Generator Paralleling Control System Module

ACM-Series/GP Control Module
Microgrid, Paralleling, Transfer Control Systems
Solutions Brochure

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**SAFE SMART SERVICEABLE SWITCHGEAR &
ENGINEERED POWER SYSTEM SOLUTIONS**

MADE IN THE USA

ALN: 551 Rev. 01

Figure 1: Standard ACM Series/GP Control System Module (Base Model)

Figure 2: GP Control System Module with Integrated Lights, Sync Control Switches

Natural Gas Engines, Turbines & Diesel Generator Paralleling

Benefits of ACM Series Control:

⊙ APT switchgear with GP paralleling control system modules allows for easier maintenance, better operator experience
  o APT generator paralleling control system modules are located in a controlled environment removed from the dangers and vibrations of rotating machines
⊙ APT GP generator paralleling switchgear is open architecture
  o Allows for use with multiple genset manufacturers
⊙ Unmatched continuity of product line and support

⊙ Generator paralleling switchgear control is one of our core competencies:
  o Developed by our engineers with decades of experience in the field of generator paralleling
  o Continuity of the product line, as electronic components become obsolete and new features are added
  o We provide the project support and version control for the life of the generator switchgear installation and beyond, we retain records of all projects indefinitely
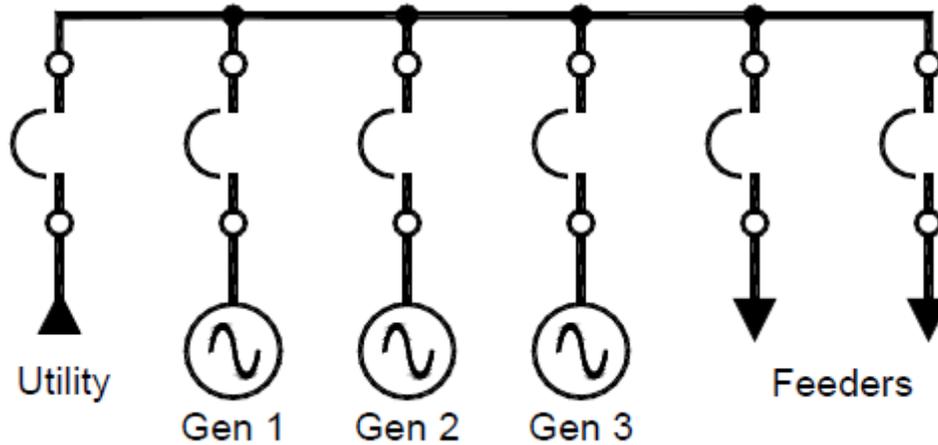⊙ Greater flexibility with modes of operation that can be achieved and future expansion capabilities

Figure 3: ACM-Series/GP Control System Module Utility & Three Generator Paralleling Application One-line Diagram

Paralleling for Low & Medium Voltage Generation Systems

- ⊙ Automatic Paralleling of Multiple Generators
- ⊙ Complete Generator Protection
- ⊙ Integrated Generator & Bus Metering
- ⊙ Remote Start/Stop Interface
- ⊙ Direct Sensing Up to 690V (No Switchgear PTs Required)
- ⊙ Inhibits Closing of Multiple Generators to a Dead Bus Simultaneously
- ⊙ First Up - First On Logic Connects First Available (which builds up voltage and frequency) to a Dead Bus
- ⊙ Intelligent integrated Microprocessor Control
- ⊙ Completely automatic operation
  - o Automatic Paralleling of Multiple Generators

  - o Remote Start/Stop Interface
  - o kW and kVAR Load Sharing
- ⊙ Optional Features:
  - o Multiple Generators Master Control Panel
  - o Redundant Generators Standby & Back-up (N+1)
  - o Operation in Parallel with Utility
  - o SCADA-ready Modbus Communications Port for Monitoring & Control
  - o Load Shed and Load Demand Control
  - o Complete Manual Paralleling Facilities
    - ▪ Synch Check Relay
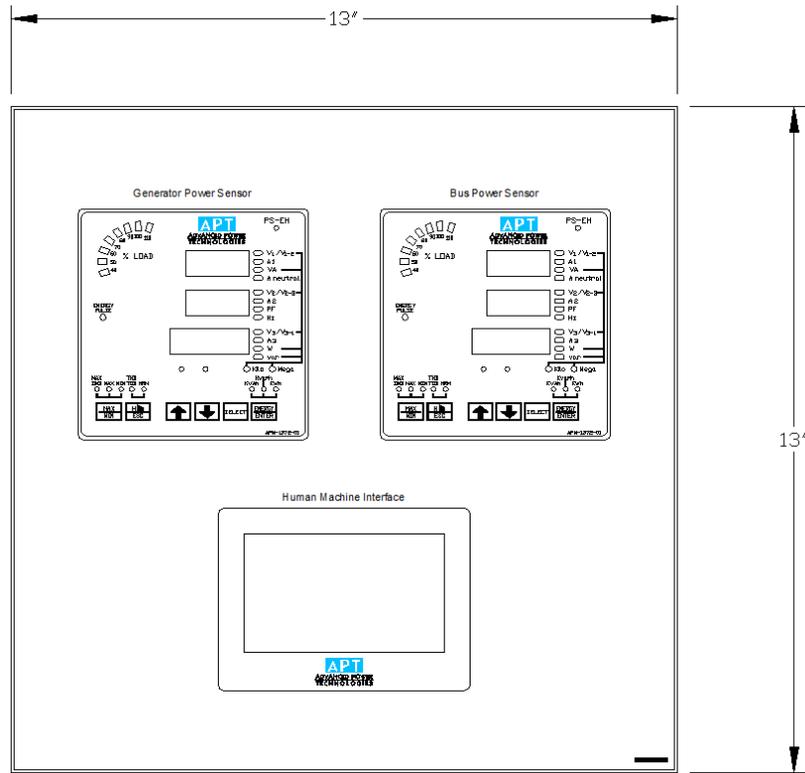   - ▪ Synch Lights
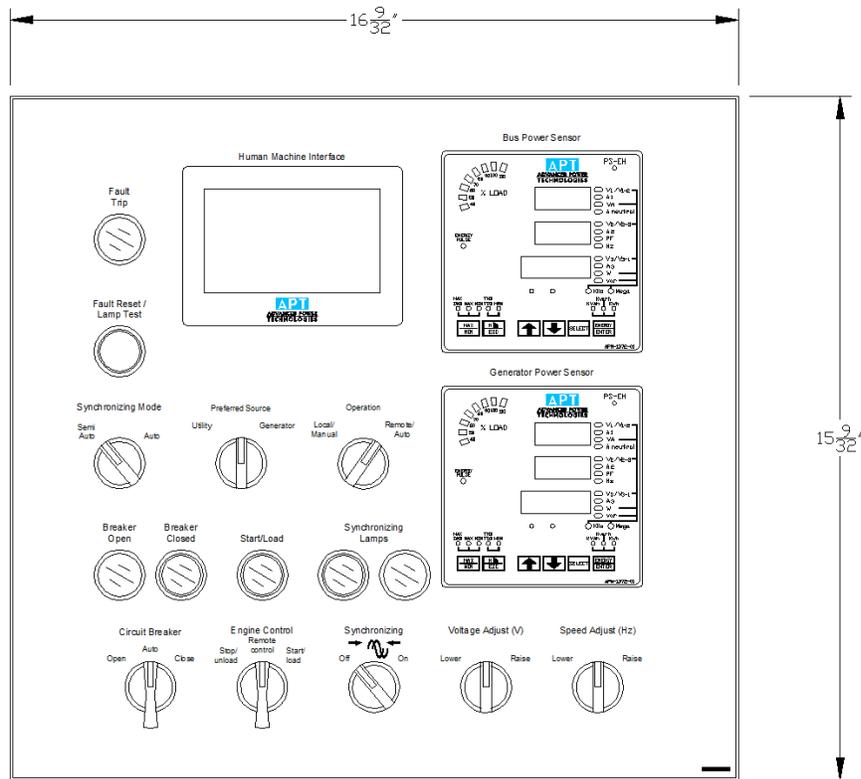   - ▪ Control switches

