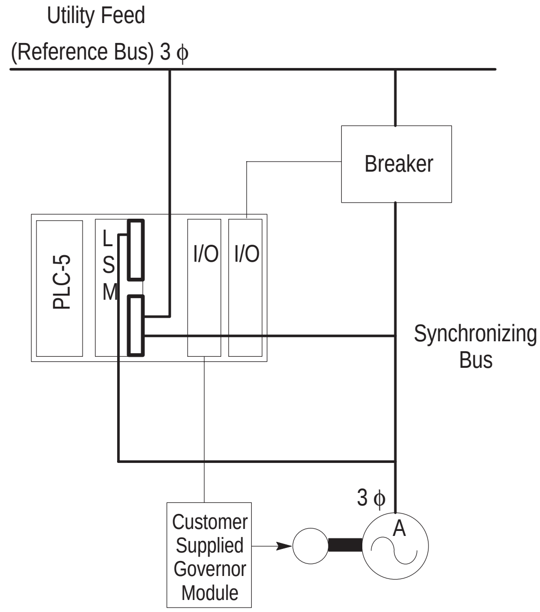
Synchronizing Bus	Current in Amps (per phase and neutral)
	Average Current in Amps
	Positive Sequence Current in Amps
	Negative Sequence Current in Amps
	Percent Current Unbalance
	Voltage in Volts (per phase L-L, and L-N on 4-wire systems)
	Average Voltage in Volts (L-L, and L-N on 4-wire systems)
	Positive Sequence Voltage in Volts
	Negative Sequence Voltage in Volts
	Percent Voltage Unbalance
	Frequency in Hz
	Phase Rotation (ABC, ACB)
	Power Factor in Percent (total, and per phase on 4-wire systems)
	Watts (total and per phase on 4-wire systems)
	VA (total and per phase on 4-wire systems)
	VAR (total and per phase on 4-wire systems)
	Power Consumption in kW Hours
	Reactive Power Consumption in kVAR Hours
	Demand (Amps, VA, and Watts)
Reference Bus	Voltage per phase in Volts (per phase L-L, and L-N on 4-wire systems)
	Average Voltage in Volts (L-L, and L-N on 4-wire systems)
	Frequency in Hz
	Phase Rotation (ABC, ACB)

All voltage and current measurements are true RMS. The power measurements are calculated from the instantaneous voltage and current measurements. The remainder of the monitoring information is derived from these values.

System Configuration

An installation with an LSM can take many forms. Typically it consists of a PLC, an LSM module, an output to a generator control device (an analog module) and an output to close the tie breaker. The figure below illustrates a typical system.

Figure 1
Typical System Configuration



Operational Characteristics

Self-Test

A complete self-test is automatically executed on power-up or when commanded from the PLC.

Also, a limited self-test which checks the validity of the stored configuration data and the performance of the analog inputs will automatically be performed at periodic intervals during normal operation. The results of this testing will be indicated in the module diagnostics data.

The red Fault LED will flash while the complete self-test is being performed. The Fault LED will remain on continuously if the self-test fails. The Fault LED will turn off if the self-test is successfully completed.

The green Run LED is illuminated during the self-test and then turned off after the test is completed. The Run LED also flashes each time a block transfer is executed.

Configuration

Configuration and Set-Up can be accomplished by sending the appropriate information to the module via the "Block Transfer Write" mechanism. Configuration data is compared for acceptable values. The user can obtain acknowledgment of the configuration data by using the "Block Transfer Read" mechanism to access the module's response. If out-of-range or illegal values are entered, an error indication that identifies the illegal or out-of-range entries is returned. If the data is acceptable, an acknowledgment indication is returned. The new configuration data is then used to scale the monitoring data and to set up the synchronization and load sharing functions.

Whenever new configuration data is sent to the LSM, all module functions (synchronization, load-sharing, and monitoring) are terminated, and the values for "Amps Demand", "kVA Demand", and "kW Demand" are cleared. The values for "kW Hours" and "kVAR Hours" are maintained at the values present before the new configuration data is sent. The new configuration data is then evaluated. Upon acceptance of the new configuration data, the module resumes operation. 6200 Programming Software is available to support this module.

