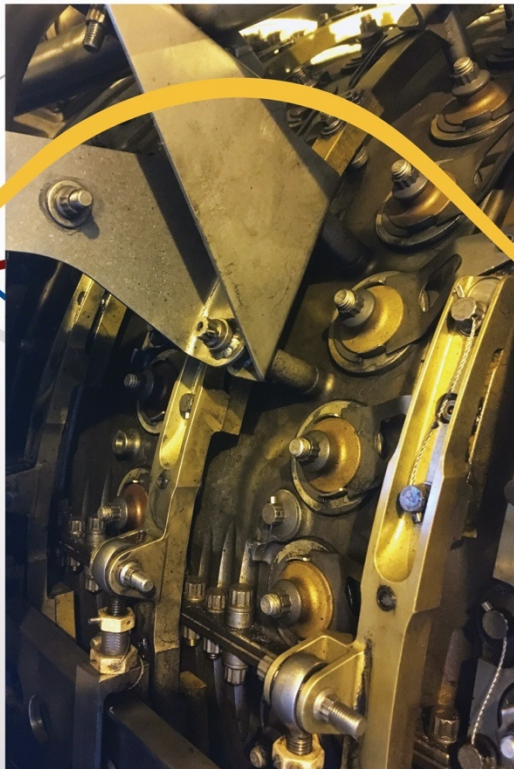


Training Manual Volume 3  
Generator Synchronizing  
and Protection





## **VOLUME III: Generator Synchronizing and Protection**

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# 1 SYNCHRONIZATION BASIC THEORY