Figure 4: ACM Series/GP Control System Module Base Model

Figure 5: ACM Series/GP Control System Module Premium Module
with Integrated Manual Control Lights & Switches

Single Generator Control Panel Summary Specifications:

Voltage Inputs:	208 – 690V, direct 3 phase sensing Above 690V, sensing from switchgear PTs Input Impedance: 1000 kΩ Voltage withstand: 1000 VAC continuous, 2000 VAC for 1 second
Current Inputs:	0-5 Amp sensing from generator or switchgear CTs Operating range: continuous 10A RMS Burden: < 0.2 VA @ In=5A Withstand: 15A RMS continuous, 300A RMS for 1 second
Sampling Rate :	128 samples/cycle
Electromagnetic Immunity:	ANSI/IEEE C37.90.1: Fast Transient SWC
Metering Accuracy:	Per ANSI C12.20-1998: Class 10 0.5% for energy 0.2% of reading and 0.02% of full scale for voltages and currents 0.3% of reading and 0.02% of full scale for active and apparent power
Generator Metering:	True RMS, 3 phase (A, V, Hz, kW, PF, kVAR, kWh, kVARh)
Bus Metering:	True RMS, 3 phase (A, V, Hz, kW, PF, kVAR, kWh, kVARh)
Generator Protection:	Three phase under/overvoltage Under/over frequency Reverse power (two setpoints) Reverse VARs (two setpoints) Current balance (two setpoints) Overcurrent protection provided by generator output or switchgear circuit breaker
Optional bus Protection:	Three (3) phase under/overvoltage and under/over frequency
Generator Set Governor & AVR Interface:	0-10 V, +/-10 V, 4-20 mA, microprocessor controlled potentiometer
Metering Displays:	Dedicated high-brightness digital LED generator and bus metering displays visible in the in the bright sun light or in the dark

ACM Series Control System Requirements:

- Engine-Generator set with engine control module (Caterpillar ADEM, EMCP or similar) and generator voltage regulator, capable of voltage droop operation
- Electrically operated generator circuit breaker with stored energy mechanism
- Circuit breaker control power source
- Generator CTs for generator metering and protection functions
- Generator and bus PTs for systems above 690 Volts

Switchgear Integration Options:

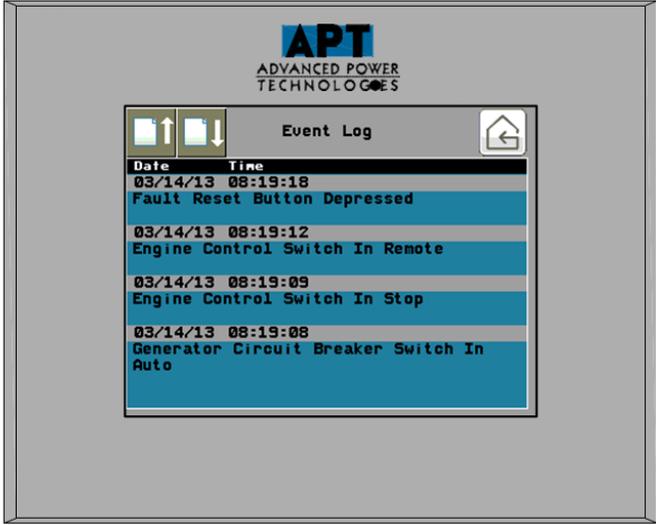|	
System Voltages:	208 – 600V, 3 phase, 3 or 4 wire 2.4kV – 15kV, 3 phase, 3 wire
Current:	Up to 4000A UL listed (low voltage) Up to 10,000A Non-UL listed (low voltage) Up to 3000A UL listed (medium voltage)
Enclosure:	NEMA 1 for indoor use, wall mount or floor standing NEMA 3R for outdoor use, wall mount or floor standing Stainless Steel, wall mount or floor standing Switchgear Door Mountable