A detailed description of the required configuration parameters are as follows:

Voltage Mode

This input parameter is used to indicate if the system being monitored is wired in a WYE, a Delta, or an open Delta. A value of "1" will indicate a WYE system, a value of "2" will indicate a three transformer Delta system, and a value of "4" will indicate a two transformer Open Delta system. Line-to-Neutral values will be provided only when a WYE is configured.

PT Primary Rating

This input parameter is used to indicate the primary voltage rating of the user supplied potential transformers. This information is used for scaling purposes. The value of this parameter must be between 120 and 115,000.

Line and Neutral CT Primary Ratings

These input parameters are used to indicate the primary ampere rating of the user supplied line and neutral current transformers. This information is used for scaling purposes. The value of this parameter must be between 5 and 10,000.

Continued on next page.

Operational Characteristics Continued

Configuration Continued

Synchronization Method

This configuration parameter is used to indicate which method of synchronization is to be implemented. A value of "0" indicates the delayed acceptance window method and is the only choice currently available.

Voltage Match Error Upper and Lower Acceptance Limits

These entries are used to specify the upper and lower acceptance limits for matching Synchronizing Bus voltage to the Reference Bus voltage. The value is specified in steps of 0.05% and must be between 0.00 and $\pm$25.00 percent.

Frequency Match Error Upper and Lower Acceptance Limits

These entries are used to specify the upper and lower acceptance limits for matching Synchronizing Bus frequency to the Reference Bus frequency. The value is specified in steps of 0.01 Hz and must be between 0.00 and $\pm$1.00.

Phase Match Error Upper and Lower Acceptance Limits

These entries are used to specify the upper and lower acceptance limits for matching Synchronizing Bus phasing to the Reference Bus phasing. The value is specified in degrees and must be between 0 and $\pm$20.

Acceptance Window Delay

This entry is used for the delayed acceptance window method of synchronization. The value is specified in steps of 0.05 seconds and must be between 0.00 and 10.00.

Maximum Synchronizing Bus Output Power

This entry is used to specify the power level at which the load sharing output voltage will be at its maximum value. The ratio of the actual power output to the value of this parameter is used to adjust the load sharing output voltage. This value will be specified in kW and must be between 0 and 999,999.

Load Share Full-scale Voltage

This entry is used to specify the load-share circuit's full-scale output voltage. The value is specified in steps of 0.01 volts and must be between 2.00 and 4.00.

Load Share Excess

This entry is used to specify the threshold for initiating action to decrease the Synchronizing Bus output power to the appropriate portion of the total system load. The value is a scalar quantity between 0.000 and –0.500.

Load Share Deficit

This entry is used to specify the threshold for initiating action to increase the Synchronizing Bus output power to the appropriate percentage of the total system load. The value is a scalar quantity between 0.000 and +0.500.

Demand Period

This entry is used to specify the desired period for demand measurement. The value is specified in minutes and must be between 1 and 99.

Number Of Demand Periods

This entry specifies the number of demand periods that should be averaged to determine the actual demand. The value must be between 1 and 15.

Synchronization

The functionality of the synchronization process is based on the synchronization discrete outputs from the PLC-5 received from the LSM via the PLC backplane. The "Initiate Synchronization" output from the PLC-5 to the LSM begins the synchronization process when it is asserted. It must remain asserted during the entire process. If the initiate signal is removed, the synchronization process is terminated. In addition to the initiate signal, one of the "Auto-Synchronization", "Check Synchronization", or the "Permissive Synchronization" discrete outputs from the PLC-5 must be asserted. If more than one of those signals is present, the synchronization fails and the "Synchronization Failure" discrete input to the PLC-5 will be asserted.

If new setup information is received via block transfer while the LSM is in the Synchronization mode, synchronization is terminated. The new configuration parameters are evaluated and normal operation is resumed upon acceptance of the data.