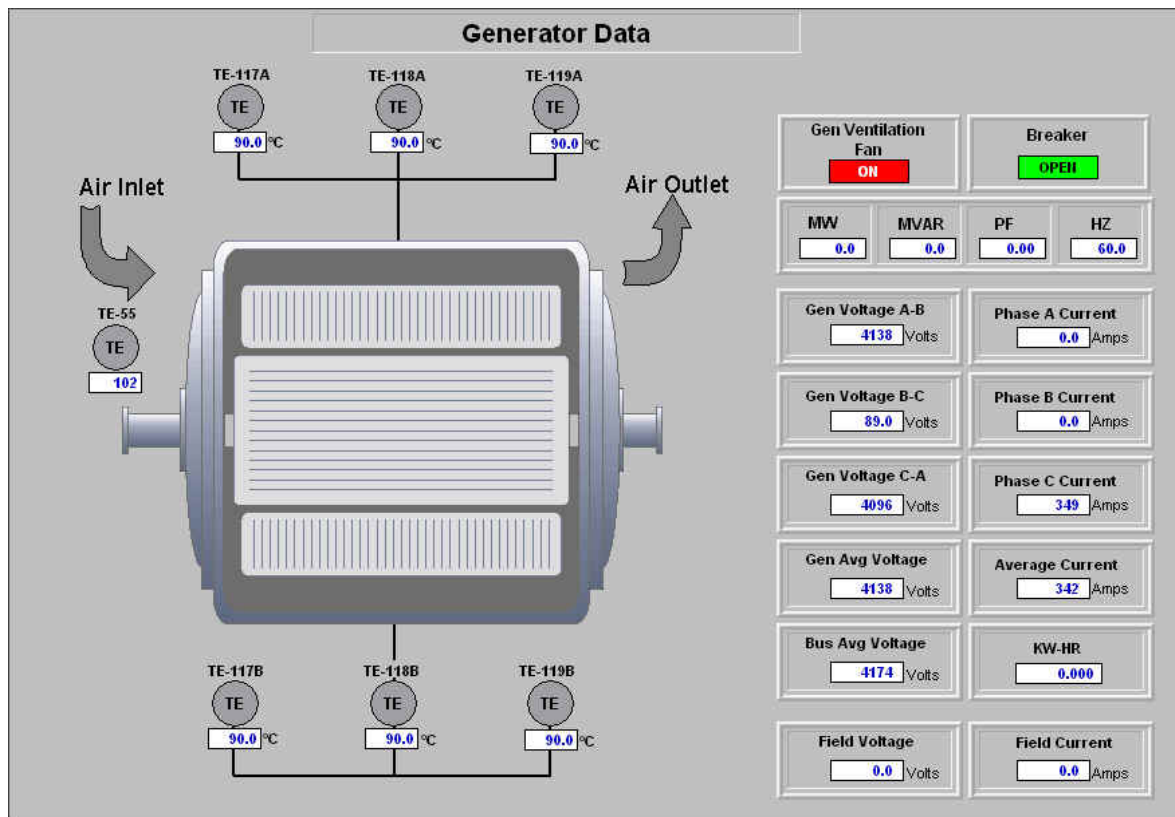


Figure 1-1

## 1.1 Generator Capacity Curves

The generator should be operated within both its real and reactive load limits and a generator capacity curve is supplied by the manufacturer to aid in this endeavour. Normal operation of the generator should be within the pink area.

Exceeding the limits can lead to the following:

- |                  |                |
|------------------|----------------|
| Under excitation | Pole slipping  |
| Over excitation  | Rotor heating  |
| Overload         | Stator heating |

## 1.2 VARS and Reactive Power

Energy stored in capacitive or inductive elements of the network give rise to reactive power flow. Reactive power flow strongly influences the voltage levels across the network.



Voltage levels and reactive power flow must be carefully controlled to allow a power system to be operated within acceptable limits.

A generator can add or remove reactive power from a grid. When the generator is removing reactive power, the generator is acting as a capacitor. Unfortunately, the absorbing of reactive power produces heat and heat damages generator components. In addition, the heat loss is energy loss.

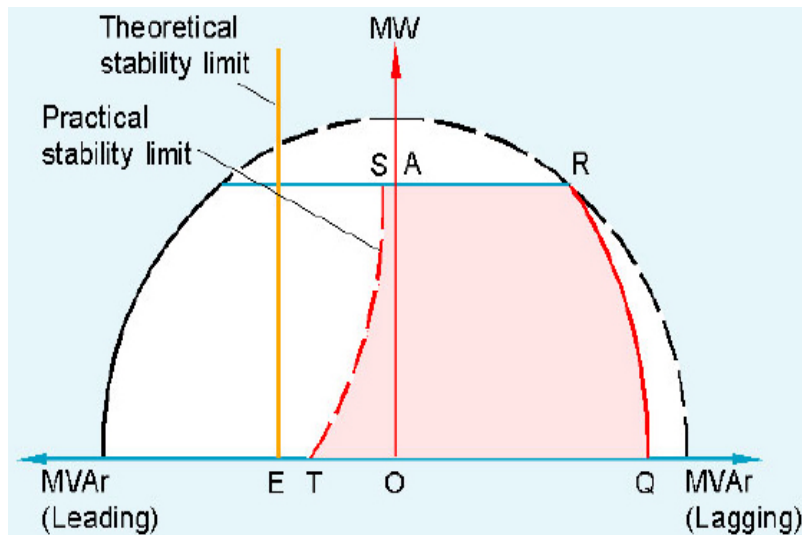


Figure 1-2

### 1.3 Practical Application

In operations, the generator field strength determines voltage and current production.

Therefore:

To produce VARS, raise the voltage by increasing the generator field current.

To absorb VARS, lower the voltage by decreasing the generator field current.

In the CGCM this function can be configured to automatically control both leading and lagging VARS.