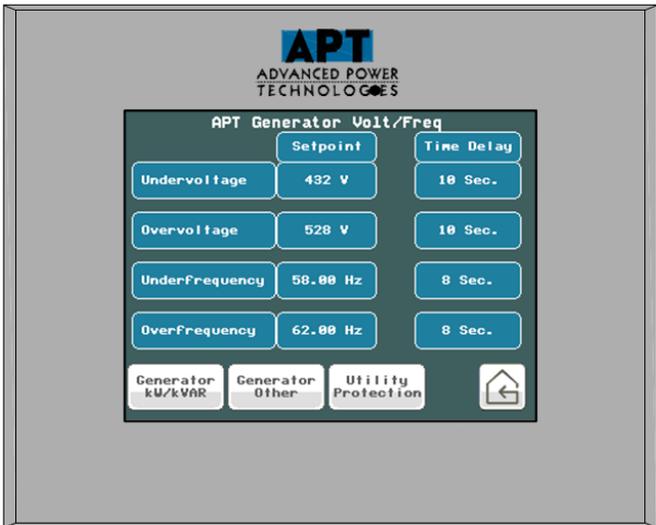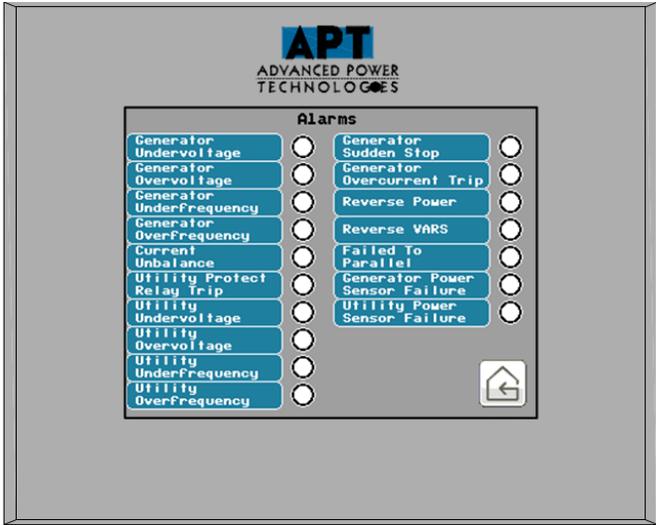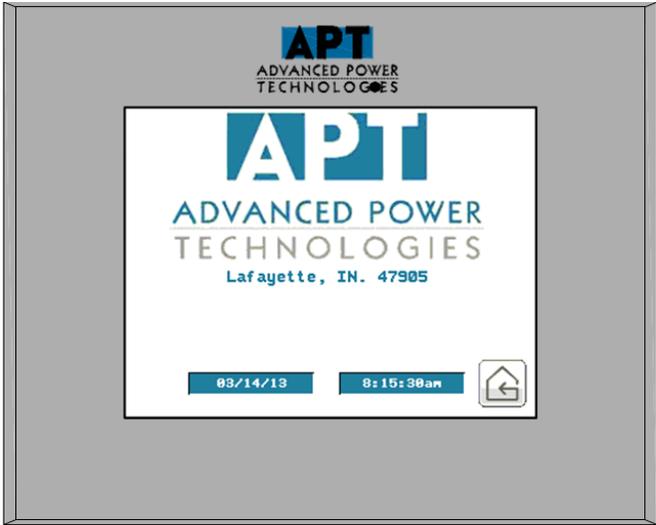Figure 6: ACM Series/GP Control System HMI
Home, Alarms, Setpoints, and Event Log Screens

1 Overview of Operation

1.1 General Information

APT paralleling panel contains various control circuits to accomplish the following major functions:

1. Provide automatic paralleling of generators.
2. Facilitate load sharing, both real load (kW) and reactive load (kVAR), among the generators, when the gensets are appropriately equipped.
3. Provide independent electrical fault protection for all generators:
   - 27/59 – three-phase generator under/over voltage
   - 81O/U – generator over/under frequency
   - 32 – generator reverse power
   - 40 – generator reverse kVAR
   - 46 – generator current unbalance

4. Provide redundant, less automated levels of control for paralleling generators.
5. When utility paralleling option is present, the control of the generator set kW and kVAR will be provided when the generator is operating in parallel with the utility.
6. Control Switches and Annunciation Lamps described below can be integrated in the control module

1.2 Automatic Paralleling On the Isolated Bus – Overview

APT paralleling panel is designed to accommodate certain characteristics of generator sets to automatically parallel them together. Paralleling generators together provides a means of combining the kW and kVAR capacity of the generators so that a load can be served that exceeds that capacity of one generator alone. Automatic paralleling simplifies the process of paralleling generators together. In general, here is how it is accomplished:

- All generator voltage regulators must be properly configured for zero gain (zero IR compensation) and for approximately 3% voltage droop. APT switchgear or the generator includes droop CT's and other circuitry necessary for voltage droop operation. By correctly configuring the voltage regulators, the generators will properly share reactive (kVAR) load.
- All prime mover speed governors must be properly configured with the correct load gain settings. This is accomplished by setting the load gains on the respective load sharing governors or load sharing modules to 6.0VDC at full load. By correctly setting the load gains, the gensets will properly share real (kW) load.
- Now the generators may be started and put on-line in any order or they may be operated one generator at a time.

1.3 Utility Paralleling Modes (when available) – General Information

APT switchgear is equipped for continuous operation of the generator in parallel with a utility or "infinite bus" and provides means of automatically paralleling to it. Utility paralleling modes can be used for peakshaving, generator load testing and bumpless transfer of load from utility to generator and from generator to utility (storm avoidance).

2 Hard Wired User Interface Control Devices

Note: The Hard Wired User Interface Control Devices described below can be integrated in to the ACM Series Control system Module, or can be provided as external components and wired to it.

2.1 Fault Trip Lamp (FTL) / Fault Reset / Lamp Test Pushbutton (FRS)

This lamp flashes on any fault condition. It must be cleared by pressing fault reset pushbutton to permit starting the genset. Prior to resetting fault, cause of fault may be viewed by pressing 'status' button on OIU. Lamp test is accomplished by pressing this pushbutton also.

2.2 Synchronizing Mode Switch (SMS)

In Auto position of this switch the generator speed will be automatically adjusted to bring it in to synchronism with the bus when CBS in not in Open position, the generator set has properly built up voltage and frequency and the bus voltage is above the Dead Bus Voltage setpoint. Also, generator frequency cannot be manually adjusted by the operator.

In Semi Auto position of this switch the generator speed will not be automatically adjusted to bring it in to synchronism with the bus. Any adjustments can be made by the operator. Generator frequency can be manually adjusted by the operator.

2.3 Circuit Breaker Open / Closed Lamps (CBOL / CBCL)

These lamps indicate the position of the circuit breaker. A circuit breaker in the open position is indicated by a green lamp (CBOL). A circuit breaker in the closed position is indicated by a red lamp (CBCL).

2.4 Circuit Breaker Control Switch (CBS)

Has primary control of tripping and closing the circuit breaker. In 'auto' position, circuit breaker is permitted to automatically trip and close as conditions dictate. In 'Trip/Off' position (maintained), breaker is immediately tripped open if closed and breaker closing is otherwise inhibited. In 'close' position, breaker will manually close if: bus is dead or bus is live and synchronizing conditions are correct.