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Operational Characteristics Continued

Synchronization Continued

The “Auto-Synchronization” discrete output from the PLC-5 directs the LSM to issue the appropriate error signals, both continuous discrete inputs plus block transfer information, to cause, through an exterior governor, the synchronizing bus voltage, frequency, and phase to align with the reference bus. Once these conditions are satisfied, the “Close Breaker” discrete input to the PLC-5 is asserted based on the synchronization configuration. In the event a “dead reference bus” condition exists, the “Synchronization Failure” discrete input to the PLC-5 is asserted.

The “Check Synchronization” discrete output from the PLC-5 causes the LSM to function in the same manner as the “Auto-Synchronization” discrete output from the PLC-5 except it will not assert the “Close Breaker” discrete input to the PLC-5. This mode is useful for testing the system.

The “Permissive Synchronization” discrete output from the PLC-5 prevents the LSM from issuing any error signals, but it asserts the “Close Breaker ” discrete input to the PLC-5 if the synchronization criteria are satisfied. This mode also recognizes a “dead reference bus” condition and asserts the “Close Breaker” discrete input to the PLC-5 to allow an operator to bring the synchronizing bus on line when the reference bus has failed.

The synchronization errors are computed as follows:

- Voltage Match Error = 100 $\times$ (Reference Bus Voltage – Synchronizing Bus Voltage) /(Reference Bus Voltage)
- Frequency Match Error = (Reference Bus Frequency) – (Synchronizing Bus Frequency)
- Phase Match Error = (Reference Bus Voltage Zero-cross Degrees) – (Synchronizing Bus Voltage Zero-cross Degrees) [This calculation is performed on either both rising zero-crosses or both falling zero-crosses and the result is adjusted to provide a value between –180 degrees and +180 degrees.]

In the “Delayed Acceptance Window” method of synchronization, the “Close Breaker” discrete input to the PLC-5 is asserted after the “Voltage Match Error”, the “Frequency Match Error”, and the “Phase Match Error” have all remained continuously within their respective acceptance windows for the configured delay time, called “Acceptance Window Delay ”.

In the event the reference bus and synchronizing bus systems are opposite in phase rotation, the synchronization fails. This is indicated by the “Synchronization Failure” discrete input to the PLC-5.

Power Monitoring

In addition to the synchronization function, the LSM provides an extensive array of monitoring information. This data is accessible through one of several different block transfers. All voltage and current measurements presented by the LSM are true RMS. All power measurements are calculated from the instantaneous voltage and current measurements. The remainder of the monitoring information is calculated from these values.

The monitored values are scaled and reported based on the configuration entries that were provided by the user. This function is terminated if new configuration data is received. The new configuration data is evaluated and normal operation is resumed upon acceptance of the data. During synchronization those parameters not required for synchronization are monitored at a reduced priority. This allows critical synchronization data to be updated at a faster rate.

Load Sharing

The load sharing function allows multiple synchronizing buses to split the load requirements on a power system based on the relative capacity of each of the alternators. To use this function, the LSM must be configured with a "Maximum Alternator Output Power" entry, a "Load Share Full-Scale Voltage" entry, a "Load Share Deficit" entry, and a "Load Share Excess" entry. The first entry specifies the maximum desired power output for the alternator. The second entry specifies the load share output voltage that will be created when the alternator is operating at maximum power. The third and fourth entries define the regions where load sharing activity will take place. The region between these two entries is the dead-band where no corrective action takes place if the discrete inputs are being utilized for control. The full-scale voltage is configurable to be between 2 and 4 volts.

The load sharing function is enabled when the "Load Share Disable" discrete output from the PLC-5 is *not* asserted and the "Isochronous/Droop" discrete output from the PLC-5 indicates isochronous mode. If new setup information is received via block-transfer while this function is enabled, load sharing is terminated. The new configuration data is evaluated and normal operation is resumed upon acceptance of the data.