### 1.4 Matching of Voltage, Frequency between Bus and Generator

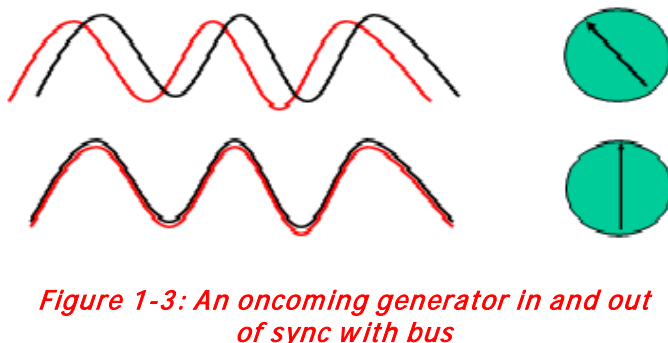
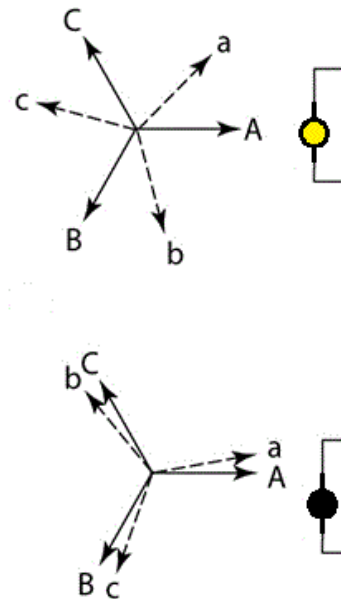
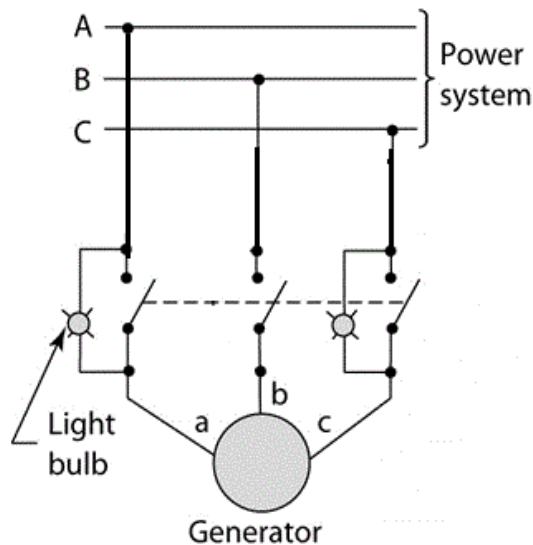


Figure 1-3: An oncoming generator in and out of sync with bus

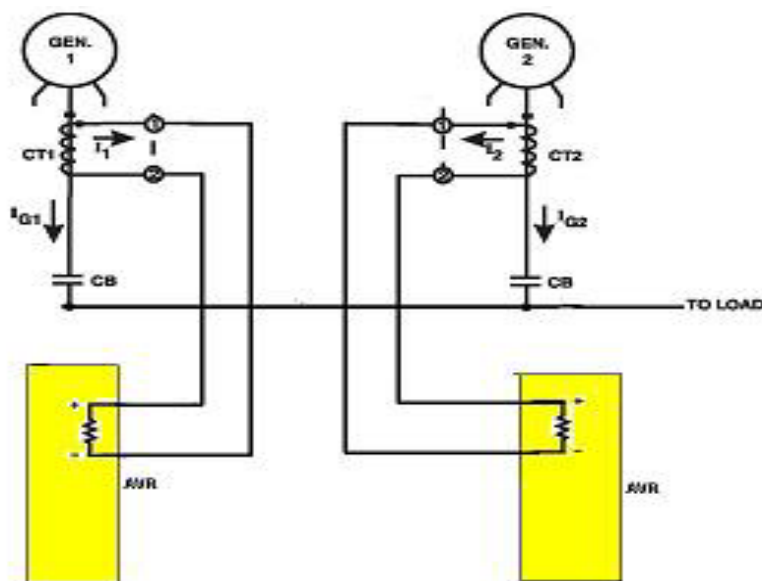
Is the process of connecting a generator to the grid. The objective here is a bump-less connection to the grid without the transfer of a large amount of energy. Effectively, this means that both the voltage and phase must be matched during the process. Should a generator be paralleled with the grid while out of phase, the

generator will try to slip into phase or synchronize by skipping ahead or slip backwards. This results in a high transfer of both active and reactive power.



*Figure 1-4: Voltage vector for 52G closing procedure*

## 1.5 AVR Connection During Breaker Closure



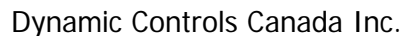
*Figure 1-5: CTs sensing signals for AVR*

There are two synchronizing systems on this example, feeder synchronizing and generator synchronizing. The diagram at left (Fig. 1-5) shows two generators configured to synchronize into a common BUS.