2.5 Start/load Lamp (SLL) / Engine Control Switch (ECS)

The Start/load lamp illuminates upon any start signal being received by the control panel.

The engine control switch initiates a start/stop sequence for generator. To be able to start requires that the prime mover is set to 'auto' with no active faults.

'Remote Control' position permits remote start/stop control. 'Stop/unload' position (maintained) removes start/load signal (if present) and does not permit generator to start except from prime mover local start/stop control if equipped. 'Start/load' position will initiate starting sequence if conditions permit.

If prime mover is already running and Generator Control switch is set to 'Start/load,' then corresponding circuit breaker will automatically close to the dead bus or will automatically parallel to the live bus.

2.6 Synchronizing Switch (SS) / Synchronizing Lamps (SL1, SL2)

Sync switch turns sync lamps on and off. For manual synchronizing, sync lamps must be completely dark for generator to be in synchronism with other generator.

NOTE: It is recommended to keep this switch in 'Off' position for automatically operated unattended systems.

2.7 Voltage / P.F. Adjust Switch / Pot (VAS / VAP)

Manual adjustment of the generator voltage can be accomplished by turning the switch or potentiometer whichever is supplied. To raise the voltage, turn the switch to the right or rotate the potentiometer in a clockwise rotation. To lower the voltage, turn the switch to the left or rotate the potentiometer in a counter clockwise rotation.

2.8 Speed (Hz) Adjust Switch / Pot (SAS / SAP)

Manual adjustment of the generator speed can be accomplished by turning the switch or potentiometer whichever is supplied. To increase the speed, turn the switch to the right or rotate the potentiometer in a clockwise rotation. To decrease the speed, turn the switch to the left or rotate the potentiometer in a counter clockwise rotation.

3   Operator Interface Unit (OIU)

The OIU provides a means of programming setpoints and diagnosing fault conditions. The OIU is comprised of a LCD screen and keys or touchscreen. An operator can select from the following menus:

- Alarms – Shows all monitored alarm and fault conditions
- Event Log – Provides event log
- Protection – Provides generator protection setpoints (reverse power, overvoltage, etc.)
- Setpoints – Provides generator infinite bus loading setpoints (voltage, kW, kVAR, etc.)
- Metering – Provides simultaneous metering of generator and bus
- Advanced Setpoints – Password protected menu of higher level functionality setpoints
- About – Project information, date, time

The 'Main Menu' can be activated at any time, from any screen, by pressing the home button.

3.1   Alarms

This screen displays the status of all monitored system alarms and fault conditions. This allows the operator to identify the fault that occurred or any fault condition that exists that inhibits automatic paralleling operation.

3.1.1   Consequences of a monitored generator fault

Generator faults are those that could cause damage to the genset or load. They are therefore treated as "locked-out" conditions until an operator intervenes, remedies the problem, and then presses the 'Fault Reset' pushbutton.

Generator faults will result in the following:

- The 'Fault Trip' lamp will begin flashing.
- The generator breaker will be tripped open and locked-out from electrically re-closing.
- The automatic start signal to the start/stop controller will be removed. The engine (if previously running) will run through a cooldown period as programmed in the start/stop controller and/or in the engine-mounted electronic controller. If the engine was manually started, then it will continue to run until manually shut down.
- The fault may be reset by pressing the 'Fault Reset' pushbutton.

3.1.2   Generator Undervoltage

Generator undervoltage (27) -- see 'Protection Menu' section for details.

Probable causes: genset overload, engine, generator, governor, voltage regulator, air intake or fuel system failure.

3.1.3   Generator Overvoltage

Generator overvoltage (59-1, 59-2) -- see 'Protection Menu' section for details.

Probable causes: generator voltage regulator, governor failure, substantial load rejection.

3.1.4 Generator Underfrequency

Generator underfrequency (81U) -- see 'Protection Menu' section for details.

Probable causes: genset overload, engine, generator, governor, voltage regulator, air intake or fuel system failure.

3.1.5 Generator Overfrequency

Generator overfrequency (81O) -- see 'Protection Menu' section for details.

Probable causes: generator set governor or speed sensing failure, substantial load rejection.

3.1.6 Current Unbalance

Generator current unbalance (46-1, 46-2) -- see 'Protection Menu' section for details.

Probable causes: unbalanced single phase loads, ground fault, loss of phase in load (ex. blown fuse).

3.1.7 Utility Undervoltage

Utility undervoltage (27) -- see 'Protection Menu' section for details.

Probable causes: loss of utility, excessive utility voltage sag, incorrect ratio of utility step-down transformer.

3.1.8 Utility Overvoltage

Utility overvoltage (59) -- see 'Protection Menu' section for details.

Probable causes: utility voltage swell.

3.1.9 Utility Underfrequency

Utility underfrequency (81U) -- see 'Protection Menu' section for details.

Probable causes: loss of utility, unstable utility.

3.1.10 Utility Overfrequency

Utility underfrequency (81O) -- see 'Protection Menu' section for details.

Probable causes: loss of utility, unstable utility.

3.1.11 Generator Sudden Stop

This is a condition that occurs when the genset is stopped by an external controlling device that has monitored a non-generator related fault or has otherwise determined to shut the genset down. These devices include the engine start/stop controller that monitors oil pressure, water temperature, etc. and the engine mounted electronic governor/controller.

3.1.12 Generator Overcurrent Trip

Generator phase overcurrent (50/51) -- this condition means that the generator circuit breaker tripped due to overcurrent; either time or instantaneous, as determined by the overcurrent sensing device.

Probable causes: overload, short circuit fault, transformer inrush.

3.1.13 Reverse Power

Generator reverse power or kW (32-1, 32-2) -- see 'Protection Menu' section for details.

Probable causes: genset speed not set to 60.0Hz when paralleling to hot bus, air intake or fuel system failure while paralleled to hot bus, generator set governor.

3.1.14 Reverse VARS

Generator reverse kVAR (40-1, 40-2) -- see 'Protection Menu' section for details.

Probable causes: voltage regulator failure or loss of generator excitation while paralleled to hot bus, voltage droop improperly set on one or more generators paralleled together, voltages not matched in one or more generators paralleled together.

3.1.15 Failed To Parallel

Fail to parallel -- see 'Protection Menu' section for details.

Probable causes: loss of charge or close control power to main circuit breaker.

3.1.16 Generator Power Sensor Failure

This condition means that the APT door-mounted generator power sensor has had a failure. This condition inhibits proper paralleling control and therefore results in a generator fault condition – including tripping of the main circuit breaker and removal of the automatic start signal.