The LSM provides a "Load Sharing Output" voltage that is resistively coupled to the dual function input/output terminals. The magnitude of the output voltage is calculated from the following formula:

("Load Share Full-Scale Voltage") (Actual Power) / ("Maximum Alternator Output Power")

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Operational Characteristics Continued

Load Sharing Continued

The “Load Sharing Input” voltage is measured from the dual function input/output terminals. The load sharing input is calculated by:

(“Load Sharing Input Voltage”) / (“Load Share Full-Scale Voltage”)

The “Load Share Error” is a fraction and is expressed as:

(Load Sharing Input Voltage) / (Load Share Full-Scale Voltage)) – (Actual Power) / (Maximum Alternator Output Power))

If the error is negative, the alternator is supplying too much of the load requirements and the “Reduce Power – load share adjust” discrete input to the PLC-5 is asserted when the error exceeds the “Load Share Excess” entry. If the error is equal to zero, the load is being properly shared. If the error is positive, the alternator is not supplying enough of the load requirements and the “Raise Power – load share adjust” discrete input to the PLC-5 is asserted when the error exceeds the “Load Share Deficit” entry.

The LSM load sharing circuit is isolated from the external circuitry whenever load sharing is disabled, droop mode is indicated, or if power is removed from the module.

Current Inputs

- Nominal Current: 0 to 5A RMS (14.14A pk-pk)
- Maximum Current: 7A RMS (19.8A pk-pk)
- Surge Current: 200A RMS for 1 second (10 minute interval)
- Frequency: 40 to 100 Hz (steady-state)
- Dielectric Withstand Voltage: 2500V RMS
- Burden: 0.2 VA

Voltage Inputs

- Nominal Voltage: 120V RMS (339V pk-pk) Maximum Peak
- Maximum Voltage: 150V RMS (424V pk-pk)
- Frequency: 40 to 100 Hz (steady-state)
- Dielectric Withstand Voltage: 2500V RMS
- Burden: 0.02 VA
- Via Block and Discrete transfer to the PLC back plane.

Update Rate

- Synchronizing Bus Error Parameters Table: 100 milliseconds
- Monitoring Parameters Tables: 200 milliseconds (Synchronization Inactive) 1 second (Synchronization Active)
- Diagnostic Parameters Tables: 1 second

Accuracy

The accuracy of the measurements and calculations made by the LSM are directly affected by the quality of the user supplied current and voltage transformers. Accuracy is affected by both the amplitude and phase errors introduced by the user supplied transformers. It is recommended that these transformers be instrument accuracy, Class 1 or better. The following accuracy values are relative to the signals that are present at the input terminals of the LSM at an ambient temperature of 25° C.

- Current Measurement = + /–0.2% of Full Scale
  (Full Scale= 1.4 × CT Primary)
- Voltage Measurement = + /–0.2% of Full Scale
  (Full Scale= 1.25 × PT Primary)
- Frequency Measurement = + /–0.05 Hz (Within the 47 to 63 Range)
- Slip Frequency = + /–0.05 Hz (Within the 47 to 63 Range)
- Power, Power Factor, VA = + /–0.4% at Full Scale Power Consumption
  (Full Scale = 1.75 × CT Primary × PT Primary)

PLC Interface

The LSM exchanges data with the PLC backplane via both discrete I/O and block transfers. Due to the physical size of the module's internal components, the LSM requires two slots in the I/O rack. However, addressing assignments are made to the lower numbered slot of the two slots used.

Discrete I/O Interface

The LSM accepts six discrete outputs from the PLC-5, and provides twelve discrete inputs to the PLC-5.

Discrete Outputs (From the PLC Processor)

The following discrete output control signals will be provided from the PLC-5 processor via the back plane:

- Initiate Synchronization
- Auto-Synchronization Mode
- Check Synchronization Mode
- Permissive Synchronization Mode
- Load Share Disable
- Isochronous/Droop Mode

Discrete Inputs (To the PLC Processor)

The following discrete input control signals will be provided to the PLC-5 processor via the back plane:

- Module Status
- Raise Voltage
- Lower Voltage
- Raise Speed — frequency adjust
- Lower Speed — frequency adjust
- Raise Speed — phase adjust
- Lower Speed — phase adjust
- Raise Power — load share adjust
- Lower Power — load share adjust
- Close Breaker
- Synchronization Failure
- Power-up Bit

Block Transfer Data Interface

The LSM is capable of exchanging large amounts of data with the PLC processor via the Block Transfer mechanism. The amount of data greatly exceeds that which could be accommodated by a single block transfer. As a result, the data is divided into several different "files" and can be obtained through the use of multiple Block Transfers.