Note the generator current measurement on each unit using a CT connected to the respective AVR. After the generators are synchronized the AVR on each unit monitors generator current and phase angle to facilitate reactive load sharing.

These CT's are commonly called reactive compensation CT's. (Droop CT's)



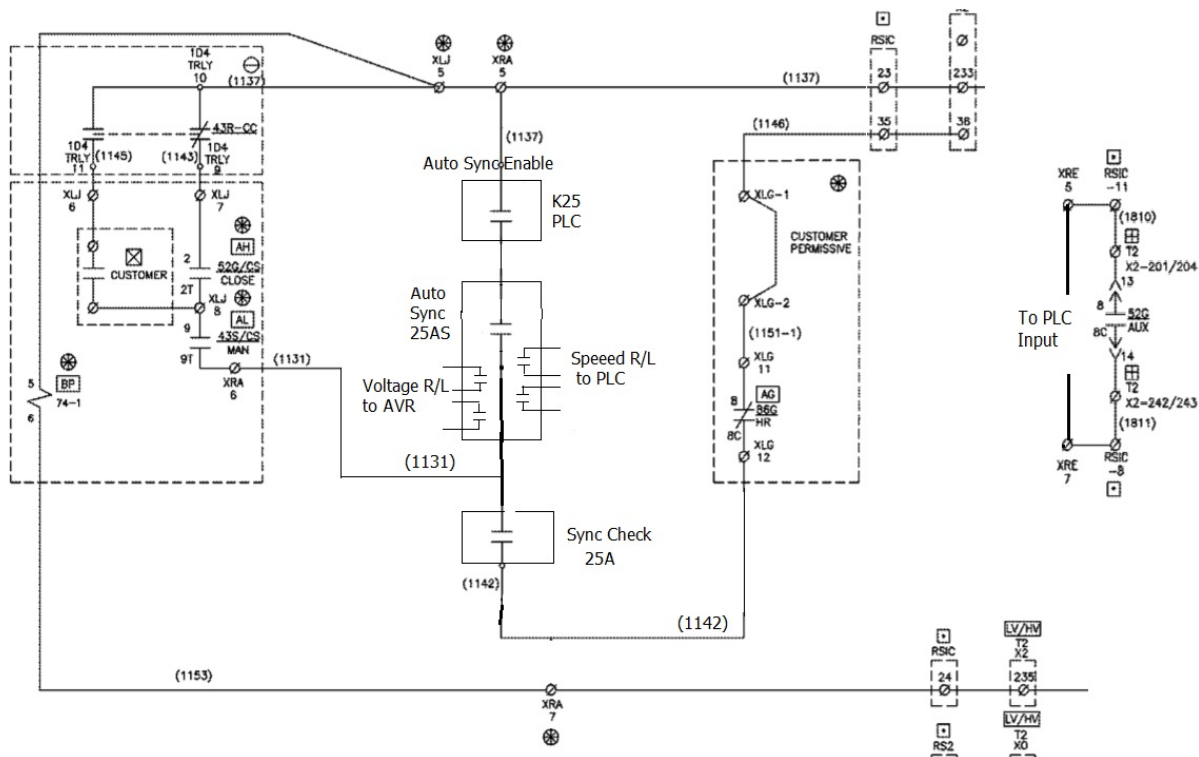


## 2.1 How Auto Syn and Syn Check Relays Operate?

The 25AS auto-synchronizer module in conjunction with the synch check relay (25F) completes the function of synchronization. In this case, the buss is synchronized to an oncoming feeder designated G and J and selected by the operator through panel selection switches.