3.1.17 Utility Power Sensor Failure

This condition means that the APT door-mounted utility power sensor has had a failure. This condition inhibits proper paralleling control and therefore results in a generator fault condition – including tripping of the main circuit breaker and removal of the automatic start signal.

3.2 Event Log

The OIU includes an event log which timestamps all events and front panel switch operations. The event log can be scrolled through with the up and down arrow buttons.

3.3   Protection Menu

APT paralleling control panel includes various protective functions that are integrated into the OIU. The Protection Menu provides viewing and adjustment of those protective functions.

Use the OIU keypad to adjust the value of the protective function setpoints as required. Enter a new desired value for a setpoint and then press the 'ENTER' key. Each setpoint can be adjusted within the allowed setpoint range (i.e. between LOW and HIGH limits). If the entered setpoint value is outside the allowed setpoint range, the new entry will be rejected by the OIU and the previous setpoint will remain active and reappear on the display.

Also see 'Alarms' section for additional, applicable information.

3.3.1   Protective Function #1: Three-Phase Generator Undervoltage

(27) Undervoltage Setpoint (Setpoint in Volts)
Undervoltage Time Delay (Time Delay in Seconds)

This function provides three-phase generator undervoltage protection and is set in volts with an associated time delay set in seconds. This condition means that the generator voltage in at least one of the phases has dropped below the undervoltage setpoint for a time period that exceeded the undervoltage time delay. This condition starts being monitored after the generator circuit breaker is closed.

Example of entering setpoint:

Assume: desired undervoltage setpoint is 432 V

Enter '432' as setpoint.

3.3.2   Protective Function #2: Three-Phase Generator Overvoltage

(59) Overvoltage Setpoint (Setpoint in Volts)
Overvoltage Time Delay (Time Delay in Seconds)

This function provides three-phase generator overvoltage protection and is set in Volts with an associated time delay set in seconds. This condition means that the generator voltage in at least one of the phases has achieved the overvoltage setpoint for a time period that exceeded the overvoltage time delay.

Example of entering setpoint:

Assume: desired overvoltage setpoint is 528 V

Enter '528' as setpoint.

3.3.3   **Protective function #3: Generator Underfrequency**

(81U) Underfrequency Setpoint (Setpoint in 0.01 Hz)

Underfrequency Time Delay (Time Delay in Seconds)

This function provides generator underfrequency protection and is set in terms of 0.01 of hertz (Hz) with an associated time delay set in terms of seconds. This condition means that the generator frequency has dropped below the underfrequency setpoint for a time period that exceeded the underfrequency time delay. This condition starts being monitored after the   generator circuit breaker is closed.

Example of entering setpoint:

Assume: desired underfrequency setpoint is 58.01Hz

Enter '58.01' as setpoint.

3.3.4   **Protective function #4: Generator Overfrequency (81O)**

Overfrequency Setpoint (Setpoint in 0.01 Hz)

Overfrequency Time Delay (Time Delay in Seconds)

This function provides generator overfrequency protection and is set in terms of 0.01 of hertz (Hz) with an associated time delay set in terms of seconds. This condition means that the generator frequency has achieved the overfrequency setpoint for a time period that exceeded the overfrequency time delay.

Example of entering setpoint:

Assume: desired overfrequency setpoint is 62.01Hz

Enter '62.01' as setpoint.

3.3.5   **Protective Function #5: Generator Reverse Power,**
Setpoint #1 and #2 (32-1, 32-2)

> **Reverse kW #1** (Setpoint in Kilowatts)
> **Reverse kW Time Delay #1** (Time Delay in Seconds)
>
> **Reverse kW #2,** (Setpoint in Kilowatts)
> **Reverse kW Time Delay #2** (Time Delay in Seconds)

Reverse power protection is divided into two setpoints, setpoint #1 and setpoint #2. Setpoint #1 may be set with a sensitive setpoint and longer time delay while setpoint #2 may be set with a less sensitive setpoint and shorter time delay to provide two tiers of protection.

This function provides generator reverse power protection and is set in terms of negative kilowatts (kW) with an associated time delay set in terms of seconds. This condition means that the generator is absorbing kilowatts (motoring) and has achieved the reverse power setpoint for a time period that exceeded the reverse power time delay.

Example of entering setpoint:

> Assume: desired reverse power setpoint is 45 kW
>
> > Enter '45' as setpoint.

3.3.6   **Protective Function #6: Generator Reverse kVAR,**
Setpoint #1 and #2 (40-1, 40-2)

> **Reverse kVAR #1,** (Setpoint in kiloVARs)
> **Reverse kVAR Time Delay #1,** (Time Delay in Seconds)
>
> **Reverse kVAR #2,** (Setpoint in kiloVARs)
> **Reverse kVAR Time Delay #2,** (Time Delay in Seconds)

Reverse kVAR protection is divided into two setpoints, setpoint #1 and setpoint #2. Setpoint #1 may be set with a sensitive setpoint and longer time delay while setpoint #2 may be set with a less sensitive setpoint and shorter time delay to provide two tiers of protection.

This function provides generator reverse kVAR protection and is set in terms of negative kilovolt-amperes reactive (kVAR) with an associated time delay set in terms of seconds. This condition means that the generator is absorbing kiloVARs (under excited) and has achieved the reverse kVAR setpoint for a time period that exceeded the reverse kVAR time delay.

Example of entering setpoint:

> Assume: desired reverse kVAR setpoint is 70 kVAR
>
> > Enter '70' as setpoint.

**3.3.7   Protective Function #7: Generator Current Unbalance,
Setpoint #1 and #2 (46-1, 46-2)**

Current Balance #1, (Setpoint in Percent of Generator Full Load Amps)
Current Balance Time Delay #1, (Time Delay in Seconds)

Current Balance #2, (Setpoint in Percent of Generator Full Load Amps)
Current Balance Time Delay #2, (Time Delay in Seconds)

Current unbalance protection is divided into two setpoints, setpoint #1 and setpoint #2. Setpoint #1 may be set with a sensitive setpoint and longer time delay while setpoint #2 may be set with a less sensitive setpoint and shorter time delay to provide two tiers of protection.

This function provides generator current unbalance protection and is set in terms of percent in relation to the generator full load Amps with an associated time delay set in terms of seconds. This condition means that the difference in current between any two phases has achieved the generator current unbalance setpoint for a time period that exceeded the current unbalance time delay.

Example of calculating setpoint:

Assume: desired current unbalance setpoint is 10%
Full Load Amps = 694

Enter '10' as setpoint.