Block Transfer Writes from the PLC (LSM Inputs)

The following Block Transfer data will be required from the PLC processor to configure the LSM:

- Voltage Mode – Wye, Delta, Open-Delta
- PT Primary Rating
- Line and Neutral CT Primary Rating
- Voltage Match Error Upper and Lower Acceptance Limits (In steps of 0.05 percent)
- Frequency Match Error Upper and Lower Acceptance Limits (In steps of 0.01 Hz)
- Phase Match Error Upper and Lower Acceptance Limits (In steps of 1 Degree)
- Acceptance Window Delay{Required for delayed acceptance window synchronization method} in seconds (In steps of 0.05 seconds)
- Maximum Synchronizing Bus Output From the PLC-5 Power in kW
- Load Share Full-Scale Voltage (In steps of 0.01 volts)
- Load Share Excess (Scalar quantity between 0.000 and –0.500)
- Load Share Deficit (Scalar quantity between 0.000 and +0.500)
- Demand Period
- Number of Demand Periods

In addition to configuration data the following control parameters may be sent to the module via a block transfer.

- Execute Self-Test (If the execute self-test option is selected, no other control options will be executed and demand functions are cleared)
- Clear kW-HR Counter
- Clear kVAR-HR Counter

Continued on next page.

PLC Interface Continued

Block Transfer Reads to the PLC (LSM Outputs)

The following block transfer data will be provided by the LSM:

- Diagnostic Parameters
  - Bulletin Number
  - Options
  - Firmware Version
  - ROM Status
  - RAM Status
  - EEPROM Status
  - Analog Power Supply Status
  - Data Acquisition Status
  - Load Share D/A and A/D Converter Status
  - Watchdog Timer Status
  - Module Date / Time
- Voltage Match Error (in steps of 0.05 percent)
- Frequency Match Error, or slip (in steps of 0.01 Hz)
- Synchronizing Bus to Reference Bus Phase Match Error (in steps of 1 degree)
- Load Sharing Error (scalar quantity between 0.000 and $\pm$ 1.000)
- Synchronization Status
  - Frequency, Voltage, and Phase Within Limits
  - Synchronization Mode Conflict Failure
  - Phase Rotation Mismatch Failure
  - No Reference or Synchronizing Bus Voltage Present Failure
  - Reference or Synchronizing Bus Over Voltage Failure

Block Transfer Reads to the PLC (LSM Outputs) Continued

Synchronizing Bus	Current in Amps (per phase and neutral)
	Average Current in Amps
	Positive Sequence Current in Amps
	Negative Sequence Current in Amps
	Percent Current Unbalance
	Voltage in Volts (per phase L-L, also L-N on 4-wire systems)
	Average Voltage in Volts (L-L, also L-N on 4-wire systems)
	Positive Sequence Voltage in Volts
	Negative Sequence Voltage in Volts
	Percent Voltage Unbalance
	Frequency in Hz
	Phase Rotation (ABC, ACB)
	Power Factor in Percent (total, also per phase on 4-wire systems)
	Watts (total and per phase on 4-wire systems)
	VA (total and per phase on 4-wire systems)
	VAR (total and per phase on 4-wire systems)
	Power Consumption in kW Hours
	Reactive Power Consumption in kVAR Hours
	Demand (Amps, VA, and Watts)
Reference Bus	Voltage per phase in Volts (per phase L-L, also L-N on 4-wire systems)
	Average Voltage in Volts (L-L, also L-N on 4-wire systems)
	Frequency in Hz
	Phase Rotation (ABC, ACB)