Below is the actual schematic of an auto-synchronizer as shown on the project schematics. Below is an example of a synchronizing relay. (25AS)

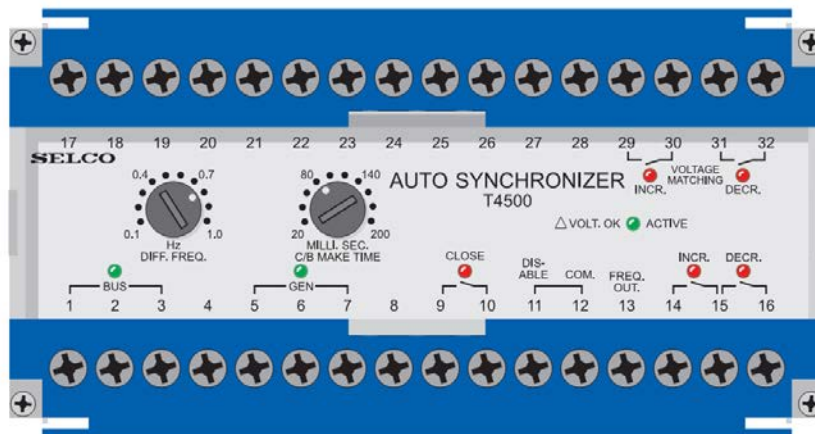
**Figure 2-1: Synchronizing system block diagram**



*Figure 2-2 Typical Closing circuit with Auto Sync and Syn Check relays*



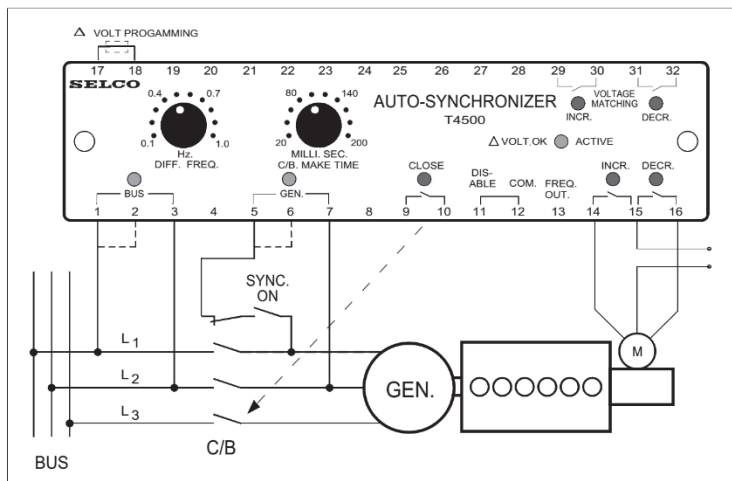
## 2.2 Typical Auto Synchronizing Relay



**Figure 2-3: Layout of Auto-Synchronizing relay – T4500**

The T4500 Auto Synchronizer provides automatic synchronization of an incoming generator to a busbar in a minimum of time, by controlling the speed via the electric servomotor on a conventional speed governor, or by controlling an electronic speed controller via an intermediate motorized potentiometer.

Note the raise and lower speed contacts to the PLC to adjust the turbine speed and the raise and lower voltage contacts to the CGCM module to raise/lower the generator excitation.



**Figure 2-4: Connection diagram of T4500**

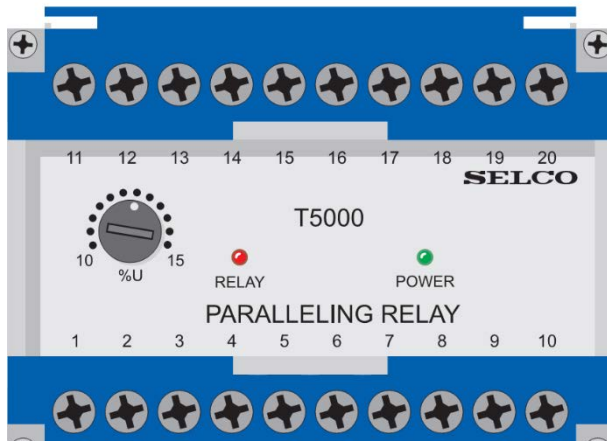
Contacts: 29-30; 31-32: Raise and Lower voltage

Contacts: 14-15-16: Raise and Lower Frequency

Contacts: 9-10: Close 52G when voltage and frequency of bus and generator are matched