If difference of Amps reading between any two phases exceeds 69.4 Amps, the current unbalance protection will trip generator circuit breaker after a corresponding time delay.

3.3.8   Protective Function #8: Dead Bus Voltage
Dead Bus Volt, (Setpoint in Volts)

This function is different from other protective functions in that it does not have an associated fault condition displayed in the Status Menu. Instead, this is a function that is used to diagnose a dead load bus. If the load bus voltage is less than this setpoint in each of the three phases, then the load bus is considered to be "dead" and immediate circuit breaker closure is permitted. If the load bus voltage is greater than this setpoint, then the load bus is considered to be "hot" and automatic synchronizing logic is activated. This function operates instantaneously and has no associated time delay.

Example of entering setpoint:

Assume: desired dead bus voltage setpoint is 60V

Enter '60' as setpoint.

3.3.9 Protective Function #9: Fail To Parallel Time Delay

Fail To Parallel (Time Delay in Seconds)

Should the main breaker fail to automatically close when appropriate, this function will shut the genset down after the corresponding time delay. This function will operate regardless of whether the breaker failed to close to a dead bus or failed to parallel to a live bus.

This function is monitored when the genset is automatically started and is running at approximately rated speed and voltage, and the Circuit Breaker control switch is in the 'Auto' or 'Close' position.

3.4 Setpoints Menu

Setpoints menu is active when the control panel is equipped with the utility (grid) paralleling option. This menu provides viewing and adjustment of all the generator loading setpoints. These setpoints may be changed at any time – while the generator is running and on-line, prior to starting the generator, etc.

Each setpoint can be adjusted within the allowed setpoint range (i.e. between LOW and HIGH limits). If the entered setpoint value is outside the allowed setpoint range, the new entry will be rejected by the OIU and the previous setpoint will remain active and reappear on the display.

3.4.1 Discussion on loading control dynamics

During a time of loading the generator against the utility, APT controls continuously monitor the loading control setpoints (desired kW) and compares it to the measured load levels of the corresponding power source (actual kW) and makes adjustments accordingly to the generator to satisfy the loading control setpoints.

Six setpoints are used to help maintain responsive, yet stable operation when in parallel with the utility:

1. Base load over window
2. Base load under window
3. Stability rate
4. Import / Export over window
5. Import / Export under window
6. Import / Export stability rate

Note: Import/Export control is optional and may not be present in your equipment.

The over and under window setpoints define an acceptable range that as long as the actual kW's fall within that range, no adjustments are made. If the actual kW's get outside of the acceptable range, then the stability rate setpoint effects how quickly the controls make corrections.

If loading controls are overshooting or oscillating – increasing the over/under window setpoints and/or decreasing the stability time will help to correct.
If loading controls are sluggish and are not maintaining constant load – then decreasing the over/under window setpoints and/or increasing the stability time will help to correct.

3.4.2   Setpoint #1: Genset Base Load Level

Baseload level (Setpoint in Kilowatts)

* This setpoint is only activated in Utility Paralleling mode when the Start / Load lamp is illuminated.

When paralleling the generator to utility in baseload mode, this setpoint determines the kW level to which the generator will softly load up and maintain.

'Base load' means to apply a constant load onto a generator (regardless of fluctuations in site load) and this is the manner in which the APT switchgear accomplishes its base load control.

Example of entering setpoint:

Assume: desired dead bus voltage setpoint is 1200 kW

Enter '1200' as setpoint.

3.4.3   Setpoint #2: Base Load Under Window

Baseload Under Window (Set in Kilowatts)

* This setpoint is only activated in Utility Paralleling mode when the Start / Load lamp is illuminated.

This setpoint defines a lower threshold of a "window." As long as the actual generator load is greater than this setpoint, then no further adjustments are made to the engine governor. Should the actual generator load fall below this threshold, then the APT controls will make an adjustment to the loading controls to bring the generator load back within this under window limit.

Example of correlating setpoint to under window threshold:

Assume: base load under window setpoint = 20
kW base load level setpoint = 1000 kW

Under window threshold = base load level setpoint – under window setpoint
$X = 1000 \text{ kW} - 20 \text{ kW}$
$X = 980 \text{kW}$

Enter '20' as setpoint

Therefore, when the generator load falls below 980kW the APT controls will make a correction to bring the generator load back within the under window limit.

3.4.4 Setpoint #3: Base Load Over Window

Baseload Over Window (Set in Kilowatts)

* This setpoint is only activated in Utility Paralleling mode when the Start / Load lamp is
   illuminated.

This setpoint defines an upper threshold of a "window." As long as the actual generator
load is less than this setpoint, then no further adjustments are made to the engine
governor.
Should the actual generator load exceed this threshold, then the APT controls will make an
adjustment to the loading controls to bring the generator load back within this over window
limit.

Example of correlating setpoint to upper window threshold:

Assume: base load over window setpoint = 15 kW
base load level setpoint = 1000 kW

Over window threshold = base load level setpoint + over window setpoint
X =   1000 kW + 15 kW
X =   1015 kW

Enter '15' as setpoint

Therefore, when the generator load exceeds 1015kW the APT controls will make a
correction to bring the generator load back within the over window limit.

3.4.5 Setpoint #4: Genset kW Load Rate

* This setpoint is only activated in Utility Paralleling mode when the Start / Load lamp is
   illuminated.

When paralleling the generator to the utility and the generator breaker is first closed, this
setpoint determines the rate at which the generator softly loads to the 'base load level.'
Increasing the setpoint will cause the generator to load faster; decreasing the setpoint will
cause the generator to load slower.

3.4.6 Setpoint #5: Genset kW Unload Rate

* This setpoint is only activated in Utility Paralleling mode when the Start / Load lamp is
   illuminated.

When it is time to come off-line after having been paralleled to the utility, this setpoint
determines the rate at which the generator softly unloads prior to automatically tripping
open the generator circuit breaker. Increasing the setpoint will cause the generator to
unload faster; decreasing the setpoint will cause the generator to unload slower.

3.4.7   Setpoint #6: Stability Rate

* This setpoint is only activated in Utility Paralleling mode when the Start / Load lamp is
   illuminated.

This setpoint defines how quickly the loading controls make corrections when the actual
generator load gets outside of the over/under window thresholds. The lower the setpoint, the
slower the corrections are made (i.e. more stable). The higher the setpoint, the faster the
corrections are made (i.e. more responsive).