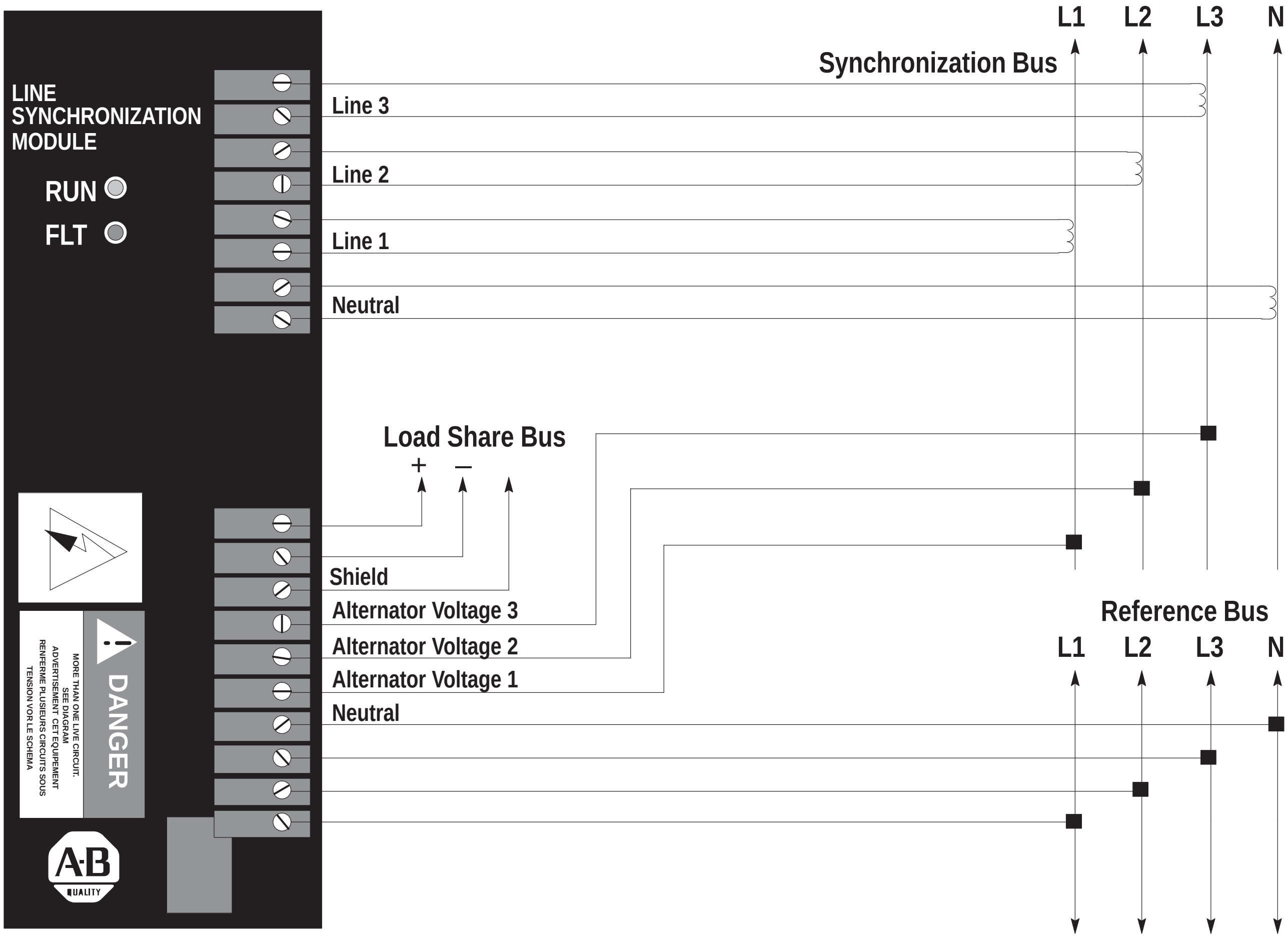
All voltage and current measurements are true RMS. The power measurements are calculated from the instantaneous voltage and current measurements. The remainder of the monitoring information is derived from these values.

Environmental Specifications

Temperature

- Operating 0° C to +60° C (+32° F to +140° F)
- Storage +40° to +100° C (+104° F to +212° F)
- Humidity 5% to 95%, non-condensing

Figure 2
Typical Wiring Diagram (See Applicable Codes and Laws)



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