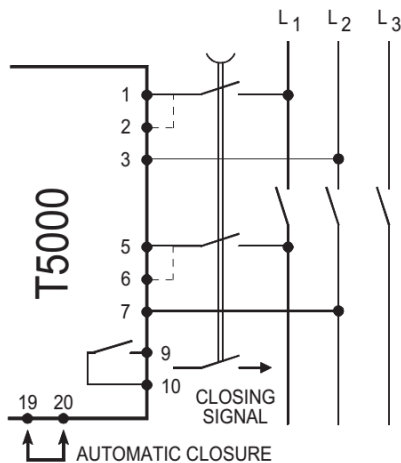


## 2.3 Typical Synchronizing Check Relay



*Figure 2-5: Layout of Synchronizing check relay – T5000*

The T5000 Paralleling Relay can be used as a check synchronizer, inhibiting closure of the circuit breaker if synchronizing parameters such as voltage, frequency and phase angle are outside limits, thus preventing generator damage and disturbance to the busbar.



Contact: 9-10: Closed when voltage and frequency of bus and generator are matched

*Figure 2-6: Connection diagram of T5000*

### Notes





### 3 GENERATOR PROTECTION RELAYS.

#### 3.1 GE SR489 Generator Management Relay

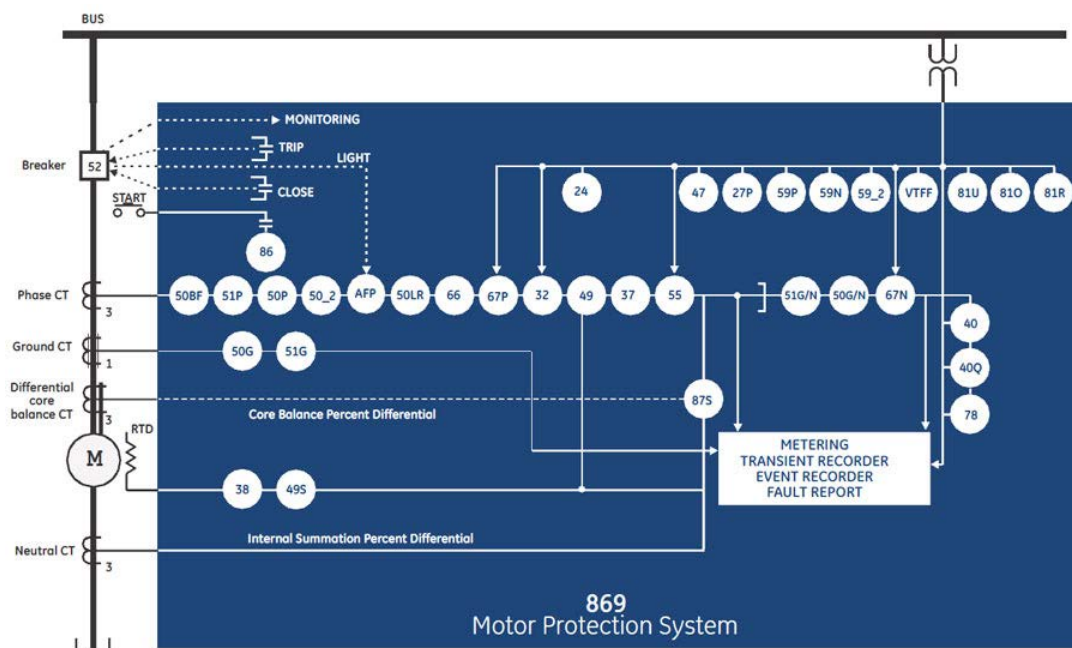
The generator management relay is designed to protect the generator under fault conditions by monitoring the voltage, current and phase difference on the three phases of the generator. The relay configured through software will trip the generator circuit breaker under the following conditions:

- Generator Stator Differential
- Generator Unbalance
- Loss of Excitation
- Phase Over-current – Voltage Restraint
- Neutral Inst./Timed Over-current
- Neg. Sequence Over-current
- Under/Over Voltage
- Under/Over Frequency
- Over-excitation – Volts/Hertz



*Figure 3-1: Layout of GE SR489 relay*

The one-line diagram below indicates the general arrangement of the relay wiring (see schematics for details).