3.4.8   Setpoint #7: Genset Unload Level
Unload Level (Setpoint in Kilowatts)

* This setpoint is only activated in Utility Paralleling mode when the Start / Load lamp is
   illuminated.

When softly unloading the generator from the utility (coming off-line), this setpoint determines
the generator kilowatt level at which the generator breaker will automatically trip open.
Typically this setpoint is set to 2-5% of the generator rated kW.

This setpoint operates similar to "Base Load Under Window" described above except
that it applies to Import / Export mode.

3.4.9 Discussion on setting kVAR setpoint

** If generator Voltage Regulator is equipped with this function, this setpoint may not be active in APT control unit.

When paralleling to the utility, there are several strategies on how to set the kVAR setpoint:

- Typical setting – normally it is recommended to produce approximately 10% of generator rated kiloVARs such that the generator is always operating in the lagging kVAR region. It is acceptable to set the setpoint to minimum kVARs (approximately 1.0 power factor); however, this will permit the generator to periodically wander into leading kVAR (power factor) region which is an abnormal mode of operation for the generator. This may result in nuisance Reverse VAR fault trips (based on the 'Reverse kVAR' setpoints in the Protection Menu).

- Correlating kVAR setpoint to power factor – when it is desired to achieve certain power factor the following calculation can be used.

  Example of calculating kVAR setpoint to achieve the desired power factor:

  Assume: desired generator load power factor = .92 lagging
  generator base load setpoint = 1000kW

  $$\text{Generator kVAR setpoint} = \sqrt{\left(\frac{kW}{PF}\right)^2 - kW^2}$$

  $$= \sqrt{\left(\frac{1000}{0.92}\right)^2 - 1000^2} = 426 \text{ kVAR}$$

- Using generator for power factor correction – in addition to producing high levels of kilowatts, in some cases it is also desirable to generate a high level of kVARs from the generator. This is for the purpose of power factor correction – much in the same way a capacitor bank is used for power factor correction. To accomplish this purpose, the generator kVAR setpoint may be set up to the kVAR high level limit.

3.4.10 Setpoint #14: Genset kVAR Setpoint

kVAR Level (Setpoint in kVAR)

** If generator Voltage Regulator is equipped with this function, this setpoint may not be active in APT control unit.

* This setpoint is only activated in Utility Paralleling mode when the Start / Load lamp is illuminated.

When paralleling the generator to utility, this setpoint determines the kVAR level to which the generator will load up and maintain. By setting this setpoint to its minimum or close to zero, the generator power factor will approach 1.0. By setting this setpoint to closer to the kVAR upper limit, the power factor will approach .8 lagging.

KiloVARs produced by the generator set are ultimately a function of the generator and the voltage regulator. Increasing kiloVARs requires increasing the generator excitation current but will not affect engine loading or fuel consumption.

3.4.11 Setpoint #15: Genset kVAR Under Window

VAR Under Window (Setpoint in kVAR)

* This setpoint is only activated in Utility Paralleling mode when the Start / Load lamp is illuminated.

This setpoint operates similar to "Base Load Under Window" described above except that it applies to kVAR level.

3.4.12 Setpoint #16: Genset kVAR Over Window

VAR Over Window (Setpoint in kVAR)

* This setpoint is only activated in Utility Paralleling mode when the Start / Load lamp is illuminated.

This setpoint operates similar to "Base Load Over Window" described above except that it applies to kVAR level.

3.4.13 Setpoint #17: KVAR Control Gain

** If generator Voltage Regulator is equipped with this function, this setpoint may not be active in APT control unit.

* This setpoint is only activated in Utility Paralleling mode when the Start / Load lamp is illuminated.

This setpoint defines how quickly the kVAR controls make corrections when the actual generator kVAR loading gets outside of the over/under window thresholds. The lower the setpoint, the slower the corrections are made (i.e. more stable). The higher the setpoint, the faster the corrections are made (i.e. more responsive).

3.5 Metering

The metering screen brings most genset and bus/utility electrical parameters to a common screen for visualization. Parameters included are Frequency (Hz), Phase to Phase Voltages (VAC), Currents (I), Active Power (kW), Reactive Power (kVAR), and Kilovolt-Amps (kVA). Touching anywhere on the screen exits to the 'Main Menu'.

3.6 Advanced Setpoints Menu

The 'Advanced Setpoints' screen is password protected. In the event that advanced troubleshooting is required an APT representative my provide the password and instruct the user as to the parameters in question. These settings usually require no adjustment once the system has been commissioned.

3.7 About

The about screen provides the project name and number associated with the piece of equipment as well as the configured date and time. In the event contact with APT becomes necessary providing this information will speed the process in which a representative can assist.

4 Operational Procedures

APT paralleling control panel is designed to:
1. Accomplish highly automated, operator initiated automatic paralleling operation.
2. Provide redundant, less automated operation in case of primary control failure.

4.1.1 Configure prime mover start/stop controllers for automatic operation

For each prime mover verify the following:
- Controller is energized and operating
- No fault conditions exist on controller
- Control switch/button is set to 'auto' position (if equipped)

4.1.2 Set APT paralleling control panel for automatic operation
- Verify 'Fault Trip' lamp is extinguished.
- Verify setpoints are set as desired in OIU
- Set 'Circuit Breaker Control' switches to 'Auto' position

NOTE: To disable a genset from starting, leave 'Engine Control' switch in 'Stop/unload' position.

4.1.3
Set the starting frequency at APT paralleling control panel. Set the starting voltage at the local start/stop controllers for all generators. For proper operation, it is necessary to set the correct starting generator voltage and frequency. Starting voltage and frequency should be the same for all generators.

To set voltage and frequency:
- Set synchronizing 'Circuit Breaker Control' switch to 'Open' position
- Verify 'Fault Trip' lamp is cleared
- Momentarily set 'Engine Control' switch to 'Start/load' position – genset should start and come up to its default voltage and frequency.
- If adjustments are required, first set frequency, then set voltage.
- When finished, momentarily set 'Engine Control' switch to 'Stop/unload' position. Genset will then shutdown after cooldown period has elapsed (as set in start/stop controller).
- Set Synchronizing 'Circuit Breaker Control' switch back to 'Auto'.

4.1.4   Set speed governor and voltage regulator for parallel operation

All generator voltage regulators must be properly configured for **zero gain (zero IR compensation)** and for approximately **3% voltage droop**. By correctly configuring the voltage regulators, the generators will properly share reactive (kVAR) load.

All engine speed governors must be properly configured with the correct load gain settings. This is accomplished by **setting the load gains on the respective load sharing module to 6.0VDC at full load**. By correctly configuring the engine speed governors and load sharing controls, the gensets will properly share real (kW) load.

4.1.5   Set APT paralleling control panel for automatic operation

- Verify 'Fault Trip' lamp is extinguished
- Verify setpoints are set as desired in OIU
- Set Synchronizing Circuit Breaker Control switch to 'Auto' position

NOTE: To disable a genset from starting, leave 'Engine Control' switch in 'Stop/unload' position.

4.2   Automatic Paralleling Operation

Automatic paralleling operates as described in the 'Overview of Operation'. The following describes the sequence of operation:

<u>Initiating Operation</u>

a. Ensure that the 'Circuit Breaker Control' switch is in "Auto" position.
b. Momentarily turn 'Engine Control' switch of the generator to 'Start/load' position.
   - Genset should start (if not already running) and come on-line (including closing breaker)

c. Momentarily turn 'Engine Control' switch of the other generator to 'Start/load' position.
   - Genset should start and come on-line (including paralleling and closing circuit breaker)

   Note: If generator set will be paralleling to a utility ensure that the settings in the Setpoints menu such as Base Load Level, etc., are entered as desired.

<u>Halting Operation</u>

d. Momentarily turn 'Engine Control' switch of generator to 'Stop/unload' position.
   - Genset should come off-line and open its circuit breaker. Generator set remote start signal will be removed, which will initiate the prime mover normal shutdown sequence.

e. Momentarily turn 'Engine Control' switch of the other generator to 'Stop/unload' position.
   - Genset should come off-line and open its circuit breaker. Generator set remote start signal will be removed, which will initiate the prime mover normal shutdown sequence.

4.3 Manual Paralleling Operation

Should normal automatic modes of operation not be available due to hardware failures or otherwise, it is possible to conduct lower levels of manual operation. To manually put the generator on-line use the following steps:

4.3.1 Put 'Synchronizing Mode' switch in 'Semi-Auto' position

4.3.2 Manually start genset(s)

Manually start genset(s) with prime mover local control switch or Generator Control switch.

4.3.3 Set generator(s) voltage and frequency

Use speed and voltage adjust switches or potentiometers on switchgear to set proper frequency and voltage.

4.3.4 Close main breaker(s)

- Turn on Synchronizing switch
- If bus is dead, use 'Circuit Breaker Control' switch to close breaker
- If bus is energized, wait until 'Synchronizing Lamps' are completely dark, at the time when 'Synchronizing Lamps' are completely dark use the 'Circuit Breaker Control' switch to close breaker.

  * Repeat this procedure for closing next generator circuit breaker.

4.3.5 When ready to shut down

- Use 'Circuit Breaker Control' switch to open circuit breaker(s) by placing it in the 'Open' position.
- Allow gensets to cooldown under no load, then use engine start/stop controller to turn off genset(s).

5 Maintaining the Back-up Battery

APT switchgear includes a back-up battery (GCB) to compensate for sags in 24VDC control power during engine cranking and for providing back-up tripping power to the generator breaker in the event 24VDC power is lost.

The back-up battery is a maintenance-free, sealed lead-acid battery with a typical life expectancy of 3-5 years. **The battery should be replaced every 3-5 years.** Should the battery be exposed to harsh ambient temperatures (outside of 0-40ºC or 32-104ºF) the life expectancy may be reduced.

Should the battery fail, it will typically exhibit the following failure mode: during an automatic start, the engine will begin to crank and then cease, begin to crank and then cease, etc., without ever starting. If this occurs, the first troubleshooting step should be to replace the back-up battery.

The battery may be periodically tested to verify its condition by using the following procedure:

1. With the genset not running, turn off 24VDC control power to the switchgear. This may be accomplished by turning off the DC circuit breaker within the switchgear (usually labeled CB1).
2. The switchgear should remain energized for a full 10 seconds. Then the switchgear should power down.
3. When the test is completed, re-energize 24VDC control power.

If the switchgear did not remain energized for the full 10 seconds during the test, the back-up battery has likely failed and should be replaced.

Advanced Power Technologies (APT) is on the cutting edge of the latest engineered power system smart technologies, as it relates to microgrid & storage management, renewable & conventional energy source deployment, demand peak shaving, and facility back-up and co-generation power systems. Located in the central United States and headquartered in Lafayette, Indiana with solutions development engineers around the country, APT provides domestic and international products and services to industry leading companies from around the world. APT engineers have decades of power system experience from working with some of the largest companies in industry. Over the last two decades, we have produced successful solutions for hundreds of large-scale electric power projects involving utility/generator paralleling, transfer, peak shaving, and distribution. We pride ourselves in providing electrical power systems that are engineered and custom built, utilizing state-of-the-art technologies to fit our customer's exact needs. The core of our business is low & medium voltage engineered power systems for a wide range of indoor & outdoor applications, such as:

- Utility(ies) and Generator(s) Paralleling/Transfer/Peak Shaving/Distribution Switchgear
- Microgrids, Microgrid Master Control Panels, SCADA systems
- Containerized Battery Energy Storage Systems (BESS)
- Photovoltaic (PV) Solar Power Collection/Distribution & Renewable Energy Storage Systems
- Low & High Resistance Grounding Systems, Grounding Systems for Photovoltaic Effective Grounding
- High Efficiency Combined Heat and Power Switchgear & Control Systems (CHP, Co-generation)
- Outdoor Walk-In Electrical Houses (E-Houses) & Skid-Mounted Switchgear
- Motor Control Centers & Motor Control Switchgear
- Automatic & Manual Load Transfer Switchgear
- Bypass/Isolation & Power Distribution Circuit Breaker Switchboards
- Generator/Loadbank Quick Connection Switchgear, Switchboards, & Tap Boxes
- Industrial Control Panels

Please see our product webpages on www.apt-power.com for product brochures and relevant information. Actual products may look different from images shown on the website and in brochures, based on actual specifications.

APT cares and understands that each power system is different. We will evaluate various solutions in order to develop the best solution for a site. APT focuses on our ability to a combine several traditional pieces of equipment/functionality into as little of a footprint possible. This saves on space, the cost of equipment, cost of installation, and accomplishes the most optimal/state-of-the-art design your facilities. APT's desires to foster and grow a culture of continued open communication with each customer. Let APT be your source to provide fully engineered power system equipment solutions for the full customer facility on time, on or under budget, and in the smallest footprint possible. We are always available to assist customers and engineers representing customers in the development of complex power solutions for all facility types.