*Figure 3-2 Principle protection diagram of SR489*



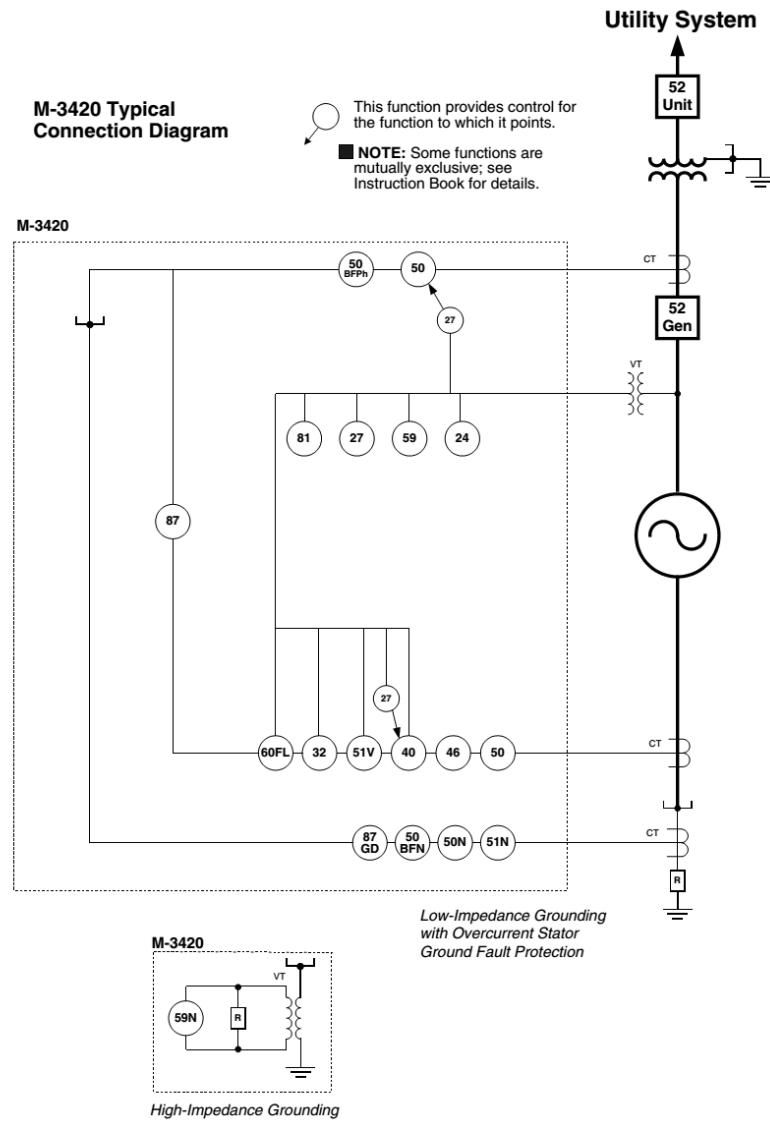
## 3.2 Beckwith M-3420 Generator Protection



*Figure 3-3: Layout of BW M-3420 relay*

### Protection Functions:

- Overexcitation (V/Hz) protection (24)
- Phase Undervoltage protection (27)
- Sensitive dual-setpoint, reverse power detection suitable for sequential tripping (32)
- Dual-zone, offset-mho loss-of-field protection (40)
- Sensitive negative-sequence overcurrent protection and alarming (46)
- Instantaneous overcurrent (50) protection
- Inadvertent generator energizing protection (50/27)
- Generator breaker failure protection (50BF)
- Neutral inverse time overcurrent (51N)
- Instantaneous overcurrent (50N) protection
- Three-phase inverse time overcurrent (51V)
- Phase overvoltage (59)
- Generator ground fault protection (59N)
- VT fuse-loss detection and blocking (60FL)
- Four-step over/underfrequency protection (81)
- Generator phase differential (87)
- Ground differential (87GD) protection



**Figure 3-4: Principle Protection Diagram of M-3420